INNOVATION AND PRODUCTIVITY IN AUSTRALIAN SMALL AND MEDIUM-SIZED ENTERPRISES: A SECTORAL ANALYSIS

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Submitted in fulfilment of the requirements of the degree of

Doctor of Philosophy

Institute for Sustainable Industries and Liveable Cities

Victoria University

Melbourne, Australia

March 2021

ABSTRACT

In the face of falling productivity and rising global competition, innovation has become a strategic focus of Australia's economic and policy debate. Small and medium-sized enterprises (SMEs) constitute the vast majority of businesses in Australia, but they are typically innovation laggards. Thus, improving SMEs' innovation performance is critical to boost the nation's productivity. The literature has extensively examined innovation and productivity in large firms and the economy as a whole. However, little is known about innovation in SMEs in various economic sectors, aside from the manufacturing sector. Most available studies focus on technological innovation, neglecting non-technological innovation. There is also a dearth of sectoral studies that examine SMEs' innovation and productivity relationship using longitudinal data. The present study bridges these gaps in the SME innovation and productivity literature.

This study explores and quantifies the determinants and impact of SME innovation in three economic sectors, namely, primary, secondary (manufacturing) and service. Based on the renowned CDM framework, an econometric model is developed, linking (i) innovation determinants, (ii) innovation outputs and (iii) firm productivity. The study uses the Australian Bureau of Statistics microdata of 1,976 Australian SMEs during the period 2011–16. The random effects probit models and simultaneous estimation approach are employed to estimate innovation output and productivity equations as one system. This approach takes into account unobserved firm heterogeneity and endogeneity in the innovation process. Further, the use of longitudinal data yields novel and more robust estimates of the impact of innovation on SME productivity.

The analysis is first conducted on the aggregate economy, followed by each economic sector. The results show significant differences in SME innovation performance across the three sectors. Innovation determinants, namely, training, collaboration, financial support, investment in information and communication technology (ICT) and innovation focus, are found to positively affect both types of innovation. Firm size, age, foreign ownership and exports, and market competition also influence some innovation outputs. The analysis further reveals a positive impact of both innovation outputs on SME productivity, with non-technological innovation showing a more significant effect than technological innovation. At the sectoral level, collaboration and innovation focus significantly influence both innovation outputs in all three sectors. However, the significance and effect of financial support, ICT and training vary across innovation types and sectors. The positive impact of firm size and the negative impact of firm age are significant in the primary and service sectors, but not in the secondary sector. Foreign

ownership, exports and market competition also influence innovation outputs across sectors, but their effect also varies. The sectoral results reveal a positive relationship between innovation outputs and productivity of SMEs in all sectors. However, the impact of each innovation type, in terms of magnitude, varies across sectors.

The thesis contributes to the literature by providing sectoral and panel data analysis of innovation and productivity in the SME case. The results confirm the sectoral patterns in innovation processes and further reveal significant differences across the three economic sectors in terms of their innovation determinants and the extent to which the two types of innovation impact productivity in SMEs. Technological innovation is found to have a greater impact on productivity of primary SMEs, while the impact of non-technological innovation is more pronounced in manufacturing SMEs. In services, the effect of technological and non-technological innovation is relatively comparable. At the aggregate level, non-technological innovation is a stronger driver of productivity improvement in SMEs rather than technological innovation. This finding is important given that non-technological innovation has largely been overlooked, especially in the SME literature. The study also makes an important contribution to the Australian literature by providing a comprehensive analysis of the two stages of SME's innovation process using panel data estimations. It further offers benchmarking and comparisons of the innovation and productivity performance across all three economic sectors, which has not been done in previous Australian research. Given the current low performance in innovation and productivity in Australia, the thesis provides important implications for policies. The findings offer additional empirical insights into various factors that significantly affect innovation and productivity in the three economic sectors, which serves as a catalyst for policy development to improve Australian SMEs' performance in innovation and productivity.

STUDENT DECLARATION

I, Van Khanh Nguyen, declare that the PhD thesis entitled "Innovation and productivity in Australian small and medium-sized enterprises: A sectoral analysis" is no more than 80,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work. I have conducted my research in alignment with the Australian Code for the Responsible Conduct of Research and Victoria University's Higher Degree by Research Policy and Procedures.

Signature | Date

[redacted]

Van Khanh Nguyen | 4^{th} March 2021

ACKNOWLEDGEMENTS

Undertaking the final year of my PhD during the COVID-19 pandemic with half a year in complete lockdown is definitely one of the most daunting challenges in my life. Fortunately, I made it before my thirtieth birthday. Completing my PhD would not have been possible without the exceptional support, guidance and encouragement that I received from many people.

First and foremost, I would like to express my deepest gratitude and appreciation to my two supervisors—Dr Riccardo Natoli, my principal supervisor, and Associate Professor Sarath Divisekera, my co-supervisor. Riccardo, I am truly thankful for your dedication, time, hard work, support and guidance during my PhD. The ongoing feedback and advice you provided has greatly improved my thesis. Not only did you provide excellent supervision, but you also offered constant encouragement and mentoring in my teaching and research training activities. Sarath, I am sincerely grateful for your assistance with my studies and career. You have constantly supported me since the first days of my studies in Australia—my Master by Research in 2014 and then my PhD in 2017. Although you retired more than two years ago, you continued to advise me on my work and kept on supporting me until the end of my PhD. Your valuable comments, high standards and demand for hard work greatly motivated me to learn and improve myself. I am very fortunate to have had you both as my supervisors. I have gained enormous benefits from working with you, from your knowledge, experience and dedication.

I am very grateful to Victoria University for offering me the Research Training Program Fees Offset and Stipend Scholarships for my PhD study, the Conference and Travel Scholarship for my presentation at the conference in Florida in 2019 and the Chancellor's Doctoral Industry Experience Placement Scholarship for my Doctoral Internship with the Victoria Tourism Industry Council. These scholarships not only allowed me to undertake my PhD in Australia with no financial pressure, but most importantly, they opened a door of opportunities to join global academia, see the world and improve myself.

My next acknowledgement goes to the Australian Bureau of Statistics for allowing me to access the ABS Business Longitudinal Confidential Unit Record File, particularly the Microdata: Business Characteristics, through the ABS Data Laboratory. I acknowledge Elite Editing for editing my thesis. Editorial intervention was restricted to the ACGR/IPED national guidelines for editing research theses and the current Australian

Standards for Editing Practice, specifically parts D and E. I would like to thank Professor Anne-Marie Hede, Dean of Graduate Research, and Dr Lesley Birch, Manager of Researcher Development, for their support over the last seven years. My appreciation also goes to the Research and Research Training Committee for including me on the committee over the last three years, and to Mr Cameron Barrie for the collaboration with the Research Ambassador program over the last two years. The knowledge and experience I gained from this involvement has been very valuable for my career.

I am indebted to my parents and grandparents for their unconditional love and support. Being the only child in the family, but away nearly seven years to pursue my Master and PhD in Australia, I felt guilty that I could not be close by to take care of them, especially during this pandemic. Growing up in a family of three generations of teachers, I have learnt so much from my family. They have not only educated me to become a good person, but have also taught me to do research and teaching with passion and dedication, to never stop learning and to never give up. Their infinite support, inspiration, love and devotion are the driving force behind my success. Dad, Mom, Grandma, Grandpa—from the bottom of my heart, I sincerely and deeply thank you for the many sacrifices you have made for me over the last 30 years. I have tried my best to complete this journey and I hope I have made you proud.

My PhD journey would not have been complete and enjoyable without the company of my good friends. I would like to thank Dr Esmedekh, whom I see as my big brother. Thanks for your advice, support and great friendship, from when I was just starting my Master’s study. Many thanks to Dr Toan and Mrs Bich for hosting many gatherings for our VU Vietnam PhD group throughout the years. Special thanks to Ms Pam, Harry, Jashan and little Jaydeep for caring and making me a part of your family from 2015 to 2018, and to Mr Binh, Mrs Van, Trang and little Stella for caring and being great company at your house from 2018 to 2021. Thank you to my PhD friends—Giang, Tien, Linh, An, Van and Roopa—for coming to many of my presentations, supporting me and having a fun time together. Finally, I would like to thank you, Norbert, for your immense support, care and encouragement over the last three years. You always patiently listened to me when I was stressed, motivated me and cheered me up when I was down and celebrated with me when I achieved success. Thank you all for supporting me and joining me on this memorable and wonderful journey of my life!

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LIST OF ABBREVIATIONS

ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
AMGC	Advanced Manufacturing Growth Centre
ANZSIC	Australian and New Zealand Standard Industrial Classification
BCS	Business Characteristics Survey
BLD	Business Longitudinal Database
CDM	Crepon, Duguet and Mairesse Model
CEDA	Committee for Economic Development of Australia
CIS	Community Innovation Survey
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CURF	Confidentialised Unit Record File
DFAT	Department of Foreign Affairs and Trade
DIIS	Department of Industry, Innovation and Science
GDP	Gross Domestic Product
ICT	Information and Communication Technology
IPP	Intellectual Property Protection
ISA	Innovation and Science Australia
IT	Information Technology
KBV	Knowledge-Based View
KIBS	Knowledge Intensive Business Services
KPF	Knowledge Production Function
NGT	New Growth Theory
OECD	Organization for Economic Co-operation and Development
OLS	Ordinary Least Squares
OISA	Office of Innovation and Science Australia

PYE	Person-Years of Effort
R&D	Research and Development
RBV	Resource-Based View
SCA	Sustained Competitive Advantage
SD	Standard Deviation
SDS	Supplier-Dominated Services
SIS	Supporting Infrastructure Services
SMEs	Small and medium-sized enterprises
STEM	Science, Technology, Engineering, and Mathematics
TAA	Tourism Accommodation Australia
UK	United Kingdom
US	United States
WEF	World Economic Forum
WIPO	World Intellectual Property Organisation

CHAPTER ONE: INTRODUCTION

1.1. BACKGROUND OF THE STUDY

Weak productivity has been an ongoing issue in Australia since 2005. This issue has worsened in recent years as the economy experienced negative growth in both labour productivity (–0.2%) and multifactor productivity (–0.4%) in 2018–19 (Productivity Commission 2020). The main driver of Australia's past output growth has been the 'strong growth in employment, rather than doing things better' (Productivity Commission 2020, p. 3). The Australian economy has relied heavily on certain industries' market growth, especially the mining industry, to sustain growth despite weak productivity (Department of Industry, Innovation and Science [DIIS] 2018b). With the mining boom coming to an end, strategic solutions to improve the nation's productivity are critical to Australia. In this context, innovation—the key driver of long-run productivity growth (Nelson & Winter 1974, 1982; Schumpeter 1934)—has become the central focus of the national economic agenda (Australian Government 2017a). With the rise of globalisation and competition, the need to be innovative has also become the essence of firms' survival and future growth, irrespective of industry or sector (Organisation for Economic Co-operation and Development [OECD] 2021; Ortiz-Villajos & Sotoca 2018).

Innovation has been an area of considerable interest among policymakers and the research community. The OECD (2015e) proposes innovation as a pivotal solution for productivity issues in advanced and emerging economies. A high-performing innovation system can 'underpin the overall competitiveness of an economy' (Australian Government 2016, p. 11). It is widely recognised that Australia has a robust research culture (Australian Government 2017c). However, its performance in innovation and the translation of research into commercialisation is generally lacking (World Economic Forum [WEF] 2019; World Intellectual Property Organisation [WIPO] 2018). According to the global competitiveness ranking, innovation capability is the second weakest pillar of the Australian economy, with a 30-point gap from the leading nations (WEF 2019). As emphasised by the Office of Innovation and Science Australia [OISA] (2019, p. 4), Australia needs more businesses to innovate to avoid 'falling further behind international competitors'. The nation's innovation efficiency ratio[1] was 0.58, placing Australia 76th in the global ranking (WIPO 2018). This implies that the economy performed poorly in translating innovation inputs into outputs compared with other countries. Consequently, how to enhance innovation performance and, ultimately, productivity has become a critical priority in both the economic and policy spheres (Australian Government 2017a; Haneda & Ito 2018).

The Australian economy is predominantly made up of small and medium-sized enterprises (SMEs)[2] which account for 99.8% of all operating businesses (Australian Bureau of Statistics [ABS] 2019b). Thus, SMEs are referred to as 'the engine room of the Australian economy' (Australian Government 2019b, p. 4). International evidence has highlighted the important role played by SMEs in economic development and improving productivity (OECD 2019f). However, SMEs, because of their small size, typically have limited resources—both financial and human—and inadequate knowledge and skills to conduct innovation (Rosenbusch et al. 2011; Woschke et al. 2017). These obstacles place SMEs at a disadvantage relative to large firms in the technological evolution and innovation race. Unlike larger firms, SMEs are hamstrung by resource scarcity and the inability to use economies of scale (Lukovszki et al. 2020). As a result, SMEs innovate differently (Hervas-Oliver et al. 2021; Salavou et al. 2004). SMEs have also been recognised as important contributors to innovation (Hall & Williams 2019; Thomas et al. 2011). Given their distinct features and role in economies, SMEs deserve more attention and support to unearth their innovation potential (Audretsch et al. 2020; OECD 2019d).

The relationship between innovation and productivity has long been a major strand of the innovation literature (Morris 2018; Hall & Williams 2019). Nonetheless, relative research in the SME context remains limited (Expósito & Sanchis-Llopis 2018). Most available studies analyse innovation and productivity in the economy as a whole or they tend to focus on manufacturing firms (Audretsch et al. 2020; Hall & Williams 2019). As proposed by evolutionary theory (Nelson & Winter 1974, 1982), innovation processes vary among sectors; thus, innovation should be examined from a sectoral perspective rather than in the context of the economy as a whole (Pavitt 1984). Yet, the role of different sectors in innovation has largely been neglected in empirical research (Baum et

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[1] The Innovation Efficiency Ratio is 'the ratio of the Output Sub-Index to the Input Sub-Index. It shows how much innovation output a given country is getting for its inputs' (WIPO 2018, p. 15).

[2] In Australia, SMEs are defined as businesses with 0 to 199 employees (Australian Government 2019b).

al. 2017; Köhler et al. 2012; Stephan et al. 2017). Beyond the well-established literature on manufacturing innovation, innovation in services is ‘relatively poorly understood’ (Szczygielska et al. 2017, p. 249) and significantly limited in the SME context (Audretsch et al. 2020). As Castellacci (2008, p. 978) emphasises that there are cetain features that make “the innovation process in services markedly different from that of manufacturing”. Thus, further research is needed to provide a better understanding of how service firms, especially those that are micro and small, innovate and improve their productivity (Audretsch et al. 2020). Regarding the primary sector, existing studies on the innovation–productivity link have concentrated on large firms or have been based on aggregated firm data (e.g. Karafillis & Papanagiotou 2011; Sauer 2017). Empirical work focusing on innovation in primary SMEs is considerably limited, while studies that investigate the impact of SME innovation on productivity in the primary sector remain lacking (Soriano et al. 2019).

As the OECD (2009) indicates, innovation can be technological (i.e. product and process) or non-technological (i.e. organisational and marketing). While technological innovation has been extensively examined, there is limited research on non-technological innovation (Azar & Ciabuschi 2017; Peters et al. 2018), especially in SMEs (Expósito & Sanchis-Llopis 2018; Radicic & Djalilov 2019). As Radicic and Djalilov (2019, p. 613) state, ‘the lack of underlying theoretical framework and empirical evidence on the impact of non-technological innovations is even more prominent in the case of SMEs’. Many scholars point out that technological innovation alone is insufficient to explain innovation, especially in service-dominated economies (De Fuentes et al. 2015; Geldes et al. 2017). This issue is particularly relevant to Australia, where services comprised 88% of total operating businesses and represented over 70% of the national gross domestic product (GDP) in 2018–19 (ABS 2019b).

An important limitation of most prior research on innovation and productivity is its reliance on cross-sectional data (Audretsch et al. 2020). Consequently, such studies do not consider unobserved firm heterogeneity and time lag of innovation activity (Peters et al. 2017; Taveira et al. 2019). Thus, as Audretsch et al. (2020, p. 1002) assert, analysis based on cross-sectional data can only conclude about ‘correlation, but not causation between innovation and productivity’. In the SME context, there is a dearth of studies using longitudinal data to estimate the link between innovation and firm productivity among the sectors. Hence, longitudinal research is required to move beyond the cross-sectional analysis of the impact of innovation (Morris 2018; Taveira et al. 2019). Given these gaps in knowledge, there is a need for more empirical research that use longitudinal data to investigate SMEs' technological and non-technological innovation and to estimate its impacts on SME productivity in various economic sectors.

Against this background, this thesis explores and quantifies the determinants of innovation and the innovation-productivity relationship in the context of Australian SMEs. While most prior research is based on cross-sectional data, this study uses longitudinal panel data drawn from the Business Characteristics Survey (BCS) conducted by the ABS (2019f). The firm-level dataset includes 1,976 SMEs in three economic sectors: primary, secondary (manufacturing)[3] and tertiary (service)[4] from 2011–12 to 2015–16. Unlike previous studies focusing on technological innovation, this study examines both technological and non-technological innovations. By doing so, it aims to shed light on whether the driving force of these two innovation types are different in SMEs and to what extent their impacts vary across the three economic sectors. The comparable analyses on SMEs' innovation process across primary, secondary and service sectors and benchmark with the aggregate economy is another important contribution to the literature. Due to differences in technological regimes, learning base and institutional settings, the innovation process should be examined in sectoral contexts and the innovation pattern in the manufacturing sector should not be used to explain for those in services (Audretsch et al. 2020; De Fuentes et al. 2015). Moreover, this study adds empirical evidence on SMEs in the primary sector since little is known about whether and to what extent the innovation and productivity relationship among SMEs in the primary sector is similar or different to that in the manufacturing or service sector.

Although SMEs account for a vast proportion of total businesses in Australia (99.8%) and employ 68.3% of the total workforce, their contribution to value added is just 56% and their innovation performance considerably lags behind large firms (Australian Government 2019b). The ABS (2020) shows that only 18.9% of small Australian firms improved productivity in 2018–19, whereas the corresponding percentage for large firms (38.3%) was approximately double. As the OISA (2019, p. 21) underscores, improving the innovation and productivity of Australian SMEs would have 'a substantial impact on

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[3] Because the secondary sector under study includes only manufacturing firms, the term 'manufacturing' is used interchangeably throughout the thesis to refer to this sector.

[4] The term 'service sector' is used in this thesis to avoid confusion with the tertiary education sector and to be consistent with previous studies in the economic and innovation literature.

the overall growth rate of the economy'. In the Australian literature, available studies on the innovation–productivity link are mostly conceptual papers (e.g. Carberry et al. 2011; Thomson & Webster 2013) or industry reports analysing innovation at the aggregate economy level (e.g. Palangkaraya et al. 2016; Soames et al. 2011). In-depth analysis focusing on SMEs and comparing their innovation processes across economic sectors remains limited. This thesis addresses this gap by providing an in-depth analysis of SMEs across three sectoral contexts. The findings of this thesis could inform policy formation to support SMEs' innovation activities in the three Australian economic sectors.

1.2. RESEARCH PROBLEM

Empirical research on innovation in sectoral contexts is limited. The scarcity of research on innovation and productivity is even more pronounced in the SME context. Very few studies have analysed SME innovation processes using longitudinal data. Existing research overwhelmingly focuses on manufacturing SMEs, while empirical knowledge on SMEs' innovation and firm productivity in other sectors remains lacking. Little is known about innovation processes, their determinants and the impacts of SME innovation in the three Australian economic sectors. These gaps in the innovation literature form the fundamental research problem that this thesis aims to address:

To empirically investigate the determinants of innovation and the impacts of innovation on firm productivity in Australian SMEs from a sectoral perspective (i.e. primary, secondary and service).

1.3. RESEARCH QUESTIONS

Given the research problem identified above, four main research questions arise:

1. *What is the state of innovation in Australia's three economic sectors (i.e. primary, secondary and service)?*
2. *How do SME innovation determinants vary in the aggregate economy and in each economic sector?*
3. *To what extent does innovation impact SME productivity in the aggregate economy and each economic sector?*
4. *How does innovation and productivity performance of SMEs vary across economic sectors?*

The main objective of this study is to examine the determinants of SME innovation and the impact of innovation on SME productivity in three economic sectors in Australia. The specific research objectives are to:

1. explore the innovativeness of SMEs and the state of innovation in the three Australian economic sectors (i.e. primary, secondary and service);
2. quantify and examine the differences in the key determinants of SME innovation in the aggregate economy and in each economic sector;
3. estimate the impacts of innovation on SME productivity in the aggregate economy and in each economic sector; and
4. examine the differences in innovation and productivity performance of SMEs across the three economic sectors.

1.4. DEFINITION OF KEY TERMS

The definitions of the key terms used in the study are given below.

1. *Innovation* is 'the implementation of a new or significantly improved product (good or service), a process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations' (OECD & Eurostat 2005, p. 46).

2. *Technological innovation* refers to the introduction or implementation of a new or significantly improved product or operational process (OECD 2009, 2015a).

3. *Non-technological innovation* refers to the implementation of a new or significantly improved organisational process or marketing method (OECD 2009, 2015a).

4. *Research and Development (R&D)* encompasses 'creative and systematic work undertaken to increase the stock of knowledge—including knowledge of humankind, culture and society—and to devise new applications of available knowledge. The term R&D covers three activities: basic research, applied research and experimental development' (Frascati Manual, OECD 2015a, p. 28).

5. *Productivity* measures 'how efficiently production inputs are being used in an economy to produce a given level of output' (OECD 2018d, p. 9).

6. *Sectors* refer to the three economic sectors of the economy, comprising primary, secondary and tertiary/service (Reeson & Rudd 2016).

7. *Sectoral systems of innovation* comprise 'a set of agents carrying out market and non-market interactions for the creation, development and diffusion of new sectoral products' (Malerba 2005, p. 65).

8. *Australian innovation system* is 'an open network of organisations interacting to produce and use new knowledge and technology to create economic and social value' (Australian Government 2010, p. 1).

1.5. OVERVIEW OF THE RESEARCH METHODS

This study uses quantitative methods to explore SME innovation and productivity in three sectors of the Australian economy. The key source of data for the study is drawn from the Microdata: Business Characteristics, Australia, 2011–12 to 2015–16, compiled by the ABS (2019f). Thus, the key input into this database is from the BCS. The database provides longitudinal firm-level panel data on Australian SMEs' innovation activities and other business information such as firm characteristics, firm performance and market conditions.

The first research question—*What is the state of innovation in Australia's three economic sectors (i.e. primary, secondary and service)?*—is addressed using descriptive and analytical methods. To answer the second research question—*How do SME innovation determinants vary in the aggregate economy and in each economic sector?* —and the third research question—*To what extent does innovation impact SME productivity in the aggregate economy and each economic sector?*—an econometric model is developed, linking innovation determinants, innovation outputs and SME productivity. In the process, the aggregate model is first estimated using the aggregate dataset of 1,967 SMEs in the Australian economy. This is followed by estimations for each of the three sectors, (i.e. primary, secondary and service). The findings from the aggregate model and comparison of the sectoral results are used to answer the fourth research question—*How does innovation and productivity performance of SMEs vary across economic sectors?*

1.6. CONTRIBUTION AND SIGNIFICANCE OF THE RESEARCH

In achieving the above objectives, the thesis contributes to the body of knowledge in five ways. First, while the broader innovation literature has extensively examined innovation and productivity, empirical research on SMEs remains scarce (Calza et al. 2019; Expósito & Sanchis-Llopis 2018). Available evidence on the relationship between innovation and firm productivity is somewhat conflicting and varies across countries and innovation types (Morris 2018; Taveira et al. 2019). Therefore, this study's first contribution is to provide further empirical evidence that enhances the current understanding of innovation and productivity in the context of Australian SMEs.

Second, the vast majority of studies on innovation and productivity are conducted in an economy-wide context or in the manufacturing sector (Audretsch et al. 2020; Hall & Williams 2019). As proposed by evolutionary theorists, innovation significantly differs across industries due to differences in institutions, knowledge and technological regimes (Nelson & Winter 1974). However, empirical research has largely neglected the sector's role in innovation and productivity (Baum et al. 2017; Efthyvoulou & Vahter 2016; Köhler et al. 2012). Consequently, further research comparing innovation processes across sectors is required (Audretsch et al. 2020; Peón & Martínez-Filgueira 2019). This gap is more profound in the SME literature since previous research on this topic has overwhelmingly focused on manufacturing SMEs (e.g. Baumann & Kritikos 2016; Calza et al. 2019; Hall et al. 2009; Mañez et al. 2013) and only limited studies were found on service SMEs (i.e. Aboal & Garda 2016; Audretsch et al. 2020). Regarding the primary sector, Soriano et al. (2019) call for future studies to investigate the impact of innovation on firm productivity of SMEs in this sector. Hence, this thesis makes an original contribution by empirically investigating SMEs' innovation and productivity in the primary, secondary and service sectors. The empirical and comparable results of this thesis answer the proposition of the evolutionary theory of economic growth, namely, whether sectoral differences exist, particularly in the SME context, and to what extent the determinants and impacts of innovation vary across the three economic sectors.

Third, although technological innovation has long been part of the mainstream innovation literature (Geldes et al. 2017; Morris 2018), empirical research on non-technological innovation is comparatively limited (Audretsch et al. 2020; Peters et al. 2018). An established theoretical framework as well as empirical evidence on the impact of non-technological innovation are lacking in the SME context (Audretsch et al. 2020; Expósito & Sanchis-Llopis 2018; Radicic & Djalilov 2019). Given this gap in SME innovation research, this thesis analyses both technological and non-technological innovation in SMEs and their relationship with SME productivity in the three economic sectors. This is an important contribution to the innovation literature since, to date, only Aboal and Garda (2016) have examined the impact of both technological and non-technological innovation on the productivity of small firms in manufacturing and service. In the primary sector, only Sauer (2017) has examined the link between non-technological innovation and farm productivity. However, that study did not estimate the impact of non-technological innovation separately for SMEs, rather than in aggregation with large firms. To the best of the researcher's knowledge, there have been no studies that examine non-technological innovation and firm productivity focusing on SMEs in the primary sector.

Fourth, prior studies on the innovation–productivity relationship have mostly been based on cross-sectional data, which does not account for the time lag of innovation (Peters et al. 2017) and unobserved firm heterogeneity (Morris 2018). Longitudinal data are needed to draw a more robust conclusion on a causal relationship between innovation and productivity (Audretsch et al. 2020). In the SME context, there are empirical studies using longitudinal panel data to estimate the impact of innovation on firm productivity; these include Rochina-Barrachina et al. (2010), Mañez et al. (2013) and Calza et al. (2019). However, the scope of these studies is limited to manufacturing SMEs. A recent study by Audretsch et al. (2020) extended the panel estimation to cover micro service firms. However, no relative studies are found on SMEs in the primary sector. The present thesis contributes to this strand of innovation literature by analysing the innovation–productivity relationship in SMEs using 5-year longitudinal panel data. The analysis is conducted for primary, manufacturing and service SMEs, shedding further light on whether the impact of innovation on SME productivity is comparable in the three different sectors.

Fifth, the study contributes to the literature on the link between innovation and firm productivity by developing a framework suitable for SME sectoral studies. The framework incorporates various factors, divided into three groups: (i) innovation inputs, (ii) firm characteristics and (iii) external environment. These are used to provide a more comprehensive picture of the determinants of innovation in SMEs. The framework further links these innovation determinants to innovation outputs and SME productivity, representing the innovation process. This framework helps improve the understanding of how various factors simultaneously affect the innovation and productivity of SMEs across economic sectors. This is an important contribution, given that existing SME studies on this topic have only analysed the innovation process using econometric models rather than constructing a specific framework applicable for studying innovation and productivity in SMEs. The framework developed in this study can be used as a foundation for further analysis of SMEs' innovation processes in various sectors and countries using innovation survey data.

Sixth, this study also makes an important contribution to the Australian literature on innovation and productivity, particularly in the SME context. Of the available Australian empirical studies on the innovation-productivity relationship, Reeson and Rudd (2016), Soames et al. (2011) and Wong et al. (2007) conduct analysis using the pooled data of all firms, i.e. large firms in aggregation with SMEs, rather than analysing SMEs separately. It is widely acknowledged that the innovative behaviour and performance of large firms and SMEs are distinct given their differences in terms of resource availability, organisational capabilities and economies of scale (Lukovszki et al. 2020; Salavou et al. 2004). Thus, such analysis should not combine SMEs together with large firms (Rosenbusch et al. 2011). A study by Palangkaraya et al. (2010) focuses on Australian SMEs, but they examine only the resources and manufacturing industries. Moreover, they analyse only technological innovation and employ cross-sectional estimation. Bosworth and Loundes (2002) use the SME panel dataset, yet they conduct analysis for all firms in aggregation regardless of sectors, and considers only technological innovation. Studies by Palangkaraya et al. (2014, 2015) provide panel data estimation on both technological and non-technological innovation and productivity. However, their analysis is also for all firms in aggregation rather than in the sectoral contexts. This study contributes to the gaps in the Australian literature by providing a comprehensive, panel data analysis on innovation and productivity in the SME context. Further, it examines not only technological, but also non-technological innovation, and most importantly provides benchmarking and sectoral analyses for the three Australian economic sectors, i.e. Primary, Secondary, and Service.

This study uses the Business Longitudinal Database (BLD), which has been used in most Australian innovation studies. Research using the BLD at the early stage, including Wong et al. (2007), Palangkaraya et al. (2010), Soames et al. (2011), Gronum et al. (2012), employs cross-sectional analysis. The key limitation of cross-sectional estimation is that its results are analysed via correlation rather than causation (Audretsch et al. 2020; Palangkaraya et al. 2010). Later work by Palangkaraya et al. (2014, 2015), Reeson and Rudd (2016), Tuhin (2016) and Soriano et al. (2019) take advantage of the BLD by conducting panel data estimation. However, as mentioned before, Palangkaraya et al. (2014, 2015) aggregate firms in all sectors together, while Reeson and Rudd (2016) combine large firms and SMEs together in their analysis. Studies by Tuhin (2016) and Soriano et al. (2019) are limited to just one stage of the innovation process, i.e. determinants of innovation. Further, the scope of Soriano et al. (2019) is only agri-food SMEs. Using the latest BLD, the present thesis adds to the Australian literature by taking advantage of the unique panel structure of the BLD to explicitly account for unobserved firm heterogeneity in the innovation process and to draw a more robust conclusion on a causal relationship between innovation and productivity. Further, it extends the panel data analysis to cover both stages of the innovation process, i.e. determinants of innovation outputs, and innovation impacts productivity. Most importantly, this thesis provides compatible estimations of the two innovation stages for SMEs in each sectoral context, i.e. Primary, Secondary, and Service, rather than estimating the pooled data.

In addition to academic contributions, this study also has significant sectoral and policy implications. According to the Australian Government (2017), innovation has become a major focal point for policy as decision makers across the nation try to identify new sources of growth, strategies to improve productivity levels and achieve long-term economic growth. However, not only is Australia's innovation efficiency ranked poorly in the global rankings, but the nation's productivity is also declining and lagging behinds its OECD counterparts. This study offers insights into the innovation processes undertaken by SMEs and the factors affecting innovation outputs and productivity in the three Australian economic sectors. Therefore, the findings of this study could serve as a catalyst for policy discussions to assist the development of policy initiatives to boost SMEs' innovation performance. In addition, the study should benefit Australian SMEs by assisting them to develop effective strategies to improve their innovative capacity as well as industry bodies to better understand and support SMEs.

1.7. ORGANISATION OF THE THESIS

The thesis consists of six chapters. Chapter One introduces the background to the study, states the research problem and research questions. This is followed by a definition of the key terms used in the thesis and an overview of the research method. The academic contribution and practical implications of the study are then outlined. The chapter concludes with a brief summary of each chapter.

Chapter Two sets the theoretical background of the study. The chapter begins with a critical review of the key theories of innovation and economic growth. First, Schumpeter's theory of economic development is reviewed, followed by neoclassical economic theories and evolutionary theories of economic growth. The next section presents empirical innovation literature. The definitions and typologies of innovation are reviewed and the characteristics of innovation in SMEs are discussed. A review of the generic innovation literature and SME literature is then conducted to identify the potential determinants of innovation and the link between innovation and productivity among SMEs. Existing evidence on the link between innovation and firm productivity in the Australian context is also elaborated upon. The chapter concludes by summarising existing gaps in the empirical innovation literature. This chapter lays the foundation for the development of a conceptual framework for the study and the choice of variables to be included in the econometric models in Chapter Four.

Chapter Three presents the descriptive and analytical analysis on the current state of innovation of Australian firms in an economy-wide context and in sector-specific contexts, i.e. primary, secondary, service. This chapter aims to answer the first research question. The beginning of the chapter presents an overview of the three Australian economic sectors, followed by a discussion of the characteristics of Australian firms. The next section analyses the current state of innovation in Australian firms, patterns of innovation and inputs used for innovation across sectors. The degree of market competition and its potential link to firm innovation are then examined. The benefits of and barriers to innovation across sectors and among SMEs are also identified. This chapter lays the contextual background for the empirical analysis using econometric models conducted in Chapter Six.

Chapter Four describes the research method used in the study, the conceptual framework and the research hypotheses, which set the foundation for the econometric analyses to be conducted in Chapter Six. The chapter begins with a review of widely used models and approaches in empirical innovation research. Given this review, the choice of the research approach is specified. This is followed by the presentation of the conceptual framework used for the study. Finally, the research hypotheses are formed.

Chapter Five provides information on the key sources of data used for the analysis, establishes the empirical model and specifies the estimation approach. It first presents and discusses the two most widely used surveys in innovation research. The next section describes panel dataset used for the econometrics analysis, measurement of variables and descriptive statistics of the sample. The econometric model is then developed. Common estimation techniques used to estimate the innovation and productivity relationship is reviewed, followed by justifications for an appropriate estimation method for the study. Finally, the modelling strategy are detailed at the end of the chapter.

Chapter Six presents the empirical results of the econometric models developed in Chapter Five and answers research questions two, three and four. First, the general model is fitted into the aggregate dataset, including all SMEs in the three Australian economic sectors. The aim of the aggregate analysis is to provide an overall understanding of the innovation process in the Australian economy and to detect whether there exist significant differences in the innovation processes among sectors. Informed by the aggregate results, the empirical analysis of the primary, secondary and service sectors is then carried out. In the process, each section begins with a summary of statistics and evaluation of the model. The results for the determinants of innovation and the impact of innovation on SME productivity are presented and discussed in each sectoral context. The sectoral results are then benchmarked and compared with the findings of other Australian innovation studies on SMEs. The findings presented in this chapter, in combination with the prevailing issues identified in Chapter Three, lay a foundation for policy implications in Chapter Seven.

Chapter Seven summarises the research process and findings, highlighting the contributions of the thesis. Based on the empirical results in Chapter Six and relevant issues in the Australian innovation system identified in Chapter Three, the thesis proposes implications for policy measures to enhance the innovation outputs and productivity of SMEs. The chapter concludes by outlining the limitations of the study and making suggestions for future research.

CHAPTER TWO:
ECONOMICS OF INNOVATION

2.1. INTRODUCTION

Innovation is recognised as a crucial component of long-term economic growth and competitiveness. Nations have recognised the need to be innovative as a means of achieving sustained growth and enhanced productivity of economies (OECD 2019f). The growing interest in the topic of innovation and technological change from an economic perspective is attributed to Joseph Schumpeter (1912, 1934)[5]. Since Schumpeter's initial contribution, several theories have been developed to explain the phenomenon of innovation. These theories either supplement or substitute each other, progressively improving our understanding of the process of innovation and economic growth.

The aim of this chapter is to present the theoretical background of the economics of innovation. The chapter begins with a review of relevant theories of innovation, technological change and economic growth. These theories are classified according to their schools of thought and the period in which the theory was introduced. First, the most important theory—Schumpeter's Theory of Economic Development—is critically reviewed. This is followed by a critical review of innovation-related theories in neoclassical economics comprising the exogenous growth model, the endogenous growth model and the theory of the growth of the firm. Next is the response from evolutionary theories to the neoclassical school. A critical review is conducted of the evolutionary theory of economic growth, systems of innovation and the new growth theory.

The focus of the chapter then shifts to the empirical innovation literature. Definitions and typologies of innovation are discussed, followed by a review of characteristics of innovation in the SME context. Next, the chapter reviews and identifies the key determinants of innovation, which are classified into three main groups: (i) innovation inputs, (ii) firm characteristics and (iii) external environment. Thereafter, a review is conducted of Australian research on innovation and productivity. This chapter provides a theoretical foundation for developing the conceptual framework of the present study.

[5] The majority of researchers refer to Schumpeter (1934) since this version was published in English while Schumpeter (1912) was in German.

2.2. SCHUMPETER'S THEORY OF ECONOMIC DEVELOPMENT

2.2.1. Key concepts, assumptions and propositions

The most influential theory of innovation is Schumpeter's seminal work entitled *Theory of Economic Development* (1934). Schumpeter (1934, p. 64) refers to innovation as the strategic stimulus to economic development since it is the 'spontaneous and discontinuous change in the channels of flow, disturbance of equilibrium, which forever alters and displaces the equilibrium state previously existing'. Essentially, economic development through innovation is a dynamic process of disturbance of the static general equilibrium of the economy. Schumpeter's theory (1934) comprises five key assumptions:

1. Innovation is a process of 'industrial mutation' and a 'creative destruction'.
2. A firm's incentive for developing an innovation is to increase profit, market share and achieve a monopoly position.
3. Entrepreneurs, the economic agents who carry out innovations, are innovators.
4. Firms react to change, and create change, simultaneously. This process of creative destruction increases economic efficiency.
5. Economic development is driven by the discontinuous emergence of new combinations (innovation).

Schumpeter (1934, p. 19) defines innovation as 'the commercial or industrial application of something new'. He emphasises that it is a critical dimension of economic change as well as a creative destruction. Creative destruction refers to 'the incessant product and process innovation mechanism by which new production units replace outdated ones' (Schumpeter 1942, p. 82), with creation having more economic value than destruction, resulting in a competitive advantage for the firm. At the early stage, innovation is mainly seen from a manufacturing or production perspective—'the setting up of a new production function' (Schumpeter 1939, p. 84)—since the theory was developed in the manufacturing context. It is a process that 'incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one' (Schumpeter 1942, p. 83). Schumpeter advocates that a firm should react to change and create change simultaneously.

Schumpeter (1934) emphasises the role of the individual entrepreneur as the innovator, who implements entrepreneurial changes in the market by making innovative investments that embody new technologies and/or resource discoveries. These could be a better allocation of scarce resources to new uses and new combinations or the endowment of existing resources with new producing capacity. Profit is the main expectation of evolutionary firms when innovating. Successful innovations enable the innovator to increase market share and enjoy temporary monopolistic profits. Similarly to Schumpeter, Kalecki (1954) also views entrepreneurs as investors making investment decisions that enable and nurture innovation[6]. Innovators introduce new knowledge and achieve cost and differentiation advantages, resulting in greater consumer and producer surplus for firms, compared with their competitors. The concept of 'creative destruction' and the emphasis on the major role played by entrepreneurs in innovative activities, so-called Schumpeter Mark I, later changed to 'creative accumulation', so-called Schumpeter Mark II proposed in *Capitalism, Socialism and Democracy* (Schumpeter 1942). Schumpeter Mark II emphasises the role of large firms as sources of innovation. Accordingly, large firms have accumulated stock of knowledge in technological areas as well as large scale R&D facilities, production and distribution. Thus, they are in the best position to contribute to an industry's innovation. Schumpeter Mark II also highlights that the market is dominated by a few large established firms with high barriers to entry to new innovators.

Innovation can take different forms. Schumpeter (1939, p. 87) proposes five forms of innovation: (i) 'introduction of a new product' with which consumers are not yet familiar or with a new quality, (ii) 'introduction of a new method of production' not yet tested by experience and considered a new scientific discovery by the firm or a new way of handling commodities, (iii) 'opening of new markets' which the firm has not yet entered, irrespective of whether this market already existed, (iv) 'development of new sources of supply for raw materials or other inputs' regardless of whether this source already existed or whether this was the first time the source was created and (v) 'creation of new market structures in an industry' given that innovation can be a creation or a destruction of a monopoly position. Schumpeter refers to innovation as a pivotal factor that allows the firm to exit the competitive balance of a long period and obtain a monopoly position. The new combinations of these elements are crucial for the development process to begin. Economic development, as stressed by Schumpeter, is driven by the discontinuous emergence of new combinations which are economically more feasible than the preceding

[6] Schumpeter viewed innovation from the supply side while Kalecki viewed it from the demand side.

ones. Such new combinations utilise idle capacity and reallocate available resources in an optimal way to increase economic efficiency.

Schumpeter (1934) divided the innovation process into four stages.

1. *Invention:* The concepts of 'invention' and 'innovation' must be distinguished because they are often used interchangeably. Basic research is strongly related to the invention process. From an economic perspective, an invention is a new idea that usually involves major scientific or technological discoveries that are not connected to industrial use. If an invention is not carried into practice, it is economically insignificant. The invention does not cause the destruction of an existing equilibrium and has 'no economic significance' (Schumpeter 1934, p. 89).

2. *Innovation:* Innovation refers to the commercial and industrial application of a new idea and is strongly linked to markets and industries. Applied research and development are associated with the innovation stage. A decisive element of innovation is something new and carried into practice. Discovery and execution are 'two entirely different things' (Schumpeter 1939, p. 85). Invention becomes worthwhile only if it results in innovation performed by the launch of a new product—an innovation. Compared with invention, innovation is a more advanced phase which deals with the implementation and commercialisation of the new idea. Different from invention, the disturbance caused by innovation initiates a new process which usually generates a new equilibrium and has economic significance (Schumpeter 1912; Nelson & Rosenberg 1993).

3. *Diffusion:* Innovation can be either developed by the firm or obtained from other firms through the process of diffusion. Once innovative investments are successful, the change creator leads others in the original industry and elsewhere, to follow. Innovation is then diffused through imitation. At first, a few firms follow the successful pioneers; then, more and more imitators start to realise the profitability potential of the newly introduced product or process, and make substantial investments in those new technologies. Innovation has economic impact when diffusion occurs from the firm creating the initial innovation (the innovator) to other firms (the adopters). Entrepreneurial changes create a stimulus environment encouraging further change (Schumpeter 1934). Through diffusion, an innovation first transforms the entire sector from which it originated, then it is

widely spread, transforming the economy. Yet not all innovations diffuse and transform the economy, only the successful ones do. Innovation is then applied in related lines and transferred to other non-related areas. Over the diffusion process, the economy embarks upon a dramatic upward surge, resulting in economic development, prosperity and growth (Schumpeter 1934).

4. *Imitation:* In the market, firms can either pursue an offensive strategy and introduce new products with a high degree of novelty or follow a defensive and imitative strategy by introducing innovations with a low degree of novelty (Freeman & Soete 1997). Imitation occurs when successful innovations are copied by imitators. Innovation with a high degree of novelty represents originality but is associated with high risk and uncertainty (Rosenberg 1976). However, when such innovation is successfully introduced to the market, it causes greater diffusion because the imitators are attracted by the profitability potential of the new product. As a result of widespread imitation, innovations 'do not remain isolated events and are not evenly distributed in time, but … on the contrary they tend to cluster, to come about in bunches, simply because some and then most, firms follow in the wake of successful innovation' (Schumpeter 1939, p. 100).

From Schumpeter's standpoint, imitation is a key element of the innovation process and economic development, and not the original innovators themselves. Innovations push capitalist economic progress forward—not evenly but rather by jerks and rushes (Rossi 2003). The clusters of new, interconnected innovations and their diffusion within an industry are the driving forces behind long-term economic cycles. Further, the behaviour of innovative entrepreneurs and their imitators, given the changes in profit expectations, are the key determinants of economic growth. Similar to Schumpeter, Rosenberg (2000, p 62) states that imitators 'have commonly been the essential carriers of an improvement process that decisively shapes the eventual contribution of new technologies to productivity improvement'.

An important focus of Schumpeter's work is dynamic efficiency—competition from innovation. From Schumpeter's perspective, dynamic efficiency is much more important and substantially more valuable to a firm than static efficiency—price competition at a given point of time. He argues that competition from innovations is 'much more effective than the other as a bombardment is in comparison with forcing a door' (Schumpeter 1950, pp. 83‒85). Arguably, gains from continuing innovation are significantly greater than those associated with competitive pricing. Hence, innovation allows a firm to achieve superior strategic and competitive advantage over the long run.

Finally, the relationship between innovation and economic development is the skeleton of Schumpeter's work. In the *Theory of Economic Development*, Schumpeter shares similar views with Adam Smith, Robert Solow and Nathan Rosenberg; that is, innovation is a source of wealth creation—the creation of prosperity in the economy. He adds that innovation is the fundamental source of economic development because it yields higher real incomes and forces reorganisations of production with greater efficiency, productivity and lower cost, while eliminating inefficient, non-innovating firms as new products, services or methods replace old ones during the creative destruction process. Kalecki (1954) shares a similar view, proposing a relationship between innovation and business cycles. He asserts that through the process of innovation, coupled with innovation-induced profits, a dynamic secular growth path is created. Profits gained through innovative investment allow further investment and innovation in the next period. Business cycles then arise as a result of the fluctuation of profits. Schumpeter's work between 1930 and 1950 saw innovation as a driver of competitive advantage, profitability, productivity and sustainable growth in a competitive economy.

2.2.2. Critical review of Schumpeter's theory of economic development

Schumpeter's work has been the subject of considerable debate and scrutiny by economists, who have highlighted the wealth of his theory, while addressing its limitations. Among the economists, Solo (1951) raised some concerns regarding Schumpeter's theory. The first relates to the distinction between invention and innovation. From Schumpeter's viewpoint, innovation is 'possible without anything we should identify as invention' (Solo 1951, p. 84). As Solow argues, it seems that invention is placed outside the economic realm and 'the definition of innovation as distinct from invention fails to account for the source of innovation' (Solo 1951, p. 421). There is no explanation of the source of innovation in various descriptions of innovation by Schumpeter. However, an apparent implication is that it does not need to originate from invention.

The only discussion of the originator of innovation relates to the entrepreneur. As Schumpeter states:

> *we look upon ability to take the lead as a part of the entrepreneurial aptitude ... who is the first to decide on the production of a new consumers' good. The reason why he did not do so before is in disturbances which we assume to have preceded the equilibrium from which we start (Solo 1951, pp. 130−131).*

It seems that the source of the innovation is perceived as mental activities—conception, plans for something new or something not yet in existence. The entrepreneur, from Schumpeter's perspective, 'may, but need not be the inventor of the good or process he introduces' (Solo 1951, p. 103). The question arising here is that if the entrepreneur is not the inventor, where does their idea stem from and how could they obtain the necessary knowledge for innovation? The theory, therefore, 'fails to make explicit the necessary link between the increase of knowledge and the new combinations' (Solo 1951, p. 422). Schumpeter describes innovation as a purely business activity. This leads to the possible implication that the entrepreneur purchases new ideas. If this is the case, knowledge and new production functions can be seen as a commercial transaction. Nevertheless, Schumpeter does not discuss the market selling these new ideas, their supply and price nor does he mention the entrepreneur's activities in collecting production factors. Thus, Solo (1951) holds that the assumption of a new idea being acquired and purchased as a part of new combinations is invalid.

Witt (2002), Dopfer (2006) and Antonelli (2011) discuss the gap related to the process of creative destruction. For Schumpeter, this process is caused and led by the entrepreneur. However, the manner in which the entrepreneur transforms new ideas into innovations is not explicitly explained. Dopfer (2006) asks for further explanation of the creation of new ideas and their innovative potential, the retention of implemented innovations and the stability of the process of creative destruction. The absence of a comprehensive framework explaining the process of innovation generation is also required. According to Witt (2002), Schumpeterian work has not provided an appropriate micro framework to explain the economic dynamics of knowledge generation. Piore (2007) questions the absence of institutional design. Innovation becomes institutionalised in the structure of large business, raising the question of institutional design, which is not mentioned by Schumpeter. Courvisanos and Mackenzie (2014) concur that the question of how to frame the innovation system is also omitted by Schumpeter. Referring to this gap in Schumpeter's work, Antonelli (2011) contributes to the innovation literature from the perspective of complex systems by considering the historical, regional and institutional determinants of how innovation is generated. The proposition of Antonelli

(2011) is that firms innovate when they find themselves outside of equilibrium conditions. The creative response of agents in the process of technological change, whether creative or adaptive, depends on the network of interactions in which the firms are involved. Innovation, in Antonelli's (2012) perspective, is an emergent property of complex economic systems.

Schumpeter's assumptions about the process and effect of innovation are also questioned by economists. According to Schumpeter (1939, p. 93):

> *major innovations and also many minor ones entail construction of new plant (and equipment) – or the rebuilding of old plant – requiring non-negligible time and outlay. We shall reason on the assumption that they always do.*

This assumption refers to innovations as investment opportunities. In fact, many innovations are 'carried out without much investment in new plant or equipment' (Solo 1951, p. 424). Further, the time lag and outlay of funds should also be accounted for research and development (R&D),[7] which most certainly leads the innovation, even before the need for constructing new plant and equipment. It is true that the entrepreneur could go ahead of others given the time required to build a new plant, but it 'could also be imputed to the time required for R&D' (Solo 1951, p. 424).

Schumpeter (1934, p. 94) suggests that 'every innovation was embodied in a new firm founded for the purposes'. Solo (1951, p. 424) raises that the link between innovation and new firm conflicts with the proposition that 'innovation is a normal business activity with many established firms'. Solo (1951, p. 425) further argues that 'established firms compete not only in terms of existing products but by altering products and processes and by introducing new products', and in the competitive battle, it is 'not the new firms which innovate and the old firms which react, but all the competing firms which innovate, some succeeding and others failing'. The more efficient innovators eliminate the less efficient ones out of the market. However, there is still the possibility that an innovating firm may be displaced by a new firm that has greater finances, selling power or general managerial capabilities.

Another assumption proposed by Schumpeter (1939, p. 96) is:

> *the rise to leadership of New Men ... it explains why new production functions do not typically grow out of old businesses—if a new man takes hold of an old firm,*

[7] Yet, many innovations do not require R&D. This issue will be discussed later in section 2.8.1.1.

they may—and hence, why their insertion proceeds by competing the old ones out of existence or by enforcing the transformation of them.

As Solo (1951) argues, when innovation is undertaken, the crucial step in building a scientific organisation is selecting the R&D executive. The decisions of this executive are mainly entrepreneurial in scope. The confidence of the management board will rely on the executive rather than on the technical proposal. From a managerial perspective, the executive's record of past successes and failures determines the final decision. Therefore, it may not be appropriate to link the innovation with the new man; instead, it should be linked with the one who has the potential to lead successful innovations.

Another limitation in Schumpeter's work is the lack of focus on the role of demand in the dynamics of innovation and competition. Schumpeter focuses mainly on the supply side. Schumpeter (1961, p. 65) states that:

the producer who as a rule initiates economic change and consumers are educated by him if necessary; they are, as it were, taught to want new things, or things which differ in some respect or other from those which they have been in the habit of using.

According to this viewpoint, Schumpeter did not view demand as a stimulus of innovation. Unlike Schumpeter, Kalecki (1968) views innovation from the demand side. Accordingly, the entrepreneur carries out investment demand decisions to nurture innovation, and this type of investment occurs in the short period. Thus, '[a] slowly changing component of a chain of short period situations' leads to the long-run economic growth path (Kalecki 1968, p. 435). Several scholars support Kalecki's viewpoint of the importance of demand in innovation, contending that changes in consumer preferences and demand factors create crucial incentives for innovation by raising high expectations on the profits generated from innovation (Brouwer & Kleinknecht 1999; Geroski & Walters 1995). Saviotti and Pyka (2010) attempt to explain the saturation of demand of old markets and the creation of new markets. They demonstrate that innovation creates a potential market and produces the adjustment deficit. In the industrial life cycle, once productive capacity develops and meets demand, the deficit is reduced. As a consequence, a growing number of consumers transform a niche into a market, which eventually reaches a saturation point with a net drop in consumers. Courvisanos and Mackenzie (2014, p. 57) recommend that studies on economics of innovation should 'begin with Schumpeter on supply side and Kalecki on demand side'.

2.3. NEOCLASSICAL MODELS OF ECONOMIC GROWTH

Since it was first introduced, the concept of innovation and economic growth has been progressively refined from different perspectives and schools of thoughts. The following sub-sections discuss key post-Schumpeterian economic theories on innovation and economic growth from the neoclassical school of thought. A summary of the theories and a discussion of their usefulness in this thesis is presented later in section 2.6.

2.3.1 Exogenous growth theory

2.3.1.1. The Solow–Swan model

In the 1950s, Solow and Swan developed a model of economic growth—the well-known Solow–Swan model (Solow 1956, 1957; Swan 1956)—also known as the exogenous growth model. The Solow–Swan model is based on a continuous production function in the absence of an investment function, with a capital−labour ratio tending to self-adjust through time in the direction of equilibrium ratio. Solow–Swan's model includes the two main variables—physical capital and labour. It also includes a third factor—technology—involving innovation, ideas, research and know-how, thereby allowing more output to be generated with the same capital and labour. The model is presented as follows:

$$Y = AL^{1-\alpha} K^{\alpha}$$

where Y represents total production, L and K are the current stocks of labour and capital, respectively, A is technology parameter and $\alpha < 1$ so that production involves decreasing returns to capital.

The Solow–Swan model (Solow 1956, 1957; Swan 1956) is based on the following key assumptions:

1. Physical capital and labour contribute to aggregate output at a diminishing rate.
2. Population growth and technological progress are exogenous factors.
3. Full employment of labour and of the available stock of capital.
4. Savings equal investment.
5. Prices and wages are flexible.

Technology is determined by forces outside the economy as well as a continuous, ever-expanding set of knowledge, which is not specifically created by economic forces. In

Solow–Swan's model, exogenous growth depends on the growth rates of the workforce and total productivity. Under perfect competition, constant returns to scale and savings-driven growth are assumed, which enables a stable path of steady growth. The model also implies that the firm needs to have access to scientific resources, knowledge and technological advancements to achieve a sustainable positive long-run growth rate. Solow–Swan's model has been used as a basic framework and theoretical foundation by several economists investigating the relative contributions of 'expanding (and improving) labour supplies and increased capital investment to driving growth' (Cortright 2001, p. 3). The model is seen as 'the benchmark for the neoclassical theory of growth' and the backbone of the economic analysis of growth (Mulder et al. 2001, p. 152)[8].

2.3.1.2. Critical review of Solow–Swan's model

Despite its important contribution to growth theories, the Solow–Swan model has been criticised for its theoretical constraints and limiting assumptions. Several economists argue that the model is unable to explain the growth of the economy. The first problem is related to the variable of technology. As pointed out by Fagerberg (1994), growth, according to Solow–Swan's model, is caused by increases in capital and labour. What cannot be explained by these factors is called 'the residual', attributed to improvements in technology. The problem here is that technological progress was supposed to be exogenous. Mulder et al. (2001) indicate that growth rates of output cannot be explained by relying on the accumulation of physical inputs. They further demonstrate that 'once output growth is corrected for the increase in physical inputs, a large and persistently positive residual remains' (Mulder et al. 2001, p. 153). Arguably, not only increases in capital accumulation and labour force, but other factors must be taken into account, while explaining economic growth.

The other criticism of the Solow–Swan model centres on its assumptions. As emphasised by Nell (2013), there is no price mechanism in the Solow-Swan model. Even in the absence of price flexibility, diminishing returns and marginal productivity conditions still can be met, as assumed by Solow. Ozdemir (2017, p. 134) adds that 'the model fails to provide a role for prices in adjusting output to changes in demand'. The adjustment is determined by the supply side, whereas the role of aggregate demand is ignored. Technological changes are presumed to enhance the productivity of capital and

[8] Solow and Swan were awarded a Nobel Prize in Economics in 1987 for their work on the model.

labour and variations in relative prices, but demand rises have no effect on the model. Another drawback is the assumption of full employment. Solow assumes an unrealistic market that is perfectly flexible in matching unfilled jobs and unemployed workers with appropriate skills. Even though forced saving mechanisms and price adjustments might work in a craft-based economy, as argued by Nell (1998), this is not the case for mass production economies. This is because employment in such economies depends only on effective demand; there is no marginal productivity adjustment. Another limitation is that the investment function is unknown in Solow–Swan's model. The model predicts that total factor productivity should be exogenous to factor accumulation. Nonetheless, an empirical study by Bernanke and Gurkaynak (2002) shows that the savings rate and population growth are positively linked to total factor productivity. This implies that the endogenous mechanism has external or scale effects determining endogenous rather than exogenous growth.

Solow–Swan's model has been criticised for its inability to explain a sustained growth process. McCallum (1996, p. 66) argues that:

> *the neoclassical approach not only fails to provide an explanation of everlasting steady-state growth, but also cannot plausibly explain actual observed cross-country growth rate differences by reference to transitional episodes.*

The model's prediction is that output per person approaches a steady-state path with the growth rate being determined outside the model (exogenous demographic) and independent of preferences, choice of resource allocation by the agents, and particularly, of savings decisions and policy actions. Consequently, the model envisages that either all economies have the same growth rate or that the rate depends on one's interpretation. Thus, countries with similar savings and technology starting from different initial per capita levels would have different growth rates at the beginning, and then converge towards a common growth rate in the long run. A number of economists oppose Solow's prediction across countries. For example, Mankiw et al. (1992) and Barro (1991) argue that there is little evidence of a convergence across countries. They advocate that poorer nations starting with lower per capita outputs are generally unable to grow faster and catch up to richer nations.

2.3.2. Endogenous growth theory

2.3.2.1. Endogenous growth model

To address the shortcomings of the neoclassical model, Romer (1986) and others (e.g. Lucas, 1988) developed models in which 'steady growth can be generated endogenously' (McCallum 1996, p. 14). Romer made a significant contribution to endogenous growth theory by endogenising technological change and developing the first endogenous growth model in a form of the AK model[9]. Romer's work was built upon the work of Arrow (1962), who was among the first to consider that the growth rate of the effectiveness of labour is based on the accumulation of workers' experience or 'learning-by-doing' in producing commodities. Romer's objective was to build a growth model with an endogenised total factor productivity, with technological progress involved in the production function. This would provide an externality of increased returns to scale, which is endlessly accumulative, without its marginal productivity decreasing. Romer's model is viewed as 'an equilibrium model of endogenous technological change in which long-run growth is driven primarily by the accumulation of knowledge by forward-looking, profit-maximising agents' (Romer 1986, p. 1003). The production function of a firm is in the form Y = AK.

$$Y_t = AK^{\alpha}L^{1-\alpha}$$

where Y represents total production, L is labour, K is capital, A denotes aggregate productivity, α measures the output elasticity of capital and $0 < \alpha < 1$.

The model was based on four key assumptions (Romer 1986, pp. 1002−1003):

1. Technology has constant returns on private capital and labour but globally increasing returns to scale when collective capital is included.
2. Knowledge is a non-rival good and freely available.
3. New knowledge created by one firm has a positive external effect on the production possibilities of other firms.

[9] An early precursor of the AK model was the Harrod−Domar model (Harrod 1939; Domar 1946). Motivated by the challenge of developing a model that combines the virtues of the Solow−Swan and Harrod−Domar models, Frankel (1962) built the first iteration of the AK model. The model assumes that 'when people accumulate capital, learning by doing generates technological progress that tends to raise the marginal product of capital, thus offsetting the tendency for the marginal product to diminish when technology is unchanged' (Aghion & Howitt 2008, p. 48).

4. Knowledge is ‘an input in production that has increasing marginal productivity and production of consumption goods as a function of the stock of knowledge and other inputs exhibit increasing returns’.

In contrast to Solow–Swan’s model, labour productivity in Romer’s model is endogenous and is an increasing function of cumulated aggregate investment by firms, rather than having diminishing returns. In addition, capital should be considered a broader concept, including both physical capital and human/intangible capital. Moreover, capital in Romer’s model should be interpreted as knowledge. The core idea of Romer’s model is that knowledge is a kind of renewable capital and a public good, it is partially excludable but is a non-rivalrous commodity, and can be accessed at zero cost. This is different from ‘physical capital that can be produced one for one from forgone output’ (Romer 1986, p. 1003). Technological progress depends on the rate of macroeconomic capital stock, offsetting the effects of diminishing returns. Technical progress is no longer exogenously determined, but rather results from the decisions of agents who respond to market incentives. The external effect stems from a learning spillover. As the model implies, growth rates can increase over time and, as opposed to the Solow–Swan’s model, long-run economic growth can be sustained without population growth and exogenous growth of technological progress.

2.3.2.1 Criticisms of endogenous growth theory

Although the endogenous growth model addressed certain limitations of the exogenous model, it still faces criticism. The first critique is related to the idea of how knowledge is acquired and diffused. It is inaccurate to assume that knowledge is a public, non-rival good, freely disseminated and accessed at no cost. As Stigler (1961) argues, knowledge dissemination is expensive and difficult. Romer’s assumption is that designs are non-rival in the research process and research activities are boosted by the entire stock of design knowledge accumulated to date. Many economists disagree with this view. For instance, McCallum (1996) contends that knowledge development requires a substantial amount of expenditure/resources, questioning why an individual firm would devote its resources to creating new knowledge or developing new products that are to be possessed by the society, including their competitors. Arguably, the firm finds research worthwhile only if it can charge a price for its ideas that would be above the marginal cost of disseminating the ideas; otherwise they would not be able to recover the research expenditure (Parente 2001). Thus, a question that arises is why an individual firm should suffer R&D costs without the potential to earn monopoly profits. The incentive motivating a firm to generate new knowledge or ideas occurs only if those ideas are excludable. Yet the more excludable the new knowledge, the less society gains from the new knowledge. Nevertheless, apart from achieving a monopoly, there are multiple ways in which a firm can also profit from its investments in innovation such as from first mover advantages and increasing returns to scale (Teece 2006). The two examples are the case of Facebook and Google.

Another limitation of the model is that although growth has been endogenised, it depends completely on external, and thus unremunerated, accumulation of knowledge (Aghion & Howitt 2009). Knowledge is accumulated through a learning-by-doing process, but this process is assumed to be external to the firm. To maximise profit, the firm pays for labour and capital but it does not offer any additional payment that contributes to technological progress. In addition, one of Romer's assumptions related to knowledge, unity and externality is criticised by Herrera (2015). According to Romer, as cited by Herrera:

> *if the elasticity of output to knowledge is more than unity, the externality is so strong that the technology has increasing returns on accumulative factors: with an increasing rate tending to infinity, growth is explosive and makes the model diverge (Herrera 2015, pp. 15−16).*

Herrera (2015) states that only in a very peculiar case, a path of constant, stable long-run growth can be obtained. This would be a case when 'an elasticity of output to the stock of private and collective knowledge equals to unity' (Herrera 2015, p. 16). The occurrence of endogenous growth is then conditioned by a knowledge externality, which must be strong enough to make returns to accumulative factors constant.

Aghion and Howitt (2009) claim that the AK model is unable to explain cross-country or cross-regional convergence. The model predicts that cross-country variations in parameters will result in everlasting differences in economic growth rates. In fact, the history of economic development provides empirical evidence that later entrants to modern economic growth are able to double their income in a far shorter period relative to early entrants (e.g. South Korea). Therefore, the growth pattern does not necessarily depend on the starting levels (Parente 2001). The conditional convergence in income per capita was neglected. Hence, both absolute and conditional divergence should be considered, while explaining economic growth across countries.

2.3.3. Theory of the growth of the firm

2.3.3.1. Resource-based view

The resource-based view (RBV) was pioneered by Edith Penrose under the theory of the growth of the firm. Penrose (1959) views a firm as a bundle of resources that the firm owns and controls. Similarly, Wernerfelt (1984) conceptualises a firm as a unique bundle of resources and capabilities (both tangible and intangible). The RBV proposes that a firm's resources are heterogenous because of the unique characteristics of each firm and further, that resources or capabilities are decisive factors in firm performance (Penrose 1959). Contributing to this field, Barney (1991, p. 102) defines resources as:

> *all assets, capabilities, organisational processes, firm attributes, information, knowledge, controlled by a firm that enable the firm to conceive of or implement strategies that improve its efficiency and effectiveness.*

The key premise of the RBV is to explain why firms are different and how they can gain and maintain a competitive advantage by using their resources. To achieve such an advantage, a firm's resources must have four core attributes: valuable, rare, non-substitutable and imperfectly imitable. Teece et al. (1997) emphasise that the most important resources are those that are difficult, if not impossible, to replicate and replace. The RBV also discusses two other concepts: organisational capability and strategy. Organisational capability is defined as:

> *a firm's capacity to deploy resources, usually in combination, using organisational processes, to affect a desired end. They are information-based, tangible or intangible processes that are firm-specific and are developed over time through complex interactions among the firm's resources (Amit & Schoemaker 1993, p. 35).*

In a changing business environment, firms must incessantly develop their resources and capabilities to sustain competitiveness and growth (Robins & Wiersema 1995; Wernerfelt & Montgomery 1988). Strategy is defined as:

> *the determination of the basic long-term goals and objectives of an enterprise and the adoption of courses of action and the allocation of resources necessary for carrying out these goals (Chandler 1962, p. 13).*

Taking the three concepts into an organisational context, resources can be seen as elements that an organisation owns or has access to, capabilities represent a potential that an organisation can achieve with the existing resources and strategy represents the intention or plan that an organisation aims to achieve, for example, generating innovation.

The RBV suggests that organisational resources and capabilities determine a firm's capacity for innovation. Organisational resources are the inputs that are in turn 'combined and transformed by capabilities to produce innovative forms of competitive advantage' (Penrose 1959, p. 85). Innovation often takes place through the combination of various resources that are effectively used. Unused resources always exist and are a stimulus for innovation because they motivate the firm to find ways to utilise them for other investments or expansions, facilitating the combination of resources—or innovation (Penrose 1959).

Drawing upon prior research, Barney (1991) classifies resources into three groups: (i) physical capital such as plant, equipment and technology (Williamson 1975), (ii) human capital consists of training, intelligence, experience, relationships and the insight of managers and employees (Becker 1964) and (iii) organisational capital includes planning, controlling, coordinating and informal relations among actors within and outside the organisation (Tomer 1987). Resources can further be divided into tangible or intangible (Hannes & Fjeldstad 2000). Kalecki (1954) upholds the view that intangible investments, such as human resources management or marketing knowledge, are the drivers of innovation. The assets, resources and capabilities held by firms are deployed to build their competitive advantage, leading to economic prosperity (Dess et al. 1995). These resources and capabilities create economic returns for the firm (Amit & Schoemaker 1993). Resources play a vital role in determining a firm's innovation capacity, while high stock of human capital increases its capability to conduct innovative activities (Huiban & Bouhsina 1998). The availability of financial resources expands a firm's capacity to invest in innovative activities (Delcanto & Gonzalez 1999; Lee et al. 2001), while the lack of finance is likely to discourage innovative investment (Baysinger & Hoskisson 1989; Teece & Pisano 1994). Today, intangible resources, such as knowledge, skills, organisational culture and reputation, have become more and more important compared with tangible resources, such as physical capital (Kor & Mesko 2013; Surroca et al. 2010).

2.3.3.2. Knowledge-based view

The knowledge-based view (KBV) or the new economy approach is an extension of the RBV (Balogun & Jenkins 2003; Grant 1996; Huizing & Bouman 2002). Among its significant contributors, Nonaka (1991, p. 96) asserts that 'the one sure source of lasting competitive advantage is knowledge'. Nonaka and Takeuchi (1995) characterise innovative firms as knowledge creating. Firms are heterogeneous entities loaded with knowledge (Hoskisson et al. 1999). Knowledge is a firm's intellectual capital that it creates, transfers and transforms into competitive advantage (Kogut & Zander 1992; Nahapiet & Ghoshal 2002). Knowledge is underscored as the most important strategic resource of the firm, and knowledge asymmetries (capabilities and competences) determine the success and differences in performance between firms (De Carolis 2002; Kogut & Zander 1992; Nonaka 1994).

The KBV literature laid the foundation for innovation research. The innovation process is seen as one of accumulating and creating new knowledge (Nonaka & Takeuchi 1995; Zahra & George 2002) and at the end, innovation is generated as a result of knowledge exchange and recombination (George et al. 2008; Nonaka 1994). There is consensus that innovation is a recombination of existing knowledge and the creation of new knowledge (George et al. 2008; Schumpeter 1939). For example, Kogut and Zander (1992, p. 391) state that firms' capability to utilise knowledge in combination with 'the unexplored potential of the technology' enables them to generate new applications based on existing knowledge. Benner and Tushman (2002, p. 679) add that innovation is:

> *increasingly exploratory the more it departs from knowledge used in prior innovation efforts and, conversely, increasingly exploitative the more deeply anchored it is in existing firm knowledge.*

Existing knowledge is referred to as a prerequisite for innovation. Cohen and Levinthal (1990, p. 130) advocate that:

> *the prior possession of relevant knowledge and skill is what gives rise to creativity, permitting the sorts of associations and linkages that may have never been considered before.*

They also argue that a firm's absorptive capacity, which can be seen as a function of prior knowledge, is strongly associated with its innovative capability.

Despite being a prerequisite for innovation, knowledge may not be a motivator of innovation. According to Nonaka and Takeuchi (1995), an innovation process is initiated by an organisation identifying and solving a problem, while Machlup (1962, p. 180) contends that this process is performed as a response to 'scientific problems and hunches'. Innovation is the ultimate solution to problems; it is both a problem-solving process and a learning process in which firms deploy existing knowledge to create new knowledge and to adapt to changing market conditions (Katila & Chen 2008; Newman 2000). Similarly to the RBV, slack may also be a stimulus for innovation. Intra-firm knowledge guides management how to leverage excess resources or utilise unused resources, thereby stimulating innovation.

The empirical literature examines various knowledge-based processes of innovation. These are viewed as the most knowledge-intensive business processes (Kanter 1988; Nonaka & Takeuchi 1995), a knowledge management process (Madhavan & Grover 1998) or an ongoing pursuit of creating new knowledge (Nonaka & Takeuchi 1995). Innovation are widely evident among firms with increased knowledge intensity (Whittington et al. 1999). Stewart (1997) underscores how new products embody organisational knowledge. Likewise, Hoopes and Postrel (1999) hold that shared knowledge is a crucial resource causing the success of new products. More specifically, Li and Calantone (1998) show that customer knowledge boosts new product development in the United States (US) software industry, whereas for Helfat and Raubitschek (2000), market knowledge is helpful for generating new product lines. In today's knowledge-driven economies, a major driver of economic growth is innovation, which is stimulated by the knowledge and technological collaborations of firms, rather than the accumulation of capital as proposed by neoclassical theories (Álvarez et al. 2013). Firms create new knowledge by recognising their competitive advantage, strategic assets and resources, making their capabilities hard to imitate (Olavarrieta & Friedman 2008).

2.3.3.3. Criticisms of the RBV and KBV theories

The RBV of the firm has been the subject of some criticisms. A first critique concerns the lack of managerial implications. The RBV only suggests organisations develop and acquire valuable, rare, inimitable and non-substitutable resources but offers no guidance on how this can be done (Priem & Butler 2001). In response to this critique, the theorists argue that the theory of RBV seeks to explain why some firms have sustained competitive advantage over others rather than to provide managerial solutions (Barney & Mackey 2005; Nelson 1991).

A second critique relates to the generalisability of the RBV. Gibbert (2006) points out that the concept of resource uniqueness, as characterised by heterogeneity and immobility, indicates the impossibility of generalising. Connor (2002) questions if the RBV applies only to large firms or also to small firms. The argument is that small firms typically have limited resources and market power compared with large firms, hence they fall outside the scope of the RBV. However, this is not a strong argument if intangible resources are considered. If small firms have valuable intangible resources, such as human capital, they are still able to obtain a sustained competitive advantage (SCA) (Kraaijenbrink et al. 2010).

Another criticism of the RBV relates to its static nature. Priem and Butler (2001) assert that the RBV offers no explanation of how environmental dynamism erodes or develops resource value. It is argued that the RBV works only if the rules of the game in an industry remain unchanged. In an environment where new technologies or markets emerge quickly, the value of resources is likely to change radically. In this scenario, the RBV may not be able to explain a firm's SCA (Barney 2002). This issue also questions the achievability of a SCA. In a fast-changing and dynamic economy, firms cannot rely on a static set of resources to derive SCA. Inimitability and knowledge spillovers are progressing, hence a firm must constantly innovate since its profits are exposed to competitors and substitute products (Porter 1980). The resources and the way firms deploy them 'must constantly change, leading to the creation of continuously changing temporary advantages' (Fiol 2001, p. 692). SCA can be a powerful concept in the short run, but it cannot last forever. It is argued that the four RBV characteristics of resources—valuable, rare, non-substitutable, imperfectly imitable (Barney 1991)—are neither sufficient nor necessary. Becerra (2008) believes resource specificity, value uncertainty and innovation are decisive conditions. Yet it is not the value of a specific resource that matters, but the strategic combination and utilisation of various resources. The RBV seems to narrow the attribute of entrepreneurs to having awareness and superior knowledge of the future value of resources. Kraaijenbrink et al. (2010) believe that a firm needs not only a bundle of resources but also managerial capabilities to recognise and take advantage of the opportunities embedded in such resources to achieve a SCA.

Another issue is the difficulty of testing the RBV since it is tautological and true by definition (Lockett et al. 2009; Priem & Butler 2001). Barney (1991) states that 'resources are valuable when they enable a firm to conceive of or implement strategies that improve its efficiency or effectiveness' (p. 105) and 'a firm is said to have a competitive advantage when it is implementing a value creating strategy not simultaneously being implemented by any current or potential competitor' (p. 102). The problem that arises here is the indefinite notion of value (Priem & Butler 2001), and whether it is determined endogenously by the firm, exogenously by the market or in some other manner.

Another claim is that the RBV provides axiomatic or overly inclusive definitions. As Kraaijenbrink et al. (2010, p. 358) argue, if we accept these definitions, 'there is nothing strategically useful associated with the firm that is not a resource'. While the RBV recognises different types of resources—physical, human and organisational capital—it does not clarify underlying differences regarding how each type of resource contributes to a firm's SCA in different ways.

The KBV has been considered one of the main streams in the growing literature on strategic theories of the firm. It lays a foundation for understanding value creation, knowledge development and innovation and firm boundaries (Krogh et al. 2013). Nonetheless, there remain some weaknesses. The first is 'the disagreement about the level of analysis at which knowledge is a valid concept' (Kaplan et al. 2001, p. 11). While Levitt and March (1988) claim that firms accumulate knowledge embodied in individuals through organisational learning, Grant (1996) believes knowledge exclusively resides in individuals, while Kaplan et al. (2001) propose that knowledge is included as a multi-level concept.

Another inconsistency relates to the types of knowledge. Apart from the two common types of knowledge—explicit and tacit—economists have also developed their own typologies corresponding to their theories, such as internal versus external knowledge or know-how versus know-what. There are also contradictions when theorists provide answers to the question of firm existence. For instance, the idea of knowledge protection by Liebeskind (1996) opposes that of knowledge sharing by Grant (1996) or knowledge combination by Kogut and Zander (1992).

The role of hierarchy has also been debated. Some scholars favour hierarchies because these facilitate knowledge transfer (Arrow 1974; Kogut & Zander 1996), whereas others believe that hierarchies prevent knowledge transfer (Demsetz 1988; Conner & Prahalad 1996). Nickerson and Zenger (2004, p. 617) point out another shortcoming of the KBV theories, which they claim are 'primarily focused on the role of firms in providing efficient knowledge exchange rather than their role in efficiently producing knowledge or capabilities'. The KBV theories also fail to draw a strong causal relation between knowledge or firm behaviour and business performance. The theories generally state that certain knowledge capabilities, such as absorptive capacity, innovation, knowledge transfer and combinative and protective capabilities create a competitive advantage for the firm, leading to performance. The mechanisms that create knowledge resulting in improved performance remain ambiguous (Kaplan et al. 2001).

In conclusion, the RBV and KBV have established a theoretical foundation to understand the core attributes leading to differences in firms' capabilities. The development of the RBV occurred with an emphasis on the classification and features of resources and their link to firms' innovation capacity and sustained competitive advantage. The KBV highlights the importance of an intangible resource—knowledge of the innovation process and firm performance. The KBV literature claims that a firm's capacity to innovate is closely dependent on its intellectual capital or its ability to deploy its knowledge resources. Although some controversy and diverging opinions were found in the literature, these critiques are necessary and useful to enrich the theories, to adapt them to today's economy. The RBV and KBV build a platform for organisational resource management and form a useful framework for understanding firms' innovation capabilities (Díaz-Díaz et al. 2008).

2.4. EVOLUTIONARY MODELS OF ECONOMIC GROWTH

2.4.1. Evolutionary theory of economic growth

The evolutionary theorists—Richard Nelson and Sidney Winter—address the gaps in neoclassical theory of economic growth, while building upon Schumpeterian work. They state that:

> *much evidence of the role of insight in the major invention process and of significant differences in ability of inventors to 'see things' are not obvious'. The same applies for the innovation process within firms. Neoclassical thoughts view the development of innovation to be exogenous to the economic process, they therefore provide no insight into the occurrence of innovation processes (Nelson & Winter 1974, p. 888).*

Nelson and Winter agree with Schumpeter that innovative entrepreneurs are the most important drivers of the system, and their main goal is to seek profit—either by innovating or imitating. Yet the emphasis on 'careful calculation over well-defined choice sets' (Nelson & Winter 1974, p. 890) has not been considered in Schumpeter's work. The authors further add that firms operate in a competitive environment and that it is a dynamic selection environment, not an equilibrium one as assumed in neoclassical theory. In this environment, innovation and selection are driving forces of growth, with capital stocks playing some roles in the process.

Another issue raised by Nelson and Winter (1974) is that neoclassical explanations of the 'residual'—which almost equal the portion of growth explained by rises in the factors of production—are not sufficient. Previous work based on neoclassical thought only labels 'residual' as 'technical change' and attempts to explain growth by improvement in the quality of different factors. However, explanations of how these quality improvements came about or how they influence growth are lacking. Thus, there is a need for better explanations of the sources and impacts of technical advances, of factors contributing to quality improvements and, importantly, how the innovation process within firms is undertaken.

Taking into account existing gaps in neoclassical work, Nelson and Winter (1974) proposed the evolutionary theory of economic growth. The essential idea is that 'growth is an evolutionary process' involving a number of important changes (Nelson & Winter 1974, p. 886). The evolutionary theory applies a behavioural approach to individual firms. Since evolutionary growth models embody a Schumpeterian perspective of economic growth, they are also referred to as 'evolutionary Schumpeterian'. The model uses simulation to analyse different search behaviour of multiple firms and therefore, different technological levels. They argue that:

> *a firm at any time operates largely according to a set of decision rules that link a domain of environmental stimuli to a range of responses on the part of firms (Nelson & Winter 1974, p. 891).*

Investment decisions are determined by the selection environment that contains 'the conditions of supply and demand for current inputs and outputs and the functioning of the financial and capital goods markets facing the firms of the sector' (p. 893). For a firm, technical change is an aspect of the pursuit of profits. It is assumed that when the profit drops below a certain threshold, the firm will search for a better technique—either by creating innovation or by imitating other firms. Nelson and Winter demonstrate that the model is capable of explaining the patterns of aggregate output, factor prices, labour and capital input.

One of the fundamental elements of evolutionary economics is heterogeneity or variety of economic agents, which is characterised by complex evolving knowledge, bounded rational agents and extreme uncertainty. Nelson and Winter's standpoint is compatible with the KBV theory, in which knowledge is viewed as a valuable resource used to create new products and achieve a competitive advantage. The initial heterogeneity is reduced after a certain time because of competition and selection in the market. If the creation of new variety did not occur, the evolutionary process would soon come to an end. These arguments lead to the central point of evolutionary economics—the introduction of innovation is an ongoing process. Consequently, heterogeneity and variety are incessantly renewed and evolution is a never-ending process.

Another focus of the theory is on the diffusion of innovation. Once the firm has developed and adopted a new technology or innovation, a follow-on round of improvements begins. The diffusion process enables firms to access new knowledge and technologies and avoid the risk of costly R&D activities or new investments. The rates of introduction and diffusion of an innovation as well as its success and failure strongly depend on 'a complex of environmental and institutional considerations that differs sharply from sector to sector, country to country and period to period' (Nelson & Winter 1974, p. 903). The innovators will have a great advantage in certain industries with an institutional regime that enables them to expand capacity quickly but makes it costly and time-consuming for imitators. In other words, innovators perform well when the conditions allow a fast pace of technological advancement and imitation is hard. Conversely, where imitation is easy, the imitators will have advantages over innovators and will do well without, or with very little, R&D costs. To support their claim, Nelson and Winter (1982) conducted simulation experiments, proving that in the market/industry where skilful and aggressive imitators exist, firms that conduct R&D tend to lose out in a competitive battle.

Evolutionary theories also make a significant contribution regarding financial constraints by proposing that investment and firm growth are constrained by available financial resources (Nelson & Winter 1982). The issue of financial constraints on innovation development and implementation has attracted considerable interest in the innovation literature, especially in SME studies. However, evolutionary theory is also subject to critique. For example, Coad (2010) questions the notion of 'bounded rationality' as proposed by Nelson and Winter (1974). He argues that a firm's future is uncertain and it also cannot make investment decisions 'on discounted expected future returns on an infinite horizon' (Coad 2010, p. 210). Thus, it is not possible to rationally predict the future of the investment. Evolutionary theorists suggest that firms accumulate knowledge and develop capabilities over time, which determine their competitive advantage and future strategic avenue (Dosi et al. 2000). This implies that high performers have persistent profits and productivity levels. Nonetheless, there is a likelihood that 'low productivity firms may have access to highly profitable investment opportunities' (Coad 2010, p. 210). In this regard, evolutionary theory does not provide any distinction between current performance and future investment opportunities (Coad, 2010).

2.4.2. Systems of innovation

Other evolutionary theorists contribute to the innovation and growth literature by addressing an aspect omitted during Schumpeter's time; that is, the absence of an innovation system. Systems of innovation can be seen from different aspects, namely, geographic boundaries such as nations or regions, or sectoral, technological dimensions.

From a systemic perspective, Freeman (1987) was among the first to explore the national innovation system (NIS), using Japan as a case study. Freeman defines the NIS as 'the network of institutions in the public and private sectors whose activities and interactions initiate, modify and diffuse new technologies' (p. 1). He believes the NIS is the most crucial factor determining Japan's remarkable economic performance after World War II. Porter (1990), in the case of 10 industrialised countries, he found great variations in innovative activities among firms in different countries. These differences resulted from: (i) factor and resource conditions, comprising natural and labour resources, (ii) demand conditions, (iii) related supporting industries, and (iv) firms' strategies and industry structure. Various economic factors may account for the differences in innovative activity and output in different countries. Nelson (1993) contributes to this theme by conducting case studies of the NIS in 15 countries. He highlights a tight relationship between innovation system and other economic systems in a national economy, stating that:

> *it is inevitable that analysis of innovation in a country sometimes would get drawn into discussion of labour markets, financial systems, monetary fiscal and trade policies and so on (Nelson 1993, p. 518).*

The other group of evolutionary economists, such as Pavitt, Breschi, Malerba and Carlsson, is interested in the technological regimes and sectoral patterns of innovation in various industries. The sectoral innovation system, as defined by Breschi and Malerba (1997, p. 131), is a group of:

> *firms active in developing and making a sector's products and in generating and utilising a sector's technologies. Such a system of firms is related ... through*

processes of interaction and cooperation in artefact-technology development and of competition and selection in innovative and market activities.

A sectoral innovation system, as envisaged by Carlsson et al. (2002, p. 236), is based on the idea that:

different sectors or industries operate under different technological regimes which are characterized by particular combinations of opportunity and appropriability conditions, degrees of cumulativeness of technological knowledge and characteristics of the relevant knowledge base.

According to Malerba (2005, p. 65), a sectoral innovation system refers to 'a set of agents carrying out market and non-market interactions for the creation, development and diffusion of new sectoral products'.

Research on sectoral innovation systems by Pavitt (1984), Pavitt et al. (1989) and Malerba (2002, 2005) all points to the proposition that the competition–selection process is different across industries and that sectors differ greatly with respect to the technology sources they adopt, the users of the technology they develop and the methods successful innovators use. The reason is because each sector is characterised by different, complex interactions between heterogeneous agents, technological characteristics, economic structure and institutions. Breschi and Malerba (1997, p. 152) suggest that technological regimes are:

a major structuring factor of the Schumpeterian dynamics of innovators, the geographical distribution of innovators and the knowledge spatial boundaries of innovative activities in sectoral innovation system.

These findings support Nelson and Winter's work (1974, 1982) in which technological knowledge, labour and physical capital, finance resources and organisational structure are core features determining innovation capability. However, there are also other forces exogenous to the sector, which affect innovation possibilities and search costs. Given the distinct features of industry sectors, research on innovation processes or systems should be undertaken in separate sectoral contexts.

To summarise, evolutionary theory arose from Schumpeter's work as well as the unsatisfactory view of technological change presented by the Solow model. The seminal work of Nelson and Winter (1974, 1982) is acknowledged as the starting point of evolutionary theories. Fundamentally, evolutionary theory explains the dynamic interactions between heterogeneity, competition, selection and innovation. Most importantly, the introduction of innovation is an ongoing process that leads to renewed heterogeneity, eventually perpetuating the growth process. Evolutionary theorists have made a significant contribution to the literature of innovation and economic growth by addressing important limitations of neoclassical work.

Among the main contributions, evolutionary economics first unearths the innovation process within firms, which was not explained by Schumpeter. It offers explanations of the sources of novelty, such as the unintended innovation created by new routines and deliberate search for new technical solutions. Second, the impacts of technological advances and factors contributing to quality improvements are explicated. Third, evolutionary theory provides arguments countering the neoclassical view of the competitive environment in which the firms operate. They suggest that this is a dynamic selection environment, not an equilibrium one. Fourth, evolutionary economics, based on a dynamic perspective, addresses the static limitations of the RBV. Fifth, in response to how to frame the innovation system, several evolutionary economists examine the innovation systems both in cross-country and sectoral contexts. The variations in resources, technological knowledge, demand conditions, organisational and industry structure and institutions explain the differences in innovation capability, underscoring the economic performance of the nation. All the insights provided by evolutionary research have proved to be key motivation, stimulating advances in growth theory and developing successive waves of new growth models (Castellacci 2007).

2.5. NEW GROWTH THEORY

The latest development in the literature of growth theories is the neo-Schumpeterian approach to endogenous growth theory, also known as new growth theory (NGT). Similarly to evolutionary economics, Schumpeter's work is recognised as a main source of inspiration for new growth theorists. The first generation of NGT models, known as endogenous growth models, was proposed by Romer (1986) and Lucas (1988). They challenge neoclassical models, for example, Solow's models, maintaining that these models do not explicitly explained what caused technology to improve over time. From NGT's standpoint, technological progress is an endogenous variable and a product of economic activities. It is not increases in physical capital that lead to growth, but knowledge and technology, characterised by increasing returns, that are the main causes. This view highlights 'the ongoing shift from a resource-based economy to a knowledge-based economy' (Cortright 2001, p. 7). Nonetheless, the major criticism of the first generation of NGT models was their unrealistic assumption, that economic agents devote their resources to invest in knowledge, which was perceived as a purely public, non-rival good.

The second generation of NGT models attempted to address the above problem. These models propose that knowledge is an appropriable good and the generation of technological progress might be appropriated by the producer through monopoly rents. According to Grossman and Helpman (1990) and Romer (1990), innovation is assumed to be generated by a separate research sector. The main aim of this sector is to create new ideas and plans for the production of intermediate capital goods. The new capital goods, once created, add to the older ones, which are not instantly driven out of the market. The increasing variety of intermediate goods eventually leads to economic growth. The source of economic progress is ideas, which are infinite and do not diminish, while knowledge is cumulative over time, with new ideas building on the last. Nevertheless, this assumption leads to the additional question of whether innovation should be modelled as a certain outcome of the activity of the research sector.

In the third generation of NGT models, Grossman and Helpman (1991, 1994) and Aghion and Howitt (1992) answer the above question by considering the uncertainty of innovation investment. The uncertainty is illustrated by the assumption that innovations are generated, as a result of research activities, according to a stochastic Poisson process, representing the productivity in the research sector. However, the role of R&D, or research activities, in innovation output and productivity has been opposed by numerous subsequent studies, especially in services (Gallouj & Weinstein 1997; Leiponen 2005) and in the SME context (Rammer et al. 2009; Toivonen & Tuominen 2009).[10] Growth, from Aghion and Howitt's viewpoint (1992), is driven by a random sequence of quality-improving innovations. This prediction concurs with the view of Grossman and Helpman (1994, p. 34) that 'intermediate goods are forever being improved, thereby raising productivity in the assembly of final output', which are the main causes of long-term economic growth.

An important focus of NGT is on the role of human capital in knowledge creation and accumulation. Human capital is 'the accumulation of effort devoted to schooling and training' and the driving force behind economic growth (Grossman & Helpman 1994,

[10] Further discussion of R&D and innovation is presented in section 2.8.1.1.

p. 35). It is the skilled workforce that generates ideas, and the skills an individual obtains may improve production technologies. Knowledge, skills and innovation, which are embodied in skilled labour and organisational routines, are crucial for firms to achieve a competitive advantage in advanced industries. Adopting the comparative advantage theories, Grossman and Helpman (1994) hold that the cost of innovation is relatively low in a country that has a great endowment of human capital. Large economies with an abundant skilled workforce will conduct R&D intensively and will grow faster than their counterparts with less human capital. The expansion of employment in R&D and the productivity of R&D is predicted to increase the rate of product innovation. A competitive advantage is no longer determined by cutting prices, but by new products with improved characteristics, for example, quality, features and variety. Economies that aggressively generate innovations and adapt to ever-changing economic and technological conditions are able to sustain economic growth (Grossman & Helpman 1994).

The competitive market in NGT is different from neoclassical theories. This market, in NGT, does not work in accordance with 'the smoothly adjusting equilibrium model of neoclassical economics' (Cortright 2001, p. 8). NGT argues that technological progress usually requires an intentional investment of resources by innovative entrepreneurs or firms that are seeking profit. The goal of these investments is to gain profit from research efforts (i.e. innovations), which in turn lead to the long-run growth of firms. However, the growth process is uneven and stochastic. Firms incessantly race to 'bring out the next generation of products, but there may be long periods without a success in some industries', while other industries may 'experience rapid successions of research breakthroughs' (Grossman & Helpman 1994, p. 34). At this stage, theories of innovation and growth have been advanced, but there remain aspects to be explored. Innovation can be radical and incremental, as proposed by Schumpeter and evolutionary economists. So how can different innovations with different impacts on the economy be fitted in NGT models? In response to this question, the next generation of NGT models (Bresnahan & Trajtenberg 1995; Helpman 1998) predicts that radical innovations have deeper impacts on the process of economic growth compared with incremental innovations. Helpman (1998, p. 13) states that a:

> *drastic innovation qualifies as a general-purpose technology if it has the potential for pervasive use in a wide range of sectors in ways that drastically change their modes of operation.*

Finally, a new aspect brought by NGT is the effect of globalisation on innovation. It is suggested that foreign ideas may be exploited to develop new products, improve existing ones or improve production process to produce goods at a lower cost. Globalisation gives innovators the opportunity to exploit new ideas on a global scale and to earn profits overseas, known as 'the scale effect'. Not only do international interactions affect the incentives for knowledge creation, but it is seen as a process of technological dissemination and diffusion. Importers gain ideas about new products and techniques from their suppliers, while exporters acquire information on product specifications or feedback from their customers abroad, which is a valuable source of ideas to improve products or to make them more attractive[11]. For foreign affiliates, knowledge about products, processes and management methods adopted from multinational corporations enhances their innovation capacity. International competition is also a driver of innovation, known as the 'competition effect'. For firms developing products for a protected domestic market, the technologies only need to be new to the local economy; however, to be able to compete in international markets, ideas must be innovative on a global scale. Depending on whether the scale effect or the competition effect is more powerful, the innovation incentives may either intensify or diminish (Grossman & Helpman 1994, 2015).

NGT contributes to the literature of innovation and growth by offering insights into various aspects of the innovation process and its impacts on economic growth. All generations of NGT point to the proposition that innovation is the engine of growth (Aghion & Howitt 1992; Grossman & Helpman 1994; Romer 1990). Fundamentally, innovation can be explained by two types of complementary mechanisms: (i) the accumulation of knowledge and human capital through the process of learning-by-doing (Lucas, 1988; Romer 1986) and (ii) R&D activity of research agents (Romer 1990; Grossman & Helpman 1991, 1994). In NGT, technological knowledge is perceived as a non-rival and partly appropriable economic good produced by a separate research sector. Another theoretical contribution of NGT is the incorporation of uncertainty of innovative activity to the modelling process. The way in which uncertainty is represented in NGT implies 'a stylized description of the growth process, but its advantage is certainly the greater tractability and stronger analytical power of NGT models compared with evolutionary works' (Castellacci 2007, p. 615). Building upon previous theories, NGT

[11] Further discussion on the export–innovation relationship is presented in section 2.8.2.4.

offers a more thorough explanation of how knowledge and innovation lead to economic growth at both national and international levels.

The development of NGT models has attracted considerable interest among empirically oriented economists, evident in the substantial number of applied and empirical studies across countries (Castellacci 2007). NGT provides new insights into the complexities of the innovation process and its effects on economic performance. As Castellacci (2007, p. 619) indicates:

> *the re-interpretation of some evolutionary insights in a dynamic equilibrium framework has in fact led to the refinement of NGT models and to new empirical applications.*

A good understanding of the determinants of a country's technological advancement is required to understand its performance in the long run. In circumstances where the market equilibrium entails too slow a pace of technological progress, the theory suggests a remedy to use R&D subsidies to spur innovation. Product-cycle trade can then accelerate innovation and growth in the global economy (Grossman & Helpman 1991). Nonetheless, NGT and its implications need more empirical tests to validate the proposed theories.

2.6. SUMMARY OF THEORIES OF GROWTH

An array of theories on innovation and economic growth has been developed since Schumpeter first introduced the concept of innovation in the 1930s. These theories can be classified into two main schools of thought: neoclassical and evolutionary economics. Several models were established that proposed and examined factors contributing to growth and innovation. Neoclassical economists such as Solow (1957) and Swan (1956) rely on increases in physical inputs, which suffer diminishing returns, in explaining growth rates. The endogenous growth model of Romer (1986) goes beyond exogenous growth theory by recognising knowledge and labour productivity as having increasing returns, while capital includes both physical and human capital. The importance of knowledge in innovation and growth is mirrored in the theory of the growth of the firm, represented by RBV and KBV. Accordingly, knowledge is the most important resource and a core base for innovation development. Moreover, a firm's resources determine its innovation capacity and organisational capability, while its strategy determines differences in performance among firms.

Inspired by Schumpeter's work, evolutionary and new growth theories were established. In comparison, neoclassical and evolutionary perspectives exhibit several differences. Neoclassicism views technological progress as an exogenous factor related to changes in the aggregate capital and labour stock, which are external to the firm or beyond its control. Technological progress under evolutionary theory is an endogenous variable. The theories also explicitly take into consideration intentional innovative investment, and suggest that new knowledge can be created from intentional R&D. Another difference between the two perspectives is related to the equilibrium market. Neoclassical models are still equilibrium models, implying that economic growth is a smooth process with the tendency returning to an equilibrium state. Evolutionary theorists disagree that it is a dynamic selection environment, not an equilibrium one. They further argue that 'the neoclassical production function does not comply with what empirical research tells us about the nature of technological change and the characteristics of innovative firms' (Mulder et al. 2001, p. 159). The evolutionary theory of economic growth highlights the complexity of the innovation process, which is shaped by the heterogeneity of economic agents, environmental and institutional settings and competition in the market. It further emphasises financial constraints as an impediment to innovation investment and firm growth.

In combination with Schumpeterian theory, an important theme in evolutionary economics that is most relevant to the present study is sectoral systems of innovation. This theme proposes the need to study innovation in a sectoral context because of significant differences in industry characteristics or sectoral patterns. The reviewed theories also shed light on innovation systems, suggesting several factors that contribute to innovation generation. All theories agree that human capital, physical capital and technology are the core components of the production process and innovation. Knowledge has been recognised as a crucial factor since endogenous growth theory onwards. Characteristics of the firm (e.g. size, age) and firm strategy (e.g. focus on innovation) were also proposed as important determinants of innovation in endogenous growth theory and RBV theory. Evolutionary theory and NGT add further insights into the innovation process and its determinants. While evolutionary economists explicitly raise the important role of sectoral patterns, new growth scholars view exports, networks, R&D, technological conditions and market competition as pivotal to innovation.

The reviewed growth models facilitate our understanding of the output production function and the key factors that drive firm productivity. The production function establishes the link between the amount of various inputs that a firm uses and the level of output that can be achieved, which lays a foundation for developing the productivity equation. Components of such function further enable the identification of the major inputs that drive output performance. There is broad agreement among various schools of economic thought such as the theory of economic development (Schumpeter 1934), evolutionary theory of economic growth (Nelson & Winter 1974), and new growth theory (Grossman & Helpman 1991), that technological change or innovation is a major driver of firm growth and long-run productivity. Innovation yields higher real incomes, reorganises the production processes or implements the new ones with greater efficiency and reduced cost, which eventually leads to improved productivity and a competitive advantage for the innovating firms (Schumpeter 1934, 1942). From this perspective, the reviewed growth models propose the important link between innovation and firm productivity.

Apart from innovations, the growth models also identify other variables that are important to productivity performance. The most often cited variable is capital investments. Physical capital, such as plant, equipment, and machinery, is a fundamental factor in the production function (Nelson & Winter 1974, 1982; Romer 1986; Solow 1956, 1957; Swan 1956). Development of growth models since Romer (1986) further emphasises that capital should be considered a broader concept, including both physical capital and human capital or knowledge with the latter determining the innovation capability and differences in performance between firms (De Carolis 2002; Kogut & Zander 1992; Nonaka 1994). Finally, evolutionary models propose the importance of sectoral patterns. Accordingly, variations in terms of technological regimes, institutional settings, knowledge base and learning processes are likely to influence innovation and production processes of firms among various industries and sectors (Nelson & Winter 1974; Malerba 2002, 2006; Pavitt 1984). This suggests that analysis on the innovation and productivity relationship needs to consider the sectoral context.

To conclude, there is an extensive body of research, both theoretical and empirical, on the process of innovation and growth. Notably, Schumpeter's work was recognised as an inspiration to the development of evolutionary and new growth theories as well as many other subsequent studies. Schumpeter's contributions to theory of economic growth have been widely acknowledged to be the most important and invaluable for innovation literature. The post-Schumpeterian period has significantly contributed to the literature on innovation and economic growth from different schools of thought, with the later theories addressing limitations and building upon the former ones. It is worth noting that criticism of previous theories should not be considered negative, rather that we must take into consideration the industrial and historical context and the time when the theories were developed. Schumpeterian theories, along with other relevant theories such as evolutionary theory, NGT and theory of the growth of the firm, supplement and facilitate our understanding of origin, features and typologies of innovation, the complexity of the innovation process and its determinants. Table 2.1 summarises the tenets, propositions and limitations of these theories as well as the key factors relating to this thesis, considered to affect innovation and economic growth.

Table 2.1: Summary of the main theories

Theories	Tenets	Main propositions	Limitations	Key factors for the thesis
Schumpeter's theory of economic development	• Innovation is a creative destruction. • Innovation is the driving force of economic growth and wealth creation. • Economic development through innovation is a dynamic process of disturbance of the static general equilibrium of the economy.	• The entrepreneur is the innovator. • Increase in profit is the main expectation of evolutionary firms when innovating. • The innovation process has four stages: invention, innovation, diffusion and imitation. • Dynamic efficiency is much more important and substantially valuable to the firm than static efficiency. • Innovation enables a firm to achieve superior strategic and competitive advantage over the long run.	• The distinction between invention and innovation is not convincing. • Lack of explanation of the sources of the innovation. • Assumptions related to the new firm and new leadership are not convincing. • An appropriate framework to explain the economic dynamics of knowledge generation is questioned. • The demand side is not considered. • More explanation of the innovation process and system is needed.	• Human capital • Capital investment • Market competition • Firm size
Exogenous Growth Theory	• Increased and improved labour supplies and increased capital investment drive growth. • Population growth and technological progress are exogenous factors. • Capital−labour ratio has a tendency to self-adjust through time in the direction of equilibrium ratio.	• Technology is determined by forces outside the economy. • Physical capital and labour suffer diminishing returns. • Savings equal investment. • Full employment of labour and of the available stock of capital. • Perfect competition, constant returns to scale and savings-driven growth create a stable path of steady growth.	• Technological progress comes from nowhere. • Growth rates of output cannot be explained by relying on the accumulation of capital and labour. • An investment function is unknown. • An unrealistic market perfectly matches unfilled jobs and unemployed workers with appropriate skills. • There is no price mechanism. • The adjustment determines the supply side, whereas the role of aggregate demand is ignored. • The model fails to plausibly explain everlasting steady-state growth and actual observed cross-country growth rate differences by reference to transitional episodes.	• Human capital • Capital investment • Technology (e.g. ICT)

Theories	Tenets	Main propositions	Limitations	Key factors for the thesis
Endogenous Growth Theory	• Labour productivity is endogenous and is an increasing function of cumulated aggregate investment by firms. • Capital includes both physical capital and human/intangible capital. • Technology progress is endogenous and depends on the rate of macroeconomic capital stock, offsetting the effects of diminishing returns.	• Technical progress results from the decisions of agents responding to market incentives. • The growth rate of the effectiveness of labour is based on the accumulation of workers' experience or learning-by-doing in producing commodities. • Knowledge is a public, non-rival good, and can be accessed at zero cost. • Long-run economic growth can be sustained without population growth and exogenous growth of technological progress.	• The misperception that knowledge is a public, non-rival good, freely disseminated and can be accessed with no cost. • Growth relies entirely on external, and therefore unremunerated, accumulation of knowledge. • The assumption that knowledge accumulation is external to the firm is not convincing. • The model cannot explicitly explain cross-country or cross-regional convergence.	• Capital investment • Human capital • Knowledge • Technology (e.g. ICT) • Firm characteristics (e.g. size, age)
Theory of the Growth of the Firm	<u>*Resource-Based View*</u> • A firm is 'a bundle of resources'. • A firm's resources and its capacity to deploy resources explains why firms are different.	• A firm's resources are heterogenous due to the unique characteristics of each firm; resources or capabilities are decisive factors in firm performance. • To achieve a SCA, a firm's resources must have four attributes: valuable, rare, imperfectly imitable and non-substitutable. • Organisational resources and capabilities are those that determine a firm's capacity for innovation. • The resources, assets and capabilities the firm possesses determine its competitive advantage, leading to economic wealth.	• The static nature does not explain how environmental dynamism develops resources/knowledge value. • The four attributes (valuable, rare, imperfectly imitable and non-substitutable) may not be sufficient or necessary. • The RBV seems to narrow the attribute of entrepreneurs to having alertness and superior information on the future value of resources. • Minor criticisms about generalisability, the difficulty of testing the theory and lack of managerial implications of the RBV.	• Financial resources • Human capital (e.g. training) • Organisational capability and strategy (e.g. innovation focus) • Firm characteristics (e.g. size)

Theories	Tenets	Main propositions	Limitations	Key factors for the thesis
	Knowledge-Based View • Firms are heterogeneous entities loaded with knowledge. • Knowledge is the one sure source of lasting competitive advantage.	• Knowledge asymmetries (capabilities and competences) determine the success and differences in firm performance. • An innovation process is initiated by an organisation creating and defining problems. • The innovation process is one of accumulating and creating new knowledge.	• Disagreement about the level of analysis at which knowledge is a valid concept. • The inconsistency relates to the types of knowledge. • The KBV has not offered a sufficient and robust explanation of when and why the firm boundaries exist.	• Knowledge • Collaboration
Evolutionary Theory of Economic Growth	• Growth is an evolutionary process. • Investment decisions of firms are determined by the selection environment. • The competition–selection process is different across different industries. • The introduction of innovation is an ongoing process so that heterogeneity and variety are continuously renewed. • Financial constraints hinder innovation investment and thereby, firm growth.	• Firms operate largely according to decision rules that link a domain of environmental stimuli to a range of responses on the part of firms. • When the profit rate falls below a certain threshold, the firm searches for a better technique—either by imitating other firms or by innovating. • Knowledge is a valuable resource used to create new products and achieve competitive advantage. • The sources of novelty created by new routines and deliberate search for new technical solutions. • Factors in the innovation system determine economic performance and growth of the nation.	• Notion of 'bounded rationality' is questioned. • No distinction between current performance and future investment opportunities.	• Sectoral pattern • Labour • Physical capital • Finance resources • External environment

Theories	Tenets	Main propositions	Limitations	Key factors for the thesis
New Growth Theory	• Technological progress is an endogenous variable and a product of economic activities. • Innovation is created by a separate research sector. • There is an uncertainty of innovation activity. • Growth is fuelled by a random sequence of quality-improving innovations. • Economies that aggressively generate innovation and continuously adapt to ever-changing economic and technological conditions are able to sustain growth.	• Knowledge is an appropriable good. • Technical progress can be generated by the producer through monopoly rents. • Innovations are generated as a result of research according to a stochastic Poisson process. • Intermediate goods are constantly being improved. Raising productivity in the assembly of final output is the cause of long-term economic growth. • Human capital is the driving force behind economic growth. • Technological progress requires an intentional investment of resources by profit-seeking firms or innovative entrepreneurs.	• The first generation of NGT models was based on the unrealistic fact that economic agents devote their resources to invest in knowledge, perceived as a purely public, non-rival good. • In the second generation, the unexplored aspect is whether innovation should be modelled as a deterministic and certain outcome of the activity of the research sector. • Another gap to be explored is how different sizes of innovation with different impacts on the economy can be fitted in NGT models. • The role of R&D activity to innovation might not be relevant for service and small firms.	• Human capital (e.g. training) • Financial resources • R&D • Export • Collaboration • Technological and market conditions (e.g. sectoral differences, market competition) • Ownership status

2.7. INNOVATION IN MODERN ECONOMIES

2.7.1. Definition of innovation: Refinements and extensions

Since its introduction in the 1930s, the concept of innovation has been subject to refinements and extensions. For example, the European Commission (1995, p. 688) defines innovation as:

> *the renewal and enlargement of the range of products and services and the associated markets; the establishment of new methods of production, supply and distribution; the introduction of changes in management, work organisation, working conditions and skills of the workforce.*

According to West and Anderson (1996), innovation is the effective application of products or processes which are new to the firm and beneficial to stakeholders. As Thompson (1965, p. 2) states, innovation is 'the generation, acceptance and implementation of new ideas, processes, products and/or services'. Similarly, Sipe and Testa (2009, p. 2) refer to innovation as 'an organisation's development and implementation of new products and services or new ways of doing things'. The definition used in a series of Australian Innovation System Reports refers to innovation as 'a new idea or path that is applied practically to create or capture value in a market' (Australian Government 2016, p. 11).

Of several international organisations that have sought to develop the concept of innovation, the OECD makes a significant contribution to guide contemporary innovation research through its *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data* (OECD & Eurostat 2005, 2018). The innovation concept proposed in the Oslo Manual is internationally recognised and widely adopted in innovation studies using survey data. Accordingly, innovation is:

> *the implementation of a new or significantly improved product (a good or a service), a process, a new marketing method or a new organisational method in business practices, workplace organisation or external relations (OECD & Eurostat 2005, p. 46).*

Despite the numerous definitions of innovation, there is consensus on the point that all innovations involve newness—innovation is essentially related to something 'new' and 'applicable'. 'New to the firm' is the minimum entry level for an innovation (OECD & Eurostat 2005, 2018). Although the concept of innovation has undergone several modifications, the contemporary literature on economics of innovation reclaims many of

Schumpeter's central ideas on the key role of innovation and his thoughts remain the foundation of modern innovation theory.

2.7.2. Typologies of innovation

Schumpeter (1912) was the first to propose five types of innovation: product, process, organisational, input and market innovation. In his seminal work, Schumpeter views innovation as:

> *introduction of new products and new production processes, opening of new markets, acquisition of news sources of inputs, and reorganisation of firms or industry sectors (Schumpeter, 1934, p. 66).*

This classification has been adopted in subsequent studies, such as those of Hjalager (2002), Drejer (2004), Fagerberg (2005) and Weiermair (2006). A modified version of Schumpeter's typology of innovation in the *Oslo Manual* by the OECD and Eurostat (2005) proposes four types of innovation: product, process, organisational and marketing innovation. This classification has been widely adopted in innovation surveys, such the Community Innovation Survey (CIS), which collected firm-level innovation data in European countries, and the BCS, which gathered innovation information among Australian firms.

Nonetheless, in several industries such as services, because of the simultaneity inherent in their activities, service processes are barely separable from the outcomes they produce. This makes the common distinction between product and process innovation increasingly tenuous in services (Mina et al. 2014; Toivonen & Tuominen 2009). Consequently, product innovation is usually grouped together with process innovation under the broader term, technological innovation. As a result, numerous studies have classified innovation based on their level of technological involvement, namely, technological and non-technological innovation (in the broader academic literature, see, for example, De Fuentes et al. (2015, 2019), Gallego et al. (2015), Geldes et al. (2017), González-Blanco et al. (2019), Heredia Pérez et al. (2019), Mothe and Nguyen (2012), OECD (2009), Peters et al. (2018), Schmidt and Rammer (2007) or in the SME context, see, for example, Aboal and Garda (2016), Hafeez et al. (2013), Radicic and Djalilov (2019)). Accordingly, technological innovation includes product and process innovation, whereas non-technological innovation refers to organisational and marketing innovation (OECD 2009). The following sections present the definition and key features of each innovation type.

2.7.2.1. Technological innovation

Product innovation

The most typical output of the innovation process is the introduction of a new product. A new product, from Schumpeter's perspective, is one with which consumers are not yet familiar or one with a new quality. Johne (1996) defines product innovation as the development and radical change of the performance attributes of the product. New types of products are 'the most obvious elements of innovation' (Kuusisto & Meyer 2003, p. 21). The *Oslo Manual* embraces Schumpeter's view, defining product innovation as 'the introduction of a good or service that is new or significantly improved with respect to its characteristics or intended uses' (OECD & Eurostat 2005, p. 48). The *Oslo Manual* goes on to describe product innovation as 'significant improvements in technical specifications, components, materials, incorporated software, user-friendliness or other functional characteristics' (p. 48). Product innovation can employ 'new knowledge or technologies or can be based on new uses or combinations of existing knowledge or technologies', hence, product innovations comprise both entirely new products and 'significant improvements to existing products' (p. 48). In Australia, the ABS's classification and definition of product innovation is in accordance with that proposed in the *Oslo Manual* (OECD & Eurostat 2005), namely:

> *any good or service or combination of these which is new to the business. Its characteristics or intended uses differ significantly from those previously produced/offered by this business (ABS 2018a, p. 15).*

A product can be a good or a service. Goods usually refer to 'tangible' objects requiring a high level of technological involvement, for example, cars, smartphones, furniture or software (Gault 2013). The introduction of Global Positioning Systems that reduce energy consumption and meet environmental standards is another example of goods innovation (OECD & Eurostat 2005). In contrast, services are 'intangible', for example, insurance, educational courses, art, tourism, consulting, spa or health care. In the manufacturing industry, product innovation is mostly the introduction of new goods, whereas in the service industries, this type of innovation typically refers to the provision of new services. Today, the service industries represent the largest sector in many developed countries. In Australia, services constitute more than 70% of GDP (Department of Foreign Affairs and Trade [DFAT] 2020). Therefore, product innovation in services has attracted considerable attention from both economists and policymakers.

In terms of its characteristics, service innovation can be considered an incremental innovation, which includes small adjustments of procedures that are rarely radical and dimensional (Sundbo & Gallouj 2000). Another feature of service innovation is the strong interaction with customers in the delivery of services. Service firms rely mainly on internal sources and customers to develop new products (Gómez et al. 2016). Van Ark et al. (2003) assert that service innovation is a multidimensional process and is less technological. It can involve the introduction of entirely new services, significant improvements to how services are delivered with respect to efficiency and speed or new characteristics and functions added to existing services. These changes aim to improve service quality and attractiveness to consumers. Service innovation is also associated with variations in product delivery or add-on services enhancing the customer's experience (Oke 2007).

Nevertheless, recent research suggests that the service sector is becoming more technology- and capital-intensive (Gallouj & Savona 2009; Witell et al. 2016). Martin-Rios and Ciobanu (2019, p. 219) show that service innovations, introduced by service firms, largely employ "new knowledge and technologies, or new combinations of existing knowledge and technologies". Gunday et al (2011) postulate that service innovations are closely connected to technological developments, while Kindström et al. (2009, p. 336) support that "technological innovations directly related to the services business". Many service firms affiliate with technology partners to develop and offer service innovations (den Hertog et al. 2010). According to Sundbo et al. (2007), numerous service innovations are technological such as a Personal Digital Assistants tool that enhances tourist experience or new delivery services driven by technology (den Hertog et al. 2010), for instance, Uber Eats, Deliveroo or DoorDash. New Internet services such as online banking or bill payment systems are some other examples of technological service innovations which significantly improve customer convenience. New services with digital technologies embedded are also popular (Nylén & Holmström 2015), for example, e-health or eMedicare (digital health services). The technological novelty of the new service enables service firms to gain a competitive advantage in the market (Evangelista & Vezzani 2010; Martin-Rios & Ciobanu 2019). Thus, service innovators need to be aware of the latest technologies in order to seize innovation opportunities (den Hertog et al. 2010; Szczygielski et al. 2017).

Product innovation can also be categorised based on the level of novelty or the characteristics of the innovation. Kahn (2018) summarises seven types of product innovation: (i) cost reduction, (ii) product improvements in terms of features, functions or form, (iii) line extensions—adding new features or options to an existing product, (iv) new markets—introducing existing products to new markets with minor changes, (v) new uses—introducing new uses of existing products, (vi) new category entries—‘new to the company, but not new to the consumer as a category’ (p. 455), for example, Apple’s entry into the watch industry with its Apple Watch and (vii) new to the world—a completely new product or one that previously did not exist.

Empirical studies on product innovation are the most dominant stream in innovation research. Product innovation is the key driver of new venture establishment (Dougherty 1992; Drucker 2014). Further, it is found that product innovation affects firm performance (Avlonitis & Salavou 2007; Prajogo 2017; Varis & Littunen 2010). Product innovations strengthen a firm’s competencies by allowing it to exploit its capacities or to explore new areas that are currently outside its capabilities. Therefore, product innovation is seen as one of the most important dynamic capabilities of a firm (Teece & Pisano 1994). Successful product innovation offers superior value to customers. This, in turn, stimulates demand, generates profits and increases market share for the innovating firm, eventually resulting in growth of market performance (Datta 2011; Fossas-Olalla et al. 2015). Thus, the success of newly introduced products enables the innovating firm to gain a competitive advantage and stay ahead of competitors or even lead the industry.

Process innovation

In the early stage, process innovation, as defined by Schumpeter (1934, p. 66), is ‘the introduction of a new method of production or a new way of handling a commodity commercially’. Hammer and Champy (1993) view process innovation in manufacturing as an organisation-wide effort involving fundamental rethinking and radical redesign of manufacturing systems and processes to dramatically improve performance in terms of quality, service, speed and cost. Process innovation aims to improve the efficiency and effectiveness of production processes and to enhance customer support and internal business efficiencies (Higgins 1995; Preissl 2000). OECD and Eurostat (2005) and Kahn (2018) indicate that the implementation of new processes is intended to reduce unit costs of production and delivery, creating greater efficiency; in other words, faster processing, higher output and lower cost, in turn leading to increased quantity or quality and finally, increased productivity. Comparing process innovations in service and manufacturing, Barras (1986) and Hughes and Wood (2000) suggest that overall, service firms tend to introduce imitative process innovations or adopt new technologies initially developed in the manufacturing industry to improve the efficiency of their processes and service quality. In contrast, manufacturing firms are more likely to introduce new processes with a high degree of novelty. According to Kuusisto and Meyer (2003, p. 21), typical process innovations include 'renewals of the prescriptive procedures for producing and delivering goods and services'. This view is consistent with the OECD and Eurostat (2005, p. 49), which considers process innovation as 'the implementation of a new or significantly improved production process, or delivery method'. In the Australian case, the ABS also adopts the *Oslo Manual's* definition of operational process innovation, namely:

> *a significant change for the business in its methods of producing or delivering goods or services. It includes any new or significantly improved (i) methods of manufacturing or producing goods or services, (ii) logistics, delivery or distribution methods for goods or services, (iii) supporting activities for business operations such as maintenance systems or processes for purchasing, accounting or computing (ABS 2018a, p. 15).*

Tidd et al. (2005) agree that process innovations, in general, refer to changes in the way products or services are created and delivered to customers. This can be either an application of a completely new method of producing or delivering or a significant improvement in procedures, techniques, equipment and/or software. Production methods relate to 'the techniques, equipment and software used to produce goods or services', while delivery methods refer to 'the logistics of the firm and encompass equipment, software and techniques to source inputs, allocate supplies within the firm, or deliver final products' (OECD & Eurostat 2005, p. 49). Like the ABS, Gómez et al. (2016) also classify three types of process innovation relating to production methods, logistics and supporting activities. They add that the major contributors to process innovation are internal sources and suppliers, followed by consultants and universities.

Ganzer et al. (2017, p. 330) emphasise that the core components of process innovation in manufacturing are significant amendments to 'machinery, production layout, software for controlling production and programming and production techniques'. In services, process innovations can be divided into two main types: the reorganisation of procedures of service provision and automation (Preissl 2000). Emerging innovations in processes are linked to automation. Existing services that used to be provided by human beings are now being performed by machines. Examples include automatic check-in systems for hotel guests and air travellers through mobile phones or the Internet, computer-operated train timetables, automated packing, ticket vending machines, mobile ordering or self-order kiosks. Another common type of process innovation is the outsourcing of support functions such as accounting or printing services. A crucial element, claimed to be the backbone of process innovations, is ICT (OECD 2015b). ICT significantly improves business procedures both in manufacturing and services. The rapid development of ICT has created new opportunities and platforms for process innovations, significantly enhancing quality and efficiency in business activities (OECD 2017b). It is suggested that there is a complementary relationship between process innovation and product innovation. While the introduction of new products may lead to the development of new processes, the implementation of new production processes may result in new products (Gómez et al. 2016; Martínez-Ros & Labeaga 2009).

2.7.2.2. Non-technological innovation

Organisational/managerial innovation

Innovation is not only the development and application of new technologies or the generation of new products or processes, but also the reorganisation of business routines or the use of new marketing methods (Baranano 2003; Boer & During 2001). Non-technological innovations are as important for the firm as technological innovations (Expósito & Sanchis-Llopis 2018). Evan (1966) defines organisational innovation as new ideas for improving processes and routines, for example, the recruitment of employees, the allocation of resources, tasks, authority and rewards. Changes in organisational structures, modification of employees' behaviours and beliefs (Knight 1967) and implementation of new rules, procedures and roles (Damanpour & Evan 1984) are also considered organisational innovations. Kahn (2018) defines organisational innovation as changes to the organisation with respect to structure, new forms of management and the workplace environment. Along with structural and procedural innovation, changes in the way the firm establishes or deals with external relations is a different but important type of organisational innovation. In this regard, a firm can focus on intra-organisational or inter-organisational innovation or a combination of both (Armbruster et al. 2008).

Organisational innovation is also known as administrative, management or managerial innovation (Damanpour 2014; Damanpour & Aravind 2012; Oke et al. 2007). Hollen et al. (2013, p. 41) describe it as:

firm-specific, new-to-the-firm management activities associated with setting objectives, motivating employees, coordinating activities and making decisions, which arise due to new inter-organisational relations [that] are intended to further organisational goals.

For Volberda et al. (2013, p. 3), managerial innovation relates to changes in 'a firm's organisational form, practices and processes in a way that is new to the firm or the industry'. These can be changes in:

the way management work is done, involving a departure from traditional processes; in practices (i.e. the routines that turn ideas into actionable tools); in structure (i.e. the way in which responsibility is allocated); and in techniques (i.e. the procedures used to accomplish a specific task) (Volberda et al. 2013, p. 3).

The OECD and Eurostat (2005, p. 51) define organisational innovation as 'a new organisational method in business practices, workplace organisation or external relations that has not been previously used by the firm'. In terms of business practices, innovations include the implementation of new methods for organising routines and procedures. Such new methods facilitate knowledge sharing and organisational learning. Innovations in the workplace include the implementation of:

new methods for distributing responsibilities and decision-making among employees for the division of work within and between firm activities, new concepts for the structuring of activities, such as the integration of different business activities (OECD & Eurostat 2005, p. 52).

Regarding external relations, this innovation type refers to 'the implementation of new ways of organising relations with other firms or public institutions' (p. 52). There are several examples of organisational innovations such as the application of innovative ideas in brand management, intellectual capital measurement, leadership development, divisional structure and the Six Sigma method (Birkinshaw & Mol 2006; Hamel 2006). Other examples include first-time introduction of an integrated monitoring system, first-time implementation of an integrated management system to improve work processes, the formation of new types of collaboration or the introduction of new staff training programs (OECD & Eurostat 2005). In Australian research, the definition of organisational/managerial process innovation used by the ABS is quite similar to that used by the OECD:

a significant change in this business's strategies, structures or routines which aim to improve the performance of the business. It includes any new or significantly improved *(i) knowledge management processes to better use or exchange information, knowledge and skills within this business, (ii) business practices for organising procedures, (iii) methods of organising work responsibilities and decision-making, (iv) methods of organising external relations with other businesses or public institutions (ABS 2018a, p. 16).*

Compared with the significant number of studies on technological innovation (i.e. product or process), organisational innovation seems to be under-researched (Alves et al. 2018). Available studies highlight the importance of organisational innovation on firm performance. Organisational innovation boosts performance by reducing costs related to administration, transaction or supplies, gaining access to non-tradeable assets, enhancing workplace satisfaction or making the best use of external relationships. It is a source of competitive advantage (Battisti & Iona 2009; Mol & Birkinshaw 2009) and an essential element in improving work efficiency and organisational management and performance (Hamel 2006; Higgins 1995; Sapprasert & Clausen 2012). Organisational innovation facilitates creativity and flexibility, resulting in better firm performance (Haned et al. 2014; Le Bas et al. 2015). It is worth noting that new organisational methods typically take time to become fully effective (Damanpour & Evan 1984; Tavassoli & Karlsson 2015). Organisational innovation also interacts and facilitates other types of innovation. Organisational innovation can be linked to process innovation since the use of new technologies in production or distribution may require the reorganisation of business routines. This may, in turn, prompt the implementation of new business practices or models. Further, organisational innovation might occur concurrently with product innovation when new products require the launch of new sales divisions and the reorganisation of workflow, responsibilities, knowledge management processes or collaboration with new external partners (Schmidt & Rammer 2007). Damanpour and Evan (1984) find that the implementation of organisational innovations in a given period is significantly linked to the introduction of technological innovations in a subsequent period. Others reveal a positive effect of organisational innovation on technological innovation (Gallego et al. 2012; Mothe & Nguyen-Thi 2012).

Marketing innovation

It is suggested that the development and implementation of 'new marketing tools and methods plays an important role in the evolution of industries' (Chen 2006, p. 101). The OECD and Eurostat (2005, p. 49) define marketing innovation as 'the implementation of a new marketing concept or strategy that differs significantly from the firm's existing marketing methods and has not been used before'. It is the use of a new marketing method or a new type of promotional effort. A new marketing concept or strategy is one that significantly departs from the firm's existing marketing methods. Firms can innovate in marketing in various ways such as changing a product's price, design, packaging, advertising or promotion. Changes in product design relate to form and appearance to attract consumers' attention, without altering its functions or user characteristics. This is popular in some industries such as foods, beverages or detergents, where packaging is the core element of the product's appearance. Using new pricing strategies to market goods or services is also a popular marketing innovation (OECD & Eurostat 2005). Innovation in product promotion refers to the use of new concepts or promotional methods that enhance the effectiveness of promotional programs for goods or services. Chen (2006, p. 101) emphasises important types of innovation, namely:

> *new ways of gathering consumer information through innovative marketing programs and technologies have enabled firms to reach consumers more effectively and to use pricing strategies that were previously not feasible; new trading formats and techniques, have expanded the market for many firms and potentially reduced consumer transaction costs.*

Chen (2006, p. 118) mentions other types of marketing innovation, including 'new methods of advertising that provide product information to consumers more effectively, new ways of product bundling, or new forms of selling institutions'. Lin et al. (2010) refer to marketing innovation as market research, customer segmentation, pricing strategy, retailing and distributing channels, advertising and marketing information systems. In the Australian literature, the ABS definition of marketing innovation is relatively aligned to that in the Oslo Manual, namely:

> *a significant change in a design, packaging, placement, pricing, promotion or sales method aimed to increase the appeal of the business's goods or services or to enter new markets. It includes any new or significantly improved (i) changes to the aesthetic design or packing or goods or services, (ii) media or techniques for product promotion, (iii) methods of products replacement or sales channels, (iv) methods or pricing goods or services (ABS 2018a, p. 16).*

Some examples of marketing innovation involve introducing a new design of bottles or packs for cosmetic products (and promotional gifts) to give the product a new look, introducing a new brand symbol aimed to position an existing product in a new market, introducing or adding new benefits to customer loyalty programs or first-time use of a new form of social media as a marketing and communication channel. The aims of marketing innovation are to effectively connect and interact with new or existing customers/consumers on new and different levels. Further, marketing innovations effectively provide information on products or services, better address customer needs or freshly position products on the market to increase the firm's sales of goods or services. Innovative marketing capabilities provide the firm with a powerful tool to satisfy market demand and effectively support the introduction of new products (Morgan et al. 2009). Kahn (2018) explains that successful marketing innovations drive customer demand by innovatively creating awareness, product uniqueness and brand recognition. Such new marketing methods create a competitive advantage for the firm (Chen 2006), overcome market crises (Naidoo 2010) and drive market performance (Ozkaya et al. 2015). Therefore, marketing innovation is a vital element leading to firms' success and growth (Han et al. 1998; Ozkaya et al. 2015) and market performance (Aksoy 2017).

Marketing innovation is often linked to product innovation. Prior studies show exceptional product innovation performance is a result of successful marketing innovations (Narver & Slater 1990; Slotegraaf & Pauwels 2008). The launch of new products may require new ways of marketing, urging the firm to implement new marketing methods to promote or position these products on the market. Therefore, a new marketing concept and strategy for new products is an integral part of a firm's innovative effort (Schmidt & Rammer 2007). The competitive environment also pushes firms to make greater marketing efforts to promote their products by designing catalogues, brochures and product parts and by conducting advertising and promotions. With the support of ICT, an increasing amount of marketing initiatives has been applied using Internet and social media platforms, effectively promoting the firm and its products globally (Ganzer et al. 2017). Marketing innovation can also be linked to process innovation. The implementation of new production technologies is likely to result in improvements in production capacities and/or quality of products. Hence, marketing is needed to promote this improved capacity or superior quality.

Further empirical evidence on technological and non-technological innovation

The rate of different types of innovation is found to vary across industry sectors; some sectors are dominated by technological innovations, while others by non-technological innovations (Aboal & Garda 2016). As Tether et al. (2005) explain, these variations are due to the nature of technological progress in the industry and industry life cycles. In the case of early industry expansion, a high rate of product innovations is evident, whereas firms in more mature industries are likely to enhance productivity through process innovations. There is a commonly held view that technological innovations play a key role in the manufacturing sector, contributing to productivity increases (Hall et al. 2009; Mañez et al. 2013; Rochina-Barrachina et al. 2010), whereas non-technological innovations have a greater impact on service productivity (Aboal & Garda 2016).

It is stated that although 'the theoretical and empirical work on technological innovations is abundant' (Radicic & Djalilov 2019, p. 616), empirical work on non-technological innovation remains lacking (Azar & Ciabuschi 2017; Peters et al. 2018), especially in the SME context (Hervas-Oliver et al. 2016; Radicic & Djalilov 2019). Scholars argued that not only technological innovation, but non-technological innovation could also be a source of competitive advantage for SMEs (Aksoy 2017; Hervas-Oliver et al. 2016). Radicic and Djalilov (2019) assert that non-technological innovation takes on greater importance in the SME case. Since most non-technological innovations do not require much investment, this opens up opportunities for SMEs that have financial constraints (Expósito & Sanchis-Llopis 2018). The more flexible and less formal organisational structures inherent in SMEs enable them to reorganise quickly to adapt to changes in the business environment (Radicic & Djalilov 2019). Non-technological innovations in organisational and managerial aspects enable firms to gain a cost advantage by using inputs more productively and improving the efficiency of organisational and managerial processes. Available evidence suggests that organisational innovation enhances work efficiency and performance (Sapprasert & Clausen 2012).

Further, due to resource scarcity, SMEs primarily rely on the market to drive change and thus use a range of innovative marketing practices (Hervas-Oliver et al. 2016; O'Dwyer et al. 2011). A high level of innovation in marketing strategy has been observed in French SMEs (Motwani 1999), Taiwanese SMEs (Lin & Chen 2007) and United Kingdom (UK) SMEs (Baregheh et al. 2012). As O'Dwyer et al. (2009) suggest, even under financial resource constraints, creative marketing practices and strategies can flourish. In addition, SMEs' advantage of being close to the markets and customers allows them to promptly react to changes in markets and emerging customer needs (Radicic & Djalilov 2019; Salavou et al. 2004). Successful marketing innovation has been identified as a driver of product demand and SMEs' market performance (Aksoy 2017).

Technological and non-technological innovation can have a complementary relationship (González-Blanco et al. 2019). As mentioned before, the commercialisation of new products may require the development of new marketing methods to drive product demand (Aksoy 2017; Morgan et al. 2009). Likewise, a new production technique often leads to better productivity, but only if it is supported by appropriate changes and adjustments in the organisation. Technological and non-technological innovations are considered to improve productivity, but in varying degrees of effect. Some studies suggest technological and non-technological innovations should be implemented jointly to maximise business success (Cozzarin & Percival 2006; Tidd et al. 2005).

2.7.2.3. Other innovation types

Business model innovation

Markides (2006, p. 20) defines business model innovation as 'the discovery of a fundamentally different business model in an existing business', while for Bucherer et al. (2012, p. 184) it is 'a process that deliberately changes the core elements of a firm and its business logic'. Casadesus-Masanell and Zhu (2013, p. 464) provide a more comprehensive definition:

> *the search for new logic of the firm and new ways to create and capture value for its stakeholders; it focuses primarily on finding new ways to generate revenues and define value propositions for customers, suppliers and partners.*

Kahn (2018) states that business model innovation is an outcome which can significantly change a given industry. IBM (2009, p. 1) classifies this innovation into three types: (i) new industry model—changing the industry value chain 'by moving into new industries, redefining existing industries, or creating entirely new ones', (ii) new revenue model—new ways of generating revenue 'through offering reconfiguration of the product/service/value mix and pricing models' and (iii) new enterprise model—changing 'the role played in the value chain by changing extended enterprise and networks with employees, suppliers, customers and others'. These types of innovation can be used on their own or in combination. Well-known examples of business model innovations are the introduction of Uber, which made a significant change to the taxi industry, or Airbnb in the accommodation industry.

Institutional innovation

Institutional innovation is 'novel, useful and legitimate change that disrupts, to varying degrees, the cognitive, normative, or regulative mainstays of an organizational field' (Raffaelli & Glynn 2015, p. 409). It is a new organisational structure or legal framework that effectively improves the business. Like other types of innovation, institutional innovation is a new idea (Van de Ven 1986) that helps to resolve problems or achieve goals in a novel way (Drazin et al. 1999). However, the core differences are that it is credible, legitimate and appropriate. Legitimacy is a distinct factor because ‘the creation, transformation and diffusion of institutions requires legitimacy, a condition whereby other alternatives are seen as less appropriate, desirable, or viable’ (Dacin et al. 2002, p. 47). Another important feature is that the novelty is less localised, rather it is in the broader organisational field in which the innovation arises. Institutional innovation can be the establishment of new institutions or changes in existing institutions (Raffaelli & Glynn 2015). The formation of new institutions is one of the most extreme types of institutional innovation. New institutions may lead to more widespread changes, significantly influencing other businesses and their customers. The force of the external environment is a crucial element fostering institutional change, for example, environmental shifts (Hoffman 1999). Examples of institutional innovations are franchising and licensing arrangements in the 1950s, boosting the dissemination of innovations to the most remote areas of the world, which may not have any innovation capacity (Lashley & Morrison 2000), establishing labelling and certification entities or implementing online reservation systems that centralise access to transport tickets, which gives customers wider access to a range of products and prices, while increasing competition among businesses (Hall & Williams 2008).

Supply chain innovation

Arlbjørn et al. (2011, p. 8) define supply chain innovation as:

> *a change within the supply chain network, supply chain technology, or supply chain processes (or combinations of these) that can take place in a company function, within a company, in an industry or in a supply chain to enhance new value creation for the stakeholder.*

Bello et al. (2004, p. 57) demonstrate that supply chain innovation combines ‘developments in information and related technologies with new logistic and marketing procedures to improve operational efficiency and enhance service effectiveness’. It refers to innovative allocations of new investments and activities to channel participants or trading partners in the supply chain. This is intended to reduce operational costs through greater efficiency and to increase revenue through better service effectiveness, ultimately maximising joint profit of the entire chain. Supply chain innovations, which include the implementation of new processes and technologies, must result in change, rather than reintroducing those that have already been used in the industry, but only new to the firm. Some examples are Dell's make-to-order, customer direct supply chain method. This innovation had a disruptive influence on the computer industry by producing state-of-art products that were reliable and high service quality at a reduced cost. Other examples are the case of Apple, Ikea, Wal-Mart, Zara, HP and Amazon. Supply chain innovations implemented by these firms disrupted their industry and served as an anchor for enhanced firm performance.

It should be noted that innovation types, such as business model, institutional or supply chain, are specific in nature and usually occur within a larger scope, such as an industrial-wide context rather than limited to a firm-level analysis. There also exist numerous other innovation types such as (i) cultural innovation, which involves sharing the cultural content of the product (Pedeliento et al. 2018) or shifting its cultural significance based on the cultural needs of consumers (Ravasi et al. 2012), (ii) production process innovation, (iii) people innovation, (iv) organisational structure innovation (Knight 1967), (v) administrative and technical innovation (Damanpour 1987), (vi) position innovation, which concerns marketing and business systems (Rowley et al. 2011), (vii) market innovation, which involves introducing new market devices, changing existing market structure, market behaviour and market agents (Kjellberg et al. 2015), (viii) commercialisation innovation and (ix) ambidextrous innovation, which is a combination of technical and commercial resources (Purchase et al. 2016). The aforementioned types of innovation are important additions because they correspond to specific tasks of firms. Nonetheless, these innovation types can also be categorised in broader terms. For example, production process innovation can be classified as technological innovation, while organisational structure innovation, cultural innovation, people innovation, position innovation and market innovation can be referred to as non-technological innovation.

2.7.3. Innovation in small and medium enterprises

SMEs play a vital role in the economic and technological development of economies across the globe (Aksoy 2017; OECD 2019f; Rosenbusch et al. 2011). SMEs account for more than 99.8% of all businesses in Australia (ABS 2019b) and comprise over 99% of all operating businesses in Europe (Muller et al. 2015; Woschke et al. 2017). As the OECD (2019b) states, SMEs are the central in improving productivity for economies that are largely made up of SMEs. With increasing competition and uncertainty in today's business environment, a key to the survival and growth of SMEs lies in innovation (Lukovszki et al. 2020; Raymond & St-

Pierre 2010). Innovation is referred to as the core of an SME's competitive advantage (Donbesuur et al. 2020; Lukovszki et al. 2020). Therefore, innovation in SMEs has garnered much interest in the literature (Baregheh et al. 2012; Woschke et al. 2017).

Resource scarcity has long been recognised as a critical factor that affects SMEs' innovative capacity, performance and growth (Baregheh et al. 2012; Lukovszki et al. 2020). Because of their small size, SMEs typically have limited resources, both financial and human (Love & Roper 2015; Radicic & Djalilov 2019; Rosenbusch et al. 2011) and inadequate knowledge and skills for innovation (Aziz & Samad 2016; Martínez-Román et al. 2015; Verreynne et al. 2019). Financial difficulties encountered by SMEs occur not only in terms of internal funds but also in accessing external financing. It is evident that SMEs are often at a disadvantage with respect to credit history (Motta & Sharma 2020; Serrasqueiro & Nunes 2014) and face tougher financing conditions compared with large firms when attracting alternative sources of finance (OECD 2017a). SMEs also have limited access to both capital markets (OECD 2017a) and venture capital to undertake innovation activities (Freel 2000; Verhees 2004). There are several other disadvantages that are likely to prevent SMEs from investing in innovation, including economies of scale, which make it challenging to recoup significant sunk costs associated with innovation, inadequate management expertise and organisational capabilities as well as the lack of market access (Aziz & Samad 2016; Tejada & Moreno 2013). Given these obstacles, SMEs typically lag behind large firms in the technological evolution and innovation race (Hall & Williams 2019; OECD 2019d, e). Many SMEs tend to adopt innovations developed by other firms or imitate proactive innovators, rather than introducing innovation with a high degree of novelty (Gomezelj 2016; Hjalager 2002; Salavou et al. 2004).

Much of the difference in the innovative potential between large firms and SMEs is attributed to resource constraints (Lukovszki et al. 2020). Unlike large firms, SMEs are unable to compete using economies of scale or learning curve effects (Fritz 1989; Sweeney 1983). Therefore, they innovate differently (Hervas-Oliver et al. 2021). Salavou et al. (2004) assert that SMEs are likely to introduce innovations that large firms mostly cannot provide. They also are strategic in their approach to planning their innovation activities (Baregheh et al. 2012) since they must rely only on a few key resources and capabilities for the innovation (Lukovszki et al. 2020). Evidence shows that resource constraints can also have a positive influence on SMEs by stimulating their creativity and innovative ideas (Hoegl et al. 2008; Weiss et al. 2011; Woschke et al. 2017). By using resource recombination or recombining existing knowledge and ideas (Baker & Nelson, 2005; Dyer et al. 2008), SMEs are able to overcome their constraints and generate innovation. As demonstrated by Zahra et al. (2007), SMEs are able to use their knowledge effectively and marshal their available resources economically for innovation.

Flexibility is an important advantage inherent in SMEs. There is a commonly held view that because of their small size, SMEs have greater flexibility than large firms (Acs & Audretsch 1990; Bunnell & Coe 2001). As Christensen and Overdorf (2000) contend, SMEs are unconstrained by internal routines. Their behavioural advantages are characterised by the lack of bureaucracy and high flexibility (Dutta & Evrard 1999; Radicic & Djalilov 2019; Sok et al. 2013). Others demonstrate that SMEs' organisational agility, adaptability and proximity to markets and customers provide them with significant innovation potential (Sáez-Martínez et al. 2014; Salavou et al. 2004). These advantages allow SMEs to adapt quickly and more efficiently to changes in the business environment, promptly react to changes in markets or emerging customer needs, thus successfully seizing innovation opportunities (Acs & Audretsch 1990; Berends 2014; Radicic & Djalilov 2019). SMEs are found to be more adept at introducing innovation in small-scale or niche markets (Shaw & Williams 2004; Sok et al. 2013) and can also expand rapidly via internationalisation (Saridakis et al. 2019; Williams & Shaw 2011). Further, the less formal organisational structures of SMEs encourage innovation since they facilitate networking, participation and experimentation throughout the organisation (Carroll, 2002; Johne & Davies 2000). O'Dwyer et al. (2009) add that the integration of organisation, its flexibility and effective use of technology enable the innovation process in SMEs. SMEs' organisational simplicity also enables them to implement new processes quicker and at lower switching costs relative to large organisations (Buckley & Mirza 1997; Mañez et al. 2013).

As SMEs have less capability to conduct significant R&D compared with large firms, they typically are more open to (i) new and innovative ideas, (ii) seeking innovative ways of doing business and (iii) becoming involved in active learning. Learning by doing and learning capabilities significantly contribute to the innovative performance of SMEs (Salavou et al. 2004; Sok et al. 2013). As Hervas-Oliver et al. (2014) assert, innovation in SMEs is mainly carried out by an informal learning-by-doing innovation process. Due to insufficient capacity to individually manage the entire innovation process, many SMEs embrace open strategies as a way of accessing the required resources and information (Freel & Robson, 2017; Gronum et al. 2012). Recent literature has paid more attention to SMEs' strategic involvement in network and external collaboration as a way of overcoming innovation barriers (Expósito et al. 2019). Via collaborative and strategic networks, SMEs can access external knowledge, alleviate financial and human capital deficiencies and overcome their liability of smallness, which consequently enhances their innovation capabilities (Expósito et al. 2019; Freel & Robson 2017). Nevertheless, the outcomes of such open strategies largely depend on the ability of SMEs to obtain the most out of their capabilities (Withers et al. 2011). As Expósito et al. (2019) stress, more research is needed to analyse the importance of open innovation to SMEs' performance.

As evidenced by Das and He (2006), small firms also exhibit higher rates of innovation given their share of sales or number of workers. Over the last decade, SMEs have increasingly been recognised as both contributors to innovation (Thomas et al. 2011) and sources of disruptive innovation (Hall & Williams 2019), with the latter providing SMEs an opportunity to surpass their larger counterparts (Chen et al. 2017). There are also fast expanding young SMEs that drastically drives economic change and employment. Birch (1989) refers to SMEs with a high growth rate as "gazelles". These SMEs grow exceptionally fast and become large or very large in a short period of time (Acs & Mueller 2008). Examples are Microsoft, Apple, Amazon, and Facebook. Gazelles grow irrespective of industry growth (Storey & Greene 2010), and exist in all industries (Henrekson & Johansson 2010). Available studies suggest that exceptionally fast-growing firms are likely to be more innovative (Coad 2009; Storey & Greene 2010). They are able to combine existing inputs in novel ways to generate innovations that allow them to outperform others in the market (Hölzl 2009). If their innovation is successful, these fast-growing SMEs can drive dynamic reallocation of resources and significantly contribute to job creation (Henrekson & Johansson 2010). Grundström et al. (2012), who studied 409 Swedish SMEs, found that there is a significantly greater share of new products as part of the turnover in the fastest growing SMEs and that these firms are able to differentiate themselves from their competitors in terms of product quality, reduced costs, high speed and customer desires. Hölzl (2009) examines fast growing SMEs across 16 EU countries. He demonstrates that R&D and innovation success are crucial for high-growth SMEs in countries which are closer to the technological frontier compared with those that are further away.

The reviewed literature has revealed the diversity of innovative strategies used by SMEs. SMEs have proven that despite their small size and related constraints, they also have innovative potential. Yet, debates relating to the innovative capabilities and performance of SMEs are still inconclusive. SMEs have their own advantages and disadvantages, which act as both facilitators and inhibitors of innovation. Given SMEs' distinct features and innovative behaviour, there is agreement in the literature that further empirical research on innovation in the SME context is needed (Donbesuur et al. 2020; Hervas-Oliver et al. 2021; Radicic & Djalilov 2019). A better understanding of innovation in SMEs is important to develop appropriate strategies and policies to encourage greater innovation among SMEs, and in turn, boost their productivity.

2.8. DETERMINANTS OF INNOVATION

The literature proposes several factors that are likely to determine innovation. These factors can be divided into three groups: (i) innovation inputs, which are investments and activities a firm undertakes in the pursuit of innovation, (ii) firm characteristics, which are internal factors related to business resources and competencies that explain a firm's innovative capability and (iii) the external environment, which refers to market conditions and the sector in which the firm operates (OECD & Eurostat 2018). As discussed in the previous section, SMEs rely on extremely scarce resources, hence it is important for them to 'identify and focus on the key drivers of innovation to gain a competitive advantage' (Lukovszki et al. 2020, p. 2). The following sections review potential factors likely to determine innovation outputs, their role, theoretical foundations and empirical validity.

2.8.1. Innovation inputs

2.8.1.1. Research and development expenditure

R&D is a core component of innovation and has long been the primary focus of the innovation literature. It is widely acknowledged as a crucial determinant of firms' innovation output in many science-based and high-technology industries. Recalling the endogenous growth theory, the firm invests in research internally with the expectation of developing new products with high profit potential (Romer 1986). From an NGT perspective, innovation can also be created by a separate research sector (Grossman & Helpman 1990; Romer 1990). Depending on the capacity and strategy of the business, firms can choose to either invest in in-house R&D or contract it out to other firms or research organisations (Huang et al. 2010). The degree of R&D activities or R&D intensity in a firm is usually measured by R&D expenditures.

In the innovation process, the firm invests in R&D activities with the aim of achieving an innovation, and in turn, productivity growth. Cohen and Levinthal (1989) explain that the contribution of R&D spending to productivity increases by reducing the production cost of existing goods or expanding the choice of products. Successful R&D generates profit through increases in sales of new products and is key to the competitiveness of many high-technology industries such as machinery, computers, pharmaceuticals, communications and automobiles. Contemporary research reveals that R&D is relatively well defined and measurable variable based on R&D expenditure. In manufacturing, R&D investments are strongly associated with measures of innovation outputs (Damijan et al. 2017) and are a frequently used indicator of innovation (Kalcheva et al. 2018). However, it is argued that R&D expenditure is technically an innovation input to the innovation process, but it cannot be used as direct measure of innovation output since not all R&D investments will lead to innovation outcome.

The innovation process in manufacturing is more technical and sophisticated, often requiring a high level of technological and R&D effort (Crespi & Zuniga 2012). Hence, a relationship between R&D and innovation is expected. However, this is not always the case, particularly in the service sector. It is argued that R&D is less important for several service industries as most service firms do not engage in R&D (Toivonen & Tuominen 2009). Hansen and Serin (1997) emphasise that in low- and medium-technology sectors, the innovation process is mostly linked to adaptation and learning-by-doing based on practical experience as well as design and process optimisation, rather than formal R&D. In the less knowledge-intensive services, innovation is less likely to depend on R&D activities and greater R&D expenditure in services is not necessarily linked to higher innovation output as in manufacturing (Gallouj & Weinstein 1997; Tether 2005). The evidence suggests that service innovation is mostly incremental in nature and characterised by low budgets for R&D (Andersen & Howells 2000; Gallouj 2002; Toivonen & Tuominen 2009). Many firms in the service sector do not have an R&D department (Drejer, 2004; Flikkema et al. 2007; Miles, 2008). A study conducted by Leiponen (2005) confirms that service innovation is often ad hoc in nature and R&D investments are not correlated with the implementation of new services. Many imitative activities popular in services, for example, reverse engineering, also do not require R&D (Kim et al. 2000).

Becheikh et al. (2006) argue that R&D expenditures do not always result in new products or processes and innovation activities are not necessarily associated with R&D investments. As Hashi and Stojcic (2013) and Kemp et al. (2003) assert, using R&D expenditure as a measure of innovation activity does not cover all the firms' innovative efforts, for example, learning-by-doing or investments in technologies and human capital. Further, R&D activities are typically conducted by large firms in R&D intensive sectors (Aboal & Garda 2016; Ortega-Argilés et al. 2009), whereas there is a high intensity of non-R&D activities found among SMEs (Arundel et al. 2008; Innovation and Science Australia [ISA] 2020; Hervas-Oliver et al. 2011; Sterlacchini 1999). As Trigo (2013, p. 48) emphasises, the innovation literature has overlooked 'the role of non-R&D activities for numerous successful innovative outcomes'. SMEs can achieve innovation success where effective human resource management is applied without the need for conducting R&D activities (ISA 2020; Rammer et al. 2009). Huang et al. (2010) propose non-R&D options for firms such as conducting creative, in-house activities without R&D investment, or being technology adopters that innovate through acquiring advanced machinery, software or licences from other businesses. Other studies, such as those of Giotopoulos et al. (2017), Higón (2011), McGuirk et al. (2015) and Sheehan (2013), show that SMEs rely heavily on non-R&D activities such as ICT and training for innovation development and implementation. As the vast majority of SMEs do not conduct R&D (Czarnitzki & Hottenrott 2011; Hervas-Oliver et al. 2016), their innovation process can also be explained using non-R&D variables (Hervas-Oliver et al. 2011).

2.8.1.2. Human capital

Of the non-R&D innovation inputs, human capital is widely known as a principal element in creating new ideas, developing and adapting to technological and organisational changes and an important input of the innovation process (Nieves & Quintana 2018; Sheehan 2013). In neoclassical economics, the role of the labour force was recognised as one of the two fundamental components of the production function, along with capital input. In his *Theory of Economic Development*, Schumpeter (1934) views the individual entrepreneur as the innovator who creates changes and invests in new technologies and resource discoveries. With the emergence of the RBV and KBV, human capital is emphasised as one of the most valuable resources of a firm, determining its innovation capacity. From these perspectives, human capital comprises training, intelligence, experience, relationships and the insight of managers and employees (Barney 1991; Becker 1964). The term 'human capital' has been defined in various ways, for example, as the knowledge and abilities of a person, allowing for change to be enacted in new ways that enhance economic growth (Coleman 1988), or as 'the set of knowledge, skills and abilities that is possessed by employees or residing with and utilised by individuals' (Subramaniam & Youndt 2005, p. 451).

Empirical research shows a positive link between human capital and firms' innovative capability (Bornay-Barrachina et al. 2012; Smith et al. 2011) and innovation performance (Grissemann et al. 2013; Orfila-Sintes & Mattsson 2009). From a KBV perspective, James (2002) and Nonaka and Takeuchi (1995) state that innovating based on generic knowledge is difficult; thus, individuals with unique and specialised knowledge and skills are the main contributors to the development of new ideas and new products. Innovation performance is decided by the firm's ability to acquire, develop and exploit new knowledge. Employees have a great knowledge of the firm's products and processes. Consequently, taking advantage of such knowledge and innovative ideas is valuable in developing new products or services (López-Fernandez et al. 2011; McKelvie & Davidsson 2006). Hence, valuable human capital is likely to discover new market opportunities, leading to new product development (Bornay-Barrachina et al. 2012) and higher innovation capability (Delcanto & Gonzalez 1999).

Innovation is a process of learning by individual employees, the employer and the organisation (Montes et al. 2005; Schneider et al. 2010), and that this process can be achieved in various ways, for example, absorptive capacity (Cohen & Levinthal 1990), teamwork (Montes et al. 2005), communication (Asheim et al. 2007) or education, training and work experience (Schneider et al. 2010). Investment in education and training to upskill employees is essential to innovation because it increases the stock of human capital (McGuirk et al. 2015; Morris 2018). An educated and skilled workforce is more likely to 'generate and implement new ideas and to adopt new technological and organisational change' (Australian Government 2012, p. 4), hence it is crucial for innovation. Smith et al. (2011) suggest that training has a greater impact on innovation performance when it is part of bundles of human resource management practices; such effective practices would increase both the quantity and quality of employees' innovation skills. Dostie (2018) finds training has a positive impact on technological innovation, with on-the-job training playing a role that is as important as classroom training. Although the importance of human capital in innovation has been widely acknowledged, the focus of the previous studies mentioned above has largely been on product innovation. There is very limited empirical evidence on other types of innovation, for example, non-technological innovations. Of the available evidence, Tan and Nasurdin (2011) demonstrate that human resource practices, particularly training, are positively related to technological innovation and administrative innovation, while Fındıklı et al. (2015) found that training is a significant contributor to organisational innovation.

Within the SME context, human resource scarcity and lack of skills for innovation are widely recognised as major constraints (Hewitt-Dundas 2006; Woschke et al. 2017). Antonioli and Torre (2016) point out SMEs have limited awareness of the risks of underinvesting in training, and they exhibit a significantly lower level of training investment compared with large firms. The topic of upskilling the workforce and its impact on innovation is under-researched in the empirical SME literature (Antonioli & Torre 2016). Limited available evidence shows that training is positively linked to innovation performance in UK SMEs

(Sheehan 2013), technological innovation in small Irish firms (McGuirk et al. 2015) and organisational innovation in Australian tourism SMEs (Divisekera & Nguyen 2018b). Antonioli and Torre's (2016) study of Italian manufacturing SMEs finds that higher investments in internal training are positively associated with organisational innovation; however, such investments show no significant impact on technological innovation. The authors also highlight the need for further investigation of the role of training in the innovation performance of SMEs (Antonioli & Torre 2016).

2.8.1.3. Collaboration

Collaboration describes 'arrangements where partners work together for mutual benefit, including some sharing of technical and commercial risk' (Australian Government 2016, p. 59). On theoretical grounds, the importance of collaboration in the innovation process can be drawn from the RBV. Arguably, investments in innovation usually require various and substantial resources, which an individual firm is unlikely to obtain all by itself (Tether 2002). The OECD (2011, p. 27) concurs that innovation 'rarely occurs in isolation'. Having a new idea 'will not yield results by itself' (Divisekera & Nguyen 2018a, p. 158); collaboration and networking are critical for a high-performing innovation system (Australian Government 2016a). A firm cannot just rely on its own knowledge to develop new products; instead, it needs extensive information and expertise from multiple fields and continuous interaction with the external environment during the innovation process (Brunswicker & Vanhaverbeke 2015; Xu et al. 2018).

A significant number of scholars are in favour of collaboration because of its substantial benefits to innovation. Lavie (2006) proposes that collaborative networks allow firms to access their partners' resources or assets that are immobile, costly to transfer or are difficult to obtain by themselves. Sharing resources helps reduce the costs of product development as well as the risk of failure (Hagedoorn 1993). Collaboration allows firms to gather information and to build on accumulated knowledge, practices and capabilities of partners in co-producing integrated products or services (Chesbrough 2017; Wang & Fesenmaier 2007). Moreover, a combination of knowledge, experience and information allows firms to make well-informed decisions and arrive at better solutions (Yuksel et al. 1999). It can also speed up the development process and enables firms to quickly respond to market opportunities and customer needs (Littler et al. 1995; OECD 2015b). Thus, firms can gain a competitive edge in the marketplace, maximise performance and achieve long-term competitiveness (Australian Government 2016; OECD 2015b; Teece 2000). Therefore, collaboration plays a significant role in the process of development, implementation, diffusion and ongoing success of innovation (Carlsen et al. 2010). Lassen and Laugen (2017) support the notion that developing innovation in a closed innovation system is no longer sufficient; instead, they view an open innovation system that collaborates with sources from the external environment as crucial to innovation success. There has been a growing number of empirical studies investigating the effect of collaboration on innovation outputs. Dyer (2000) demonstrates a positive association between collaboration and innovation. External collaboration with customers, suppliers and universities positively influences innovative outcomes (Belderbos et al. 2004; Cassiman & Veugelers 2002) and increased openness leads to better innovation performance (Grimpe & Sofka 2009; Laursen & Salter 2006). Internal R&D collaboration also has a positive link with innovation (Naidoo & Sutherland 2016; Ryoo 2015; Zhang & Tang 2017).

Despite the benefits of collaboration, there are contrasting views of the role of collaboration in innovation. For example, there is the possibility of innovation being imitated by other firms, particularly in services where innovation is considered easily imitable (Cassiman & Veugelers 2002; Deegan 2012). Many firms are afraid that external partners may steal their ideas and information, imitate their innovation and become future rivals. Some firms choose to undertake a closed innovation system in which they conduct in-house R&D activities, build competencies and carefully protect their ideas through strict organisational boundaries (Lassen & Laugen 2017). Tether (2002) contends that the collaboration–innovation relationship is not straightforward in the case of UK firms, while Arundel and Bordoy (2006) note that the effect of collaboration on firms' innovation performance was not significant in seven European countries. Yet this effect applies to collaboration with firms, but not to collaboration with universities and public research institutes.

In relation to SMEs, it is widely acknowledged that they face resource constraints (Lukovszki et al. 2020). In this regard, collaboration provides SMEs with access to necessary resources, knowledge and skills, which are not internally available (Expósito et al. 2019; Gronum et al. 2012). The transfer of human resources and technologies is also facilitated by collaboration (Jones & Zubielqui 2017). Moreover, engaging in collaboration is associated with better innovation performance (Brunswicker & Vanhaverbeke 2015; Gronum et al. 2012; Vahter et al. 2014). However, this is not clear-cut since bigger collaboration partners tend to dominate SMEs in most collaborative innovation projects, and SMEs find it challenging to manage them to their advantage (Rosenbusch et al. 2011). Other scholars indicate that the outcomes of collaboration largely depend on the ability of SMEs to obtain the most out of their capabilities (Withers et al. 2011). They also depend on their collaborative partners and innovation types (Expósito et al. 2019). Although the link between collaboration and innovation is evident, there is limited empirical research on the impact of collaboration on the different types of SME innovation and in various industry contexts. This points to the need for a better understanding of the role of collaboration in SME innovation among different industries (Lee & Miozzo 2019; Santoro et al. 2018).

2.8.1.4. Information and communication technology investment

The rapid development, adoption and diffusion of ICT has revolutionised business activities, such as operations, communication, management and marketing (OECD 2017b) and transformed numerous industry sectors (Gössling & Hall 2019; Law et al. 2014). The use of computers and the Internet has rapidly spread across all economic sectors, transforming business operations, intensifying competition and stimulating innovation (Moshiri & Simpson 2011). Therefore, ICT has attracted considerable attention. It is proposed as a key input into the development and adaptation of innovation (OECD 2015b) and a decisive factor determining the innovative capability of SMEs (Gërguri-Rashiti et al. 2017). The use of ICT makes innovation development processes easier and more cost-effective, thus enhancing process efficiency (Gretton et al. 2004). Not only does ICT reduce transaction costs but it can also ‘improve business processes, facilitate coordination with suppliers, fragment processes along the value chain and across different geographical locations and increase diversification’ (Koellinger 2005, p. 6). Each of these efficiency gains provides the firm with an opportunity for innovation. ICT further facilitates communication, broadens the access to information and facilitates the use of e-marketing and online sales of products. It also fosters innovation by facilitating flexibility in business structures and reorganisation (Higón 2011) and creating substantial opportunities for re-engineering operations and business processes, for instance back-office or reservation systems, especially in the service sectors (Buhalis et al. 2019; Stamboulis & Skayannis 2003). The adoption of ICT moves service provision closer to manufacturing production processes, opening up substantial opportunities for service improvements and productivity gains (OECD 2017). ICT applications in small service firms have been considered a must, not only for innovation opportunities but also to stay competitive in the marketplace (Preissl 2000).

In relation to the impact of ICT on different types of innovation, Todhunter and Abello (2011) find a positive link between ICT intensity and innovative activities among Australian firms. More intense ICT firms are more likely to undertake and introduce innovations with high degrees of novelty, engage in multiple types of innovation and develop these innovations internally. Gretton et al. (2004) discover a positive association between ICT and product innovation, while Arvanitis et al. (2013) reveal that the use of internal information systems has a positive effect on technological innovation in Greek firms. In Moshiri and Simpson's (2011) study, the introduction of automatically linked ICT systems results in process and organisational innovation. As Arvanitis and Loukis (2015) advocate, the application of ICTs facilitates the development of new products and services, expands their variety and personalises requirements that were not operational or economically feasible before. Freeman (1995) and Sood and Tellis (2009) refer to ICT as a facilitator of marketing innovation, while Cuevas-Vargas et al. (2016) view it as a valuable source of product and marketing innovation in manufacturing and service firms. For Buhalis and Law (2008) and Buhalis et al. (2019), the advancement of ICT has resulted in numerous innovations in the marketing and management spheres in the service industries.

The use of ICT is key to SMEs' innovation capability (Parida & Örtqvist 2015), survival and competitiveness (Giotopoulos et al. 2017; Higón 2011). ICT investment fosters innovation in SMEs by enhancing process efficiency and flexibility in business structures and reorganisation (Higón 2011). New forms of ICT provide efficient channels to communicate with suppliers and customers without geographical constraints and significantly affect the way firms market their products (Liao et al. 2009; Parida & Örtqvist 2015). Nevertheless, evidence suggests that because of resource constraints, SMEs face substantial difficulties in adopting ICT (Giotopoulos et al. 2017). The costs of implementation and an insufficient understanding of ICT-related opportunities act as barriers to ICT adoption by SMEs (Ghobakhloo et al. 2011; Papadopoulos et al. 2020). Yet empirical research on the effect of ICT on SME innovation is still limited (Parida & Örtqvist 2015). Of the available evidence, Higón (2011) shows that ICT creates a competitive advantage for UK SMEs through product innovation. There is also a positive influence of ICT capability on innovativeness of small technology-based Swedish firms (Parida & Örtqvist 2015). Divisekera and Nguyen (2018b) also demonstrate a positive correlation of increased ICT investment and the implementation of non-technological innovation among Australian tourism SMEs.

2.8.1.5. Financial resources

Finance or financial capital has been a core component of the production function in almost all economic models—from neoclassical to evolutionary theories. Innovation is risky and normally requires large amounts of investment (Hall & Lerner 2010; Hashi & Stojcic 2013). Thus, the availability of financial resources is essential given the risks and uncertainties associated with innovation activities (Beneito 2003; Hall & Bagchi-Sen 2002; Lööf & Heshmati 2002). Scholars suggest that the cost of innovation development can act as an inhibitor, discouraging firms from undertaking innovative investments (Cohen 1996; Coronado et al. 2008; Hall & Lerner 2010). Coronado et al. (2008) affirm that high levels of indebtedness hamper innovation. Hoegl et al. (2008) add that not only is finance crucial for innovation development, but also for implementing innovation. Several studies have identified the negative impact of financial constraints on innovation, for instance, in German manufacturing firms (Hottenrott & Peters 2012), French manufacturing firms (Savignac 2008), Portuguese firms (Silva & Carreira 2012), European countries (Efthyvoulou & Vahter 2016) and transition economies (Gorodnichenko & Schnitzer 2013; Männasoo & Meriküll 2014). It is also noted that the negative effect of financial constraints is more pronounced in small firms (Canepa & Stoneman 2008) and in manufacturing rather than services (Efthyvoulou & Vahter 2016).

There are two sources of finance: internal sources, such as equity or retained earnings, and external sources, such as debt, bank loans or grants (Efthyvoulou & Vahter 2016). It is suggested that external public funding, such as industry financing and government grants, is important for nurturing innovation (Kalcheva et al. 2018). However, since investment in innovation is characterised by a high degree of information asymmetry and large sunk costs (Alderson & Betker 1996), external lenders would ask for a higher rate of return from innovation projects than less risky investments (Hall 2002; Czarnitzki & Hottenrott 2010). Finance from external sources for innovation investments is therefore usually expensive or difficult to obtain. Thus, many firms rely heavily on internal finance for their innovative investments (Hall 2002; Hottenrott & Peters 2012). Those with limited internal financial resources are more likely to face difficulties in conducting innovation activities or have low innovative capability. Efthyvoulou and Vahter (2016) show that internal financial constraints have a stronger effect on innovation output than external financial constraints alone, while the ABS (2003) notes that not all types of innovation require the same commitment of financial resources. This leads to a question whether and to what extent the role of financial resources is different across different types of innovation.

SMEs, as resourced-constrained organisations, typically face substantial financial difficulties such as insufficient internal funds, which impede their propensity to invest in innovation (Antonioli & Torre 2016; Rosenbusch et al. 2011). In addition, they have limited access to both capital markets (OECD 2018b) and venture capital to conduct innovation activities (Freel 2000; Verhees & Meulenberg 2004) and are disadvantaged in terms of credit history (Motta & Sharma 2019; Serrasqueiro & Nunes 2014). As highlighted by the OECD (2017a), SMEs also face tougher financing conditions compared with large firms when attracting alternative sources of finance. Financial support is arguably crucial for innovation in SMEs. Nonetheless, empirical evidence shows conflicting results regarding the impact of financial support on SME innovation. For example, Romero-Martínez et al. (2010) indicate that Spanish service SMEs receiving European Union funding were more likely to implement technological and non-technological innovation. However, Svensson (2008) shows that government funding has a negative influence on innovation performance of small technology-based firms in Sweden. Un and Montoro-Sanchez (2010) found that public funding has a negative impact on technological innovation, whereas private funding shows a positive impact on technological innovation in Spanish service SMEs. Martínez-Román et al. (2015) identify a positive impact of short-term bank loans and a negative impact of medium and long-term bank loans on innovation. However, they report no effect of public finance on innovation in Spanish tourism SMEs, which is similar to Baumann and Kritikos (2016) in the case of German manufacturing micro firms. Cecere et al.'s study (2020) suggests that public funding for innovation has a positive impact on small firms when other types of external funding are also in place. These mixed results suggest a need for further investigation of the role of financial support in the SME context.

2.8.1.6. Innovation focus

The RBV proposes that organisational strategy is important to innovation because it determines the way in which a firm allocates resources to achieve a specific goal (Chandler 1962). Hurley and Hult (1998) advocate that one of the elements contributing to the success of the innovation process is innovation-oriented culture, which refers to whether an organisation encourages or resists innovation. A positive attitude towards innovation, as stated by Claver et al. (1998), is a crucial prerequisite for accepting challenges and creating changes. Halim et al. (2015) concur that innovation is not easy to embrace without an organisational culture that supports innovative ideas. Organisational culture has a bearing on the degree to which 'creativity and innovation are stimulated in an organisation' (Martins & Terblanche 2003, p. 64). This is because a supportive environment is conducive to employees' creativity, fostering new ideas, sharing and obtaining new knowledge and exploiting opportunities for innovation (Skerlavaj et al. 2007; Valencia et al. 2010). Creativity, teamwork, open communication and good working relationships are essential for the success of new product development. These norms, values, philosophy and behaviours build an innovation culture in the firm (Ali & Park 2016; Hellriegel et al. 1998). The firm' capacity to absorb innovation into the organisational culture and management processes is decisive in business success (Syrett & Lammiman 1997; Tushman & O'Reilly 1997). De Jong (2011) adds that a firm with a strategic focus on innovation will prioritise new developments, thus being proactive in initiating and implementing innovations. Not only do firms encourage new ideas but they also dedicate resources and effort to develop innovation and enhance their innovative capabilities (Branzei & Vertinsky 2006).

The empirical literature proposes a significant link between organisational culture and innovation (Büschgens et al. 2013). A favourable attitude towards innovation is a driver of a firm's decision to develop or adopt innovations (Baldwin & Scott 1987; Rogers 1995) and is a predominant factor in product innovation and openness to new ideas (Waarts et al. 2002). Organisational culture, as stated by Vossen (1998), is even more important in SMEs than in larger organisations since it has a more direct effect on their capacity to generate new knowledge and exchange resources with other players in the business environment. Rosenbusch et al. (2011) suggest that an innovation focus provides an effective response for SMEs to overcome liabilities associated with their smallness. Vorhies and Harker (2000) find that an innovation culture enables SMEs to discover new strategies for creating new sales or marketing channels and employing new methods for selling products and reacting to customer needs. Baregheh et al. (2012) demonstrate that UK SMEs are committed to encouraging new ideas and cultivating innovation among employees, who are the contributors to firm innovativeness. Focusing on product and marketing innovation, Aksoy (2017) finds that not only does innovation culture positively influence new marketing strategies but it also fosters new ideas for new goods or services, leading to increased product innovation performance. Lukovszki et al. (2020) state that as SMEs rely on extremely scarce resources, it is critical that they use these resources strategically and efficiently to obtain innovation outcomes. It is noted that most studies on this topic focus on product innovation, while little is known about the influence of innovation focus on other types of innovation, for example, non-technological innovation, particularly in the case of SMEs (Aksoy 2017; Baregheh et al. 2012).

2.8.2. Firm characteristics

2.8.2.1. Firm size

Among the factors related to firm characteristics, firm size is often considered the most important. In the RBV, firm size reflects resource availability, such as financial and human resources (Skuras et al. 2008) and expenditure on R&D (Lee & Sung 2005; Tsai & Wang 2005). Large firms have greater access to resources to finance their innovation projects and are also able to employ more highly qualified R&D staff and scientific personnel for developing innovations (Coronado et al. 2008; Macher & Boerner 2006). Further, large firms enjoy the advantages of economies of scale in terms of technology, learning and management; this acts as a major facilitator of innovation investments (Hewitt-Dundas 2006). In contrast, SMEs often deal with resource shortages (Lukovszki et al. 2020), which makes it difficult to create innovative knowledge on their own or acquire such knowledge from commercial organisations (Hadjimanolis 2000; Hjalager 2010). Limited resources are also related to high risk and insufficient time for innovation (Howells & Tether 2004). The lack of finance, personnel, technology and organisational capabilities are key challenges faced by SMEs to investing in innovation (OECD 2019d; Rosenbusch et al. 2011). Nevertheless, advantages of small firms are flexibility and responsiveness (Berends 2014). These advantages allow SMEs to adapt quickly and more efficiently to changes in the business environment, in the market or to emerging customer needs. This means they can successfully seize innovation opportunities (Acs & Audretsch 1990; Berends 2014; Radicic & Djalilov 2019). To summarise, SMEs and large firms possess many differences in terms of technology levels, resources, market power, organisational structures and management styles, which consequently reflect the variations in their innovative capability (Koski et al. 2012).

An extensive body of innovation research points to the role of firm size in innovative capability and performance (Herrera & Sanchez-Gonzalez 2013; Rogers 2004). The majority of empirical studies demonstrate a positive association between firm size and innovation propensity (Damijan et al. 2017; Divisekera & Nguyen 2018a; Mel et al. 2009; Soames et al. 2011). In the case of transition economies, Gërguri-Rashiti et al. (2017) contend that larger firms undertake more innovative activities than smaller firms. Other authors go further by examining the effect of firm size on different types of innovation output. For example, Hewitt-Dundas (2006) shows that larger firms are more likely to generate technological innovations than smaller ones. Likewise, Fossas-Olalla et al. (2015) report that the tendency for product innovation is also higher in larger firms. However, Mel et al. (2009) contend that firm size has a stronger, more positive effect on process innovation and organisational innovation than on product innovation.

There is also contradictory evidence on the negative or industry-specific impact of firm size on innovation activity and performance (Knott & Vieregger 2015; Shefer & Frenkel 2005; Vaona & Pianta 2008). For example, Acs and Audretsch (1988), Mansfield (1964), Scherer

(1984) and Shefer and Frenkel (2005) reveal a negative effect of firm size; that is, small firms are more innovative than large firms. A study by Lafore (2008) on non-hi-tech manufacturing SMEs finds that SMEs are more proactive towards market opportunities, thus they are more innovative in introducing new products. De Jong and Marsili (2006, p. 226) indicate that micro and small firms can indeed 'play a role as the fruit flies of innovation' and that these firms are more responsive to rapid changes in the business environment. Cucculelli (2018) also finds that firm size has a negative impact on the likelihood of introducing new products. Rhee et al. (2010), in the case of technology-intensive SMEs, and Nordman and Tolstoy (2016) in Swedish SMEs, found no significant link between firm size and innovativeness. As shown, existing evidence on the effect of firm size on innovation capability is conflicting and inclusive; consequently, further examination is needed.

2.8.2.2. Firm age

Firm age is known to influence innovation, but its effect on innovation is mixed (OECD 2018). The theoretical argument for the effect of firm age can be dated back to endogenous growth theory, particularly the work of Arrow (1962) and Romer (1986). One of the propositions of the theory is the accumulation of work experience or learning-by-doing, which influences the effectiveness of labour and arguably, the firm's innovation capability. Cohen and Levinthal (1990) support that firm age is highly associated with experience and organisational learning. As evident by Huergo and Jaumandreu (2004), firms' innovative abilities are likely to improve with time and the probability of introducing product innovation tends to change along the firm life. Firms that have been established for a long time have gained experience, built on previous routines, improved capabilities and competences (Coad et al. 2016, Cucculelli, 2018). They have developed and accumulated substantial resources, managerial knowledge, practices and ability to handle uncertainty and risks (Herriott et al. 1984). Long-established firms have also occupied a certain market position and reputation, which to some extent ensures stable support from existing customers, suppliers and collaborators for their innovation development and further, the launch of new products. These advantages are more likely to enable mature firms to innovate.

While theoretical grounds suggest a positive effect of firm age on innovation (Arrow 1962), most empirical evidence reveals a negative effect, implying that the younger the firm, the more likely it is to innovate (Abdelmoula & Etienne 2010; Acs & Audretsch 1988; Becheikh et al. 2006). To explain for this effect, Hannan and Freeman (1984) and Majumdar (1997) relate firm age to organisational inertia—the longer the firm operates in the market, the more likely it is to suffer from some degree of organisational inertia. Not only does organisational inertia discourage firms from making changes but it also hinders learning effects. Further, for long-established firms, it is very difficult, costly and not economically optimal to create and adjust their organisational capabilities to a large extent (e.g. skills, routines, structures) (Hannan & Freeman 1984) or to change organisational strategies (Coad et al. 2016). In contrast, young firms start with neither routines nor capabilities, which means they can quickly establish both daily operating routines and higher-level innovation capabilities (Helfat & Peteraf 2003). Balasubramanian and Lee (2008) reveal a negative association between firm age and patent quality, especially in technologically active areas. Although incumbent firms may be advantageous in conducting incremental innovations, they may face substantial difficulties if innovation with high technical quality requires a large amount of capability adjustments—a significant departure from the core capabilities. Likewise, Cucculelli (2018) explains that the lower innovation activities observed in mature Italian manufacturing firms could be shaped by the dynamics of the industry lifecycle. Sørensen and Stuart (2000) propose two effects of age on innovation—learning effects and obsolescence effects.[12] Some studies find young and private firms are the key drivers of ground-breaking innovation (Acs & Audretsch 1993; Chava et al. 2013). Other studies also confirm the role of firm age in the creation of new products (Sivadas & Dwyer 2000), R&D investment (García-Quevedo et al. 2014) and innovation performance (Tripsas & Gavetti 2000).

In the existing evidence on SMEs' age and innovation, Salavou et al. (2004) and Rosenbusch et al. (2011) find that firm age negatively affects innovation performance in SMEs. Smith and Hendrickson (2016) reveal that younger SMEs are more likely to engage in technological and marketing innovation compared with older firms. However, in relation to managerial innovation, the effect of firm age is weak. Huergo and Jaumandreu (2004) illustrate that the effect of firm age on the probability of technological innovation varies across industries. A study by Rhee et al. (2010) observes no significant impact of firm age on the innovativeness of South Korean SMEs. As revealed in prior research, the link between firm age and innovation, particularly in the SME context, is inconclusive and subject to innovation type and industry context.

[12] Learning effects: older firms with more experience generate more innovations. Obsolescence effects: the organisation–environment fit declines with firm age (Sørensen & Stuart 2000).

2.8.2.3. Ownership

Ownership type has been recognised as influencing firms' innovation performance (Aghion et al. 2013; Choi et al. 2011). Grossman and Helpman's (1994) NGT is one of the first attempts to link globalisation and foreign ownership to innovation. It is suggested that knowledge of products, processes and management methods adopted from multinational corporations enhances the innovation capacity of foreign-owned firms. Further, there are other advantages associated with foreign ownership, notably, greater availability of funding and resources, better access to advanced technology and superior knowledge, practices and international experience transferred from multinational enterprises (Divisekera & Nguyen 2018a; Ghazalian & Fakih 2017) and broader international business networks and foreign market opportunities (Nordman & Tolstoy 2016). Therefore, these firms tend to be more innovative relative to domestic firms. Ample empirical evidence shows that firms with foreign ownership have a greater propensity to innovate than domestic firms (Castellani & Zanfei 2004; Divisekera & Nguyen 2018a, b; Hewitt-Dundas 2006; Palangkaraya et al. 2010). In line with previous studies, Guadalupe et al. (2012) indicate that multinational firms tend to introduce more technological innovation and adopt more foreign technologies than domestic firms. Gërguri-Rashiti et al. (2017) also demonstrate that firms with more than 10% foreign ownership are more innovative than state-owned or domestic firms. In their study of food firms in transition economies, Ghazalian and Fakih (2017) found that foreign ownership prompted firms to innovate.

Other studies show conflicting evidence, with foreign ownership having no significant impact on innovation in firms in Austria and four Nordic countries (Dachs & Ebersberger 2009; Dachs et al. 2008). A study by Damijan et al. (2017) indicates that the effect of foreign ownership depends on the type of innovation. While organisational innovation and marketing innovation are positively associated with foreign investment, the effect of foreign ownership is negative for process innovation and insignificant for product innovation. One possible reason could be that multinational firms tend to conduct technological innovation in their home country rather than in foreign affiliates (Damijan et al. 2017; Falk 2008). Yet foreign ownership might bring radical changes in organisational structure and marketing activities, positively influencing non-technological innovation (Damijan et al. 2017). It should be noted that most of the previous studies were undertaken in the manufacturing industry, while evidence in other industries remains scarce.

In the SME context, the empirical literature on the link between ownership and innovation is limited (Minetti et al. 2015), with mixed findings (Corsi & Prencipe 2018). Corsi and Prencipe (2018) find that foreign-owned European SMEs have better innovation performance. Nonetheless, this impact of foreign ownership is found to be negative in German SMEs (Stiebale & Reize 2008) and Italian manufacturing SMEs (Minetti et al. 2015). Considering both types of innovation, Aboal and Garda (2016) note that foreign ownership has a negative impact on technological innovation in small Uruguayan firms in both the manufacturing and service sectors; however, this effect is insignificant in non-technological innovation.

2.8.2.4. Exports

The relationship between innovation and trade has been the key focus of several economic studies. NGT can be used as a theoretical foundation when studying the link between exporting and innovation. New growth theorists propose that internationalisation may urge more innovation activities and boost innovation performance (Aghion & Howitt 1998; Grossman & Helpman 1991; Romer 1990). The NGT explains that through involvement in international trade, exporters can acquire information from customer feedback in the foreign markets, which is a valuable source of ideas to create new products or enhance the attractiveness of existing products. Exports also affect the firm's innovative behaviour through the process of learning and accumulating knowledge and experience, while trading in international markets (learning-by-exporting hypothesis).

Subsequent research favours the claim that exporters are more innovative than non-exporters. For example, a study by Tomiura (2007) on Japanese manufacturing firms reveals that exporters own more patents and have more R&D spending compared with non-exporters. Lileeva and Trefler (2010) highlight a correlation between exporting, R&D investment and innovation, while Gërguri-Rashiti et al. (2017) find a positive effect of export intensity on innovation. In European transition economies, export has a strong influence on firms' decision to innovate (Abazi-Alili 2014). Bratti and Felice (2012) find a positive relationship between exporting and the likelihood of introducing product innovation, whereas Lee et al. (2014) identify such a relationship between internationalisation and product innovation and organisational innovation in Korean service firms. Using a large dataset from European CISs, Damijan et al. (2017) confirm the positive correlation between exporting status and all types of innovation, with the strongest correlation being in product innovation and the weakest in organisational innovation.

Several attempts have been made to explain the influence of exporting on innovation. Filatotchev and Piesse (2009) and Park et al. (2010) propose advantages associated with exporters, such as better access to advanced technologies, foreign knowledge spillover, higher quality standards in foreign markets, international networks, quicker learning, more up-to-date information about market opportunities and better capacity utilisation thanks to economies of scale. Criscuolo et al. (2010) show that internationally-engaged UK firms generate more innovation due to their broader access to sources and worldwide pools of information. Fassio (2015) demonstrates that technological learning positively affects product innovation, whereas demand influences the innovation strategies of EU firms. Further, the wider international exposure to new and advanced technologies compared with those available in the domestic market allows exporters to gain an edge over their domestic competitors (Harris & Li 2009). The competitive pressure in global markets also pushes exporters to innovate to remain competitive, either through 'the learning-by-exporting mechanism' or through 'economies of scale in production' (Damijan et al. 2017, p. 587). Arguably, products developed for a protected domestic market only need to be new to the local economy, whereas for firms competing in global markets, their ideas for new products must be innovative on a global scale. The diversity and variability of demand in international markets, together with intense competition from foreign producers, motivate firms to develop new products (Coronado et al. 2008).

SMEs are typically less involved in exporting than large firms (Export Council of Australia 2018; Gashi et al. 2014). This could be due to large sunk costs and economics of scale (Radicic & Djalilov 2019). Available research reports a positive link between exporting and innovation (Golovko & Valentini, 2011; McMahon, 2001; Tuhin, 2016). Nonetheless, a study by Aboal and Garda (2016) on small manufacturing firms shows that exporters are less likely to implement non-technological innovation than non-exporters. Some scholars propose a two-way relationship between exports and innovation, implying that innovation can also stimulate export (Cassiman et al. 2010; Radicic & Djalilov 2019). Yet the reverse impact of export on innovation was absent in some cases (Damijan et al. 2010; Tuhin 2016) or depended on innovation type (Higón & Driffield 2010; Radicic & Djalilov 2019). As Radicic and Djalilov (2019) and Love and Roper (2015) suggest, due to the mixed results, the link between exporting and innovation in SMEs requires further investigation.

2.8.3. External environment

2.8.3.1. Sector

The evolutionary theory of Nelson and Winter (1974, 1982) highlights the importance of sectoral differences in innovation capability and firm growth. The proposition of the theory is that the introduction and diffusion of new techniques as well as their success and failure strongly depend on 'a complex of environmental and institutional considerations that differ sharply from sector to sector, country to country and period to period' (Nelson & Winter 1974, p. 903). Along the economic history, certain sectors are witnessed to have developed and grown much faster than others and the sectoral pattern of growth has varied from time to time. In a search of the reason why some sectors grow faster than others, technological opportunity is often mentioned as the crucial element stimulating growth and knowledge development (Klevorick et al. 1995; Nelson & Winter 1982). Industrial sectors differ greatly with respect to 'the sources of technology that they adopt, the users of the technology that they develop and the methods used by successful innovators' (Pavitt 1984, p. 353; Pavitt et al. 1989). Cowan et al. (2000) assert that knowledge is different among sectors with regard to sources, domains (i.e. the specialised scientific and technological areas) and applications, while Dosi et al. (2002) add that the directions and rates at which firms learn also differ greatly across sectors. As Skuras et al. (2008) emphasise, economic activities of a given sector affect capital structure and further the decision to invest in innovation. Firms operating in high or medium-high technology sectors or in more dynamic the sectors are more likely to have a favourable attitude towards innovation (Koberg et al. 2003).

A sectoral study on innovation by Malerba (2002) indicates that the competition–selection process varies across industries, which is probably due to the different and complex interactions 'between heterogeneous agents, economic structure, institutions and technological characteristics' involved in each industrial sector (Castellacci 2007, p. 602). Malerba (2005, p. 63) further develops a framework for understanding sectoral systems of innovation, which comprises 'three building blocks: knowledge and technologies, actors and networks and institutions'. In reviewing the evolutionary literature, Malerba (2006, p. 12) concludes that 'sectors and technologies differ greatly in terms of the knowledge base and learning processes related to innovation'. Science is evident as the key driver of knowledge in some sectors, whereas learning-by-doing and 'cumulativeness of advancements' are the major forces in other sectors. Contributing to this area, Castellacci (2008) proposes a new taxonomy of sectoral patterns of innovation for the manufacturing and service industries.

As ‘the rate and type of innovation and the organisation of innovative activities greatly differ across sectors’ (Malerba 2005, p. 63), the innovation processes across sectors should be examined separately. Yet, empirical research has largely neglected the impact of the sector on innovation (Köhler et al. 2012). Of the limited available evidence, Damanpour (1996) found differences in innovation patterns between the manufacturing and service sectors, while Amable and Palombarini (1998) and Martin-Rios and Ciobanu (2019) found differences within the service sector. As in Aboal and Garda (2016), factors that influence innovation outputs of small firms are not the same between the manufacturing and service sectors. A review of the literature reveals that empirical studies comparing the innovation processes among primary, secondary and service sector in the SME context is scant. Therefore, a better understanding of sectoral patterns and the drivers of innovation in each sector is required for building a successful sectoral innovation system.

2.8.3.2. Market competition

The impact of competition on firms’ innovation propensity has long been debated in the innovation literature. Theoretical predictions and empirical findings are contradictory. The early work of Schumpeter (1942) proposes a linear and negative relationship between competition and innovation. Schumpeter predicts that in an intensely competitive market the benefits or potential future profit from innovation would be lower compared with a situation where the degree of competition is weaker. Competition, thus reduces the innovation incentive of the firm; this is known as the ‘Schumpeterian effect’. This prediction was later endorsed by Mansfield (1968) and Hashmi (2013). In line with Schumpeter’s viewpoint, Mel et al. (2009) also find a negative effect of competition on innovation. They further show that this negative effect seems to be more profound on process and organisational innovation than on product innovation.

As discussed earlier, the Schumpeterian effect has been subject to debate. Arrow (1962) argues that more intense competition in the market favours innovation, indicating a linear, positive relationship between competition and innovation. Hart (1983) explains that increased competition creates an incentive that prompts firms to find a way out, escaping low-profit sectors and investing in potentially profitable areas. Competition thus creates an opportunity for innovation. Several post-Schumpeterian economists are of the view that product market competition is likely to increase the incremental profits from innovating and thus encourage more R&D investments to escape competition. This is labelled as the ‘escape competition effect’ (Aghion et al. 1997, 2001; Aghion & Howitt 2009). This proposition was supported by

Blundell et al. (1995), Nickell (1996), Correa (2012) and Moen et al. (2019). The nature and intensity of the prevailing competition is found to be a driving force of innovation (Bhattacharya & Bloch 2004; Rogers 2004). A study on Australian firms by Soames et al. (2011) revealed that intense competition puts pressure on firms to reduce costs, resulting in more innovation. Pirnar et al. (2012) demonstrate that innovation improves operation efficiency, satisfies customers' needs and creates more flexibility in responding to demand, thus enabling firms to gain a competitive edge and stand out from competition. In the context of transition economies, Gërguri-Rashiti et al. (2017) show the competitive pressure from foreign firms encourages domestic firms to undertake more innovation activities.

Scherer (1965) differs from both Schumpeter and Arrow's predictions by proposing a nonlinear relationship between competition and innovation. Scherer's research on US firms reveals an interesting result, because the relationship between competition and innovation follows an inverted U-shape. The results show that as the degree of competition increases, the rate of innovation first increases then decreases. Scherer's prediction is supported by other studies. For example, Aghion et al. (2005) arrive at a similar result—an inverted U-shape relationship— in the case of UK firms. The authors' proposition was that competition had both an 'escape competition effect' and a 'Schumpeterian effect'. Here, competition might raise incremental profits from innovating but it may also reduce innovation incentives for laggards. Using patent data of US firms, Im et al. (2015) also showed an inverted U-shape relationship between market competition and innovation value. They conclude that a firm's incentive to innovate is to respond to a tariff-cut shock when the market is not very competitive, but then decline when product market is intensely competitive. Negassi and Hung (2014) examine the competition–innovation relationship in different sectors and find that product market competition is not associated with innovation output in the public sector, but significantly and positively influences innovation output in the civil sector. From the reviewed literature, there exists an extensive, though inconclusive, body of theoretical predictions and empirical findings on the relationship between competition and innovation. However, a general conclusion can be drawn, namely, competition does have an effect on innovation. More empirical work is needed, given that previous research has focused mainly on product market competition, while evidence on other types of innovation is still lacking.

2.9. INNOVATION AND FIRM PRODUCTIVITY

Schumpeter (1934) highlights that innovation is the fundamental source of economic development since it yields higher real incomes and forces reorganisations of production with greater efficiency and productivity. As reviewed earlier, various economic theories, such as the evolutionary theory of economic growth and the NGT are in line with the stance of Schumpeter, that innovation is a driver of firm growth and long-run productivity. Porter and Ketels (2003, p. 7) emphasise that 'true competitiveness is measured by productivity', while Krugman (1994, p. 9) states that 'in the long run' productivity is 'almost everything'. There has been increasing empirical evidence demonstrating that the implementation of innovation boosts production, enhances operational efficiency and drives output and productivity, which altogether enables firms to sustain a competitive advantage in the marketplace (e.g. Crespi et al. 2016; González-Blanco et al. 2019). In the face of intense competition and uncertainty, the need to be innovative has become essential for the survival and future growth of firms (Buddelmeyer et al. 2010; OECD 2019f; Ortiz-Villajos & Sotoca, 2018).

According to the OECD (2018d, p. 9), productivity measures 'how efficiently production inputs are being used in an economy to produce a given level of output'. As per the Productivity Commission (2020, p. 7), productivity is estimated as "the ratio of the quantity of output produced to some measure of the quantity of inputs used" (e.g. labour, capital, raw materials). The most common measure of productivity used in the empirical innovation literature is labour productivity. The vast majority of innovation studies uses sales or turnover per employee as their measure of labour productivity (e.g. Aboal & Garda 2016; Álvarez et al. 2015; De Fuentes et al. 2019; Peters et al. 2018; Raffo et al. 2008; Taveira et al. 2019), while some others use value added per employee (e.g. Benavente 2006; Lööf 2005; Gallego et al. 2015). Since labour productivity focuses only on a single type of input (i.e. labour), the Productivity Commission (2020) suggests that it is better to use multifactor productivity, which also takes into account technological change and efficiency improvements. Multifactor productivity is "the ratio of the total quantity of final goods and services produced [output] divided by the quantity of labour inputs plus the quantity of capital inputs" (such as machinery and equipment) (Thomson & Webster 2013, p. 484). This measure of productivity is employed in innovation studies by Van Leeuwen and Klomp (2006) and Friesenbichler and Peneder (2016). Another type of productivity measure is total factor productivity which is estimated by constructing an index of productivity, taking into account various factors such as labour, physical capital, energy, material cost, etc. As this measure requires data on various input variables, it is not commonly used. Available research on the innovation-productivity relationship using the total factor productivity measure includes Karafillis and Papanagiotou (2011), Goedhuys (2007) and Morris (2018). Apart from objective measures of productivity, some studies adopt a subjective measure of productivity – perceived productivity based on a firm's subjective assessment of their productivity performance. For example, Torrent-Sellens et al. (2016) and Verreynne et al. (2019) examine the impact of innovation on perceived productivity of SMEs in Spain and Australia respectively. Using the Business Longitudinal Database (BLD) data, Nguyen et al. (2021), Reeson and Rudd (2016) and Soames and Brunker (2011) estimate the link between innovation and self-reported productivity performance of Australian SMEs.[13]

The relationship between innovation and productivity has been the central focus of the empirical innovation literature. A substantial strand of research has adopted a structural model developed by Crépon et al. (1998), known as the CDM model[14], to estimate this relationship (to be reviewed in the next chapter). The CDM model establishes a link between innovation input, innovation output and productivity, which represents the firm's innovation process. This model has been applied in several studies in manufacturing and services using innovation survey data (Chudnovsky et al. 2006; Crespi & Zuniga 2012; Crespi et al. 2016; Griffith et al. 2006; Raffo et al. 2008). Using the CDM model, a significant number of studies find a positive impact of innovation on productivity in the manufacturing industry (e.g. Crespi & Zuniga 2012; Gallego et al. 2015; Hall et al. 2009; Morris 2018) and service industries (e.g. De Fuentes et al. 2015, 2019; Gallego et al. 2015; Masso & Vahter 2012; Musolesi & Huiban, 2010). In the primary sector, empirical and quantitative evidence on the link between innovation and firm productivity is still limited and focuses mainly on large firms.[15] Of the available academic studies, Sauer (2017), adopting the CDM framework, shows that innovation leads to productivity gains in Dutch farms. Other econometric studies, which did not apply the CDM, also indicate a positive impact of innovation. For example, Sauer and Latacz-Lohmann (2015) demonstrate a weak but positive effect of innovative investments on farm productivity, while Karafillis and Papanagiotou (2011) and Kimura and Sauer (2015) show that innovative farms are more productive than non-innovative ones.

[13] Further discussion on BLD measure of productivity is provided in section 5.4.1.

[14] The CDM is named after the first letter of each of the three authors' surname: Crépon, Duguet and Mairesse.

[15] In the primary sector, most prior work on innovation and productivity is either conceptual, descriptive or in the form of industry reports. The focus of these studies was narrowed to technology adoption in dairy production; however, there has been no quantitative analysis of the innovation–productivity link in mining firms.

Despite the majority of studies demonstrating a positive impact of innovation in various industries, there are conflicting results where the link between innovation and productivity is found to be insignificant or varies depending on the country under study. For instance, Benavente (2006) and Raffo et al. (2008) report no significant impact of innovation on firm productivity in Chile and Argentina, respectively. Using a large dataset of 43 countries, Morris (2018) further shows that the positive relationship of innovation is not universal, but rather, it varies across countries and innovation types. A recent study by Taveira et al. (2019), using the CDM and panel data of Brazilian firms, also finds the impact of innovation on productivity to be insignificant. Except for Morris (2018) and Taveira et al. (2019), much of the prior research was based on cross-sectional data to estimate the innovation–productivity relationship. There is a need for longitudinal research to move beyond the cross-sectional analysis of the impact of innovation (Haneda & Ito 2018; Taveira et al. 2019).

In terms of innovation types, technological innovation is often referred to as a major driver of manufacturing productivity, whereas non-technological innovation is considered to generate a greater impact on service productivity (Aboal & Garda 2016; Álvarez et al. 2015; Pires et al. 2008). However, there is mixed evidence on the impact of technological and non-technological innovation on firm productivity. A cross-country study by Crespi and Zuniga (2012) reveals that technological innovation is the key driver of productivity in manufacturing firms in Argentina, Colombia, Chile, Uruguay and Panama but not in Costa Rica. In addition, non-technological innovation has a positive impact on manufacturing productivity in Argentina and Colombia, although this effect is smaller compared with technological innovation. Studies by De Fuentes et al. (2019) and Gallego et al. (2015) reveal that non-technological innovation, rather than technological innovation, is the major driver of productivity in Mexican and Columbian manufacturing sectors, where technological innovation is often anticipated to be the most important driver of innovation in this sector. They further report that non-technological innovation is also the key driver of productivity in services. Conflicting results are also evident for Musolesi and Huiban (2010) and Masso and Vahter (2012). Musolesi and Huiban (2010) demonstrate that productivity improvement in French knowledge-intensive business services is driven by technological innovation, not non-technological innovation. However, Masso and Vahter (2012) contend that it is non-technological innovation that significantly drives productivity of Estonian knowledge-intensive service firms. In the case of less knowledge-intensive services, Masso and Vahter (2012) provide further evidence of a stronger effect of technological innovation on firm productivity. As Peters et al. (2018) claim, analysis of the link between innovation and productivity in service firms is still lagging behind the manufacturing industry and the role of non-technological innovation, in particular, requires further investigation. With respect to the primary sector, empirical research quantifying the impact of innovation on firm productivity remains scarce and overwhelmingly focuses on technological innovation. Of the available academic studies, Karafillis and Papanagiotou (2011), Sauer and Latacz-Lohmann (2015) and Kimura and Sauer (2015) indicate that adoption of innovative technologies positively affected productivity in the case of Greek olive farms, German dairy farms and Dutch dairy farms, respectively. Empirical evidence of non-technological innovation and productivity in the primary sector is hardly available in academic literature, except for Sauer (2017), who demonstrates that in addition to process innovation, non-technological innovation also leads to significant productivity gains in Dutch farms. Given the relative dearth of empirical research on innovation and productivity in the mining industry, further study is required.

As reviewed above, the relationship between innovation and productivity has been extensively examined in the broader innovation literature, although the results are inconclusive. Nonetheless, academic empirical research on innovation and firm productivity in the SME context remains scant. Of the limited SME evidence, Van Auken et al. (2008), Rochina-Barrachina et al. (2010) and Mañez et al. (2013) find innovation positively affects productivity in Spanish manufacturing SMEs, while Hall et al. (2009) and Calza et al. (2019) show a similar effect in the case of manufacturing SMEs in Italy and Vietnam. In their study on German firms, Baumann and Kritikos (2016) observe that the effect of innovation among micro manufacturing firms varies depending on the type of innovation, while Audretsch et al. (2020) reveal a positive impact of innovation on productivity of micro knowledge-intensive service firms. A study by Aboal and Garda (2016) shows a positive impact of innovation on productivity of small service firms in Uruguay; however, for small manufacturing firms, the impact varies across innovation types. It is apparent that existing research on SMEs focuses considerably on the manufacturing industry; empirical knowledge relating to SME innovation and productivity in other sectors is still under-explored (Hall & Williams 2019; Martin-Rios & Ciobanu 2019).

Further, in the SME literature, prior studies on innovation and productivity have overwhelmingly focused on technological innovation, while neglecting the role of non-technological innovation (González-Blanco et al. 2019). In fact, the focus of Van Auken et al. (2008), Hall et al. (2009), Baumann and Kritikos (2016), Calza et al. (2019) and Audretsch et al. (2020) was on technological innovation, whereas Rochina-Barrachina et al. (2010) and Mañez et al. (2013) specifically examine process innovation. In their cross-industry study, Aboal and Garda (2016) consider both technological and non-technological innovation. Their results reveal that, while technological innovation has a positive impact on small firms' productivity in manufacturing and services, the effect of non-technological innovation is positive for service but negative for manufacturing firms. In contrast, Díaz-Chao et al. (2016) demonstrate a negative effect of non-technological innovation on productivity of Spanish tourism SMEs. Therefore, the lack of empirical research and conflicting results on the role of innovation in non-technological aspects of productivity in the SME context requires more attention.

2.10. AUSTRALIAN LITERATURE ON INNOVATION

Innovation and productivity: Australian studies

In Australia, the topic of innovation has attracted attention from academics, industry and government. Table 2.2 summarises relevant studies on innovation in Australia, classified by topic, author, year, sample, scope, time coverage and type of publication. As shown in the table, most of the previous attempts to analyse the relationship between innovation and productivity in Australia occurred via research reports or working papers. Of the three journal articles found, two were conceptual papers. Thomson and Webster (2013) review the concepts and measures of innovation and productivity, while Carberry et al. (2011) review the development and adoption of technologies and possible sources of productivity growth, such as R&D investment, skill and human capital, in the context of dryland agriculture in Australia. An empirical study by Reeson and Rudd (2016) examines ICT, innovation and productivity in the three Australian sectors. They find that ICT activity is associated with all types of innovation and that increases in ICT investment are more likely to increase productivity for Australian firms. Nonetheless, their study uses a very limited set of variables to examine innovation and productivity, which are ICT investment, industry type and firm size, neglecting the possible effect of other factors such as innovation inputs, firm characteristics and external environment.

A series of working papers conducted by the Melbourne Institute and research papers by the ABS use the BLD to analyse innovation and productivity. For example, Bosworth and Loundes (2002) examine the impact of discretionary investments on innovation and productivity. They report that innovation has a positive impact on productivity (10% significance level) with the determinants of productivity being capital, employees, ownership, business plan and market share. In Wong et al.'s (2007) study, product and process innovations have a moderate positive influence on labour productivity, while the impact of organisational innovation is not significant. In addition, capital intensity is found to be strongly linked to labour productivity growth, whereas the influence of market competition and inter-industry differences varies. It should be noted that Wong et al. (2007) only report the significant level and the direction of the effects of each factor rather than their magnitude. A weak relationship between product innovation and labour productivity is also evidenced in Palangkaraya et al.'s (2010) study. The impact of process innovation is not significant and non-technological innovation is not examined. Further findings by Palangkaraya et al. (2010) reveal an impact of R&D investment intensity, firm size, firm age and market structure on productivity and differences in productivity performance between the resources and manufacturing industries. Soames et al. (2011) demonstrate a positive relationship between all types of innovation and productivity. Nevertheless, the model considers only the impact of innovation on productivity, with no control variables included in the model. It must be acknowledged that the ABS research papers conducted by Wong et al. (2007), Palangkaraya et al. (2010) and Soames et al. (2011) have enhanced our understanding of innovation and productivity; however, all three studies employ cross-sectional modelling. As indicated by Morris (2018) and Rodriguez-Sanchez et al. (2019), cross-sectional estimation does not account for simultaneity and unobserved firm heterogeneity in the innovation–productivity relationship.

A research report and a conference paper by Palangkaraya et al. (2014, 2015, 2016) on a similar topic are a step forward since they employ longitudinal panel models to examine productivity. They found innovations related to operational and organisational processes have a positive impact on productivity, while the impact of product or marketing innovation were not significant. Their study also revealed an influence of firm size, age, ownership, skill, collaboration and market competition on productivity. Nonetheless, the role of finance, ICT, training, innovation focus, export activities and sectors to innovation was not considered in the analysis. In addition, they conduct analysis for all firms in aggregation rather than in the sectoral contexts. Finally, an industry report conducted by Matysek and Fisher (2016) reviewed productivity trends in Australian mining from 1990 to 2015 and identified a decline in multifactor productivity of the industry since 2001. Using a case study of Rio Tinto, the study further highlights the role of technological adoption and innovation, particularly automation and enabling technologies, to improve mining productivity.

Table 2.2: Summary of Australian studies on innovation

Topic	Author & Year	Sample	Scope	Time coverage	Types of publication		
					Reports/industry or working papers	Journal articles	
						Conceptual	Empirical
Innovation and productivity	Bosworth & Loundes (2002)	SMEs	Manufacturing, Service, Mining	1994–1998	x		
	Wong et al. (2007)	All firms	Manufacturing, Service, Mining	2001–2003	x		
	Palangkaraya et al. (2010)	SMEs	Resources, Manufacturing	2004/05	x		
	Soames et al. (2011)	All firms	Manufacturing, Service	2005–2008	x		
	Carberry et al. (2011)	n/a	Agriculture	1980–2010		x	
	Thomson & Webster (2013)	n/a	n/a	n/a		x	
	Matysek & Fisher (2016)	n/a	Mining	1990–2015	x		
	Reeson & Rudd (2016)	All firms	All sectors	2007–2011			x
	Palangkaraya et al. (2014, 2015)	SMEs	Manufacturing, Service	2001–2012	x		
Innovation and firm performance	Bosworth & Rogers (2001)	Large firms	Manufacturing, Non-manufacturing	1994–1996			x
	Rogers (2002)	Large firms	Manufacturing, Non-manufacturing	1995–1998	x		
	Feeny & Rogers (2003)	Large firms	Mining, Manufacturing	1995–1998			x
	Lee et al. (2016)	All firms	Restaurants	n/a			x
	Jones & Zubielqui (2017)	SMEs	All sectors	2014			x
	Verreynne et al. (2019)	SMEs	Tourism	2010–2011			x

Topic	Author & Year	Sample	Scope	Time coverage	Types of publication		
					Reports/industry or working papers	Journal articles: Conceptual	Journal articles: Empirical
Drivers of innovation	Bhattacharya & Bloch (2004)	All firms	Manufacturing	1997–1998			x
	Rogers (2004)	All firms	Manufacturing, Non-manufacturing	1994–1997			x
	Webster (2004)	Large firms	All sectors	2001–2003			x
	Griffiths & Webster (2010)	Large firms	All sectors	1990–2005			x
	Upstill & Hall (2006)	n/a	Minerals industry	2003		x	
	Terziovski (2010)	SMEs	Manufacturing	n/a		x	
	Bloch & Bhattacharya (2016)	SMEs	Not specified	n/a		x	
	Palangkaraya et al. (2016)	All firms	Manufacturing, Service	2005–2012	x		
	Divisekera & Nguyen (2018a, b)	SMEs	Tourism	2006–2011			x
	Soriano et al. (2019)	Small firms	Agriculture	2006–2011			x
Barriers to innovation	Kotey & Sørensen (2014)	Small firms	Cotton industry	2004–2009		x	
Innovation and firm survival	Jensen et al. (2008)	Large firms	Primary, Manufacturing	1997–2005			x
	Buddelmeyer et al. (2010)	Employing firms	All sectors	1997–2003			x
Innovation networks	Mohannak (2007)	SMEs	Biotechnology firms	n/a			x
	Gronum et al. (2012)	SMEs	All sectors	2004–2007			x
Innovation and export	McMahon (2001)	SMEs	Manufacturing	1994–1998			x
	Palangkaraya (2013)	SMEs	All sectors	2004–2007	x		
	Tuhin (2016)	SMEs	All sectors	2004–2009	x		

Topic	Author & Year	Sample	Scope	Time coverage	Types of publication		
					Reports/industry or working papers	Journal articles	
						Conceptual	Empirical
Innovation and ICT	Todhunter & Abello (2011)	All firms	All sectors	2005–2007	x		
Patterns of innovation	Trewin & Paterson (2006)	All firms	All sectors	2002/03	x		
Intellectual property	Jensen & Webster (2006)	All firms	All sectors	1994–2001	x		
Australian innovation system	Australian Government (2010–2017)	All firms	All sectors	2010–2017	x		

Other Australian innovation studies

Other Australian studies on the impact of innovation which employed other performance measures rather than productivity, are discussed in this sub-section. Early work by Bosworth and Rogers (2001), Rogers (2002) and Feeny and Rogers (2003) examined R&D investment and firm performance in the context of large manufacturing and non-manufacturing firms. The findings of Bosworth and Rogers (2001) reveal that R&D and patent activity are positively linked to firm performance, as measured by market value. Rogers (2002) adds that the market valuation of R&D activity is higher in industries with weaker degrees of competition. Feeny and Rogers (2003) conclude that innovation increases market value for large Australian firms.

In the context of the Australian restaurant industry, Lee et al. (2016) find that innovation leads to improved firm performance, as measured by sales, profitability, growth, overall performance and achieving expectations. Further, human capital indirectly influenced restaurant performance through innovation and entrepreneurial self-efficacy. Jones and Zubielqui (2017) examine university–industry interactions, innovativeness and SME performance. Their results reveal that innovativeness is positively linked to SME performance, measured by sales growth and profitability. Similarly to Lee et al. (2016), Jones and Zubielqui (2017) highlight the importance of human capital since human resource transfer is found to impact firm performance through innovativeness. A recent study by Verreynne et al. (2019) using longitudinal data collected over a period of 18 months (2011–2012) showed a strong relationship between innovation diversity and perceived firm performance.

A number of Australian studies have sought to identify the drivers of innovation. Early work by Bhattacharya and Bloch (2004) on manufacturing SMEs found that size, R&D intensity, market structure and trade shares influence innovative activity. Rogers (2004) examined manufacturing and non-manufacturing firms. His results highlight the influence of networks, management training, R&D activity and export on a firm's innovative status, yet the significance and impact of each factor varies across firm size and sector. In their review of the economics literature, Palangkaraya et al. (2016) indicate that innovative firms are more collaborative, and research, IT and science are the core skills used in undertaking business activities. Innovative firms are also more likely to operate in competitive markets rather than captive markets. Using the BLD, Divisekera and Nguyen (2018a, b) and Soriano et al. (2019) shed light on the drivers of innovation in tourism SMEs and small food firms, respectively. The four determinants identified in both studies include collaboration, ICT, finance and market competition. Other empirical work on this topic includes that of Webster (2004) and Griffiths and Webster (2010), who focus on large firms. Both studies emphasised the significance of a managerial approach to innovation in large Australian firms. There are also conceptual papers and research notes that reviewed the literature and identified innovation drivers, such as those of Upstill and Hall (2006) in the Australian minerals industry, Terziovski (2010) in manufacturing SMEs and Bloch and Bhattacharya (2016) in Australian SMEs as a whole.

Other Australian studies have examined various aspects of innovation. For example, Jensen et al. (2008) and Buddelmeyer et al. (2010) shed light on the importance of innovation for firm survival. Trewin and Paterson (2006) describe the patterns of innovation in Australia. Mohannak (2007) investigates innovation networks of Australian high-technology SMEs, while Gronum et al. (2012) underscore the role of networks in SME performance. Jensen and Webster (2006) explore intellectual property usage by firm size. In the case of the Australian cotton industry, Kotey and Sørensen (2014) identify barriers to innovation faced by small firms. Palangkaraya (2013) and Tuhin (2016) examine the link between innovation and export activities among SMEs, while Todhunter and Abello (2011) analyse the relationship between ICT and innovation among Australian firms as a whole. Finally, a series of Australian Innovation System Reports, conducted by the Australian Government from 2010 to 2017, illustrates the characteristics of the Australian innovation system, innovation activity of firms and contribution of innovation to the Australian economy.

To summarise, several attempts have been made by academics, industry and government to examine innovation in Australia. The majority of Australian studies on innovation were conducted using data from the 1990s and early 2000s. However, arguably, the last decade has witnessed the most rapid evolution of technologies, particularly ICTs. The unprecedented speed of technological change is significantly transforming economies around the globe and firms' activities in all business aspects (WEF 2018). While previous work sets the foundation to understand the concepts of innovation, further research is needed to provide a more up-to-date picture of innovation patterns in today's economies. Further, many prior Australian studies are reports or conceptual papers, while quantitative and empirical academic research on the innovation process is relatively limited.

Despite Australia being a service-based economy, studies on innovation in manufacturing firms remain dominant in the Australian innovation literature. In contrast, there is little empirical evidence on innovation in the primary sector, which includes the Agriculture, Forestry, Fishing and Mining industries. In addition, most research uses economy-wide aggregation analysis, while some focuses on a particular industry such as tourism or food. International evidence shows that differences exist between sectors (Castellacci 2008; Martin-Rios & Ciobanu 2019). Yet sectoral comparisons of innovation processes in the three economic sectors (i.e. primary, manufacturing and service) are still scarce in the Australian empirical academic literature. Further, there is a need for more empirical academic studies that analyse innovation and productivity in the SME context given the distinct features of SMEs compared with large firms.

With respect to modelling and data, most of the previous work in Australia analysing innovation determinants, innovation outputs and productivity employed a single equation estimation or cross-sectional estimation, which does not account for simultaneity in the innovation process nor does it consider unobserved firm heterogeneity (Morris 2018; Taveira et al. 2019). Therefore, these limitations highlight the need for more empirical research using up-to-date innovation data to examine innovation and productivity across economic sectors. Moreover, longitudinal panel data should be used to better examine innovation and its impact on firm performance and productivity among Australian firms, as recommended by Verreynne et al. (2019) and Soriano et al. (2019).

2.11. SUMMARY OF THE EMPIRICAL RESEARCH ON INNOVATION, ITS DETERMINANTS AND IMPACTS

To summarise, innovation theories and prior empirical research have identified several factors that are likely to affect innovation propensity and capability among firms. These factors can be classified into three main groups: (i) innovation inputs, (ii) firm characteristics and (iii) external environment. Most prior studies largely relied on R&D expenditure as a measure of innovation input. However, in the SME context, the vast majority of firms do not invest in R&D (Hervas-Oliver et al. 2011; 2016; Huang et al. 2010), relying instead on non-R&D activities. A growing body of innovation research over the last decade has highlighted the importance of non-R&D variables, including training, ICT investment, collaboration, financial support and innovation focus, in firms' innovation success. In addition, factors relating to firm characteristics such as size, age, ownership and exports are likely to influence innovation performance. The external environment, including the degree of market competition and the sector, is also considered an important externality in firm innovation. While the extensive body of innovation research has recognised the significant role played by these factors, empirical findings on SMEs are relatively limited and mixed. Available studies predominantly focus on product innovation; little is known if the influence of these factors varies among different types of innovation (e.g. non-technological innovation) and whether factors across the three groups simultaneously affect the innovation process (Heredia Pérez et al. 2019). Moreover, the majority of previous studies were conducted in the manufacturing sector, while empirical knowledge of other sectors, such as primary and service, remains limited. The review of the literature further highlights the differences in innovation processes resulting from sector characteristics, suggesting a need for further investigation into the determinants of innovation and their impacts in different industry contexts as well as the relationship between different innovation types and firm productivity across sectors.

Empirical research on SME innovation revealed several important gaps. First, existing research is mostly conducted in the manufacturing sector, whereas knowledge of SME innovation and productivity in other sectors is still under-explored (Audretsch et al. 2020; Hall & Williams 2019). Second, prior studies have overwhelmingly focused on technological innovation (Radicic & Djalilov 2019); thus, drivers of non-technological innovation and the impact of this innovation type on SME productivity are rather limited (Audretsch et al. 2020; Expósito & Sanchis-Llopis 2018). Third, the SME innovation literature has not yet offered clear evidence on the impact of various innovation types on specific performance measures (Rosenbusch et al. 2011) and their magnitude (Hall et al. 2009). Fourth, the findings on the link between technological and non-technological innovation and SME productivity are mixed. Fifth, much of the previous work is based on cross-sectional data (Audretsch et al. 2020; Morris 2018). Thus, the need for longitudinal data is emphasised (Expósito & Sanchis-Llopis 2018; Haneda & Ito 2018). The present thesis, using a longitudinal dataset, addresses the above shortcomings and provides empirical evidence on the determinants of both technological and non-technological innovation and the impact of these innovation types on SME productivity in the primary, secondary (manufacturing) and service sectors in Australia. The review of literature presented in this chapter lays a theoretical foundation for developing a conceptual framework and research method in the next chapter.

CHAPTER THREE:
INNOVATION IN AUSTRALIA: A SECTORAL PERSPECTIVE

3.1. INTRODUCTION

This chapter presents the descriptive and analytical analysis on the innovativeness and characteristics of Australian firms, inputs for innovation and market conditions across the three Australian economic sectors. Various data sources are used to provide a comprehensive contextual background for the empirical analysis conducted in the next chapter. The three key sources of ABS data used are Characteristics of Australian Businesses, the Innovation in Australian Business Survey and Business Characteristics Microdata. This chapter addresses the first research question: *RQ1: What is the state of innovation in Australia's three economic sectors (i.e. primary, secondary and service)?*

This chapter begins with an overview of the three Australian economic sectors. The characteristics of Australian firms are then examined with a focus on identifying the nature of innovative firms. Subsequently, the current state of innovation across sectors is explored. In the next section, various inputs for innovation are elaborated, followed by insights into the condition of market competition in Australia. Finally, the benefits of and barriers to, innovation among Australian firms in general and SMEs in particular, are identified and discussed. Prevailing issues regarding the strengths and weaknesses of the Australian innovation system identified in this chapter are used for policy discussion in Chapter Seven. It should be noted that due to unavailability of certain SME data at the industry level, RQ1 refers to all firms, yet where data is available, SMEs are specifically discussed. This limitation would not affect the main aim of the RQ1 which is to identify the state of innovation in the three Australian economic sectors and explore if innovation patterns vary among sectors. The sectoral patterns identified in this chapter lays a background context for empirical analysis on SMEs from a sectoral perspective to be carried out in chapter Six.

3.2. OVERVIEW OF THE THREE AUSTRALIAN ECONOMIC SECTORS

3.2.1. Primary sector

The primary sector comprises two industry divisions: (i) Agriculture, Forestry and Fishing and (ii) Mining. The Agriculture, Forestry and Fishing industry serves as the cornerstone of the Australian economy. The industry added $31.1 billion to the national economy, accounting for 2.2% of GDP and employing 482,000 workers in 2017–18 (ABS 2019a). The industry relies heavily on exports, with 70% of the total value of its production being exported to global markets, contributing to 11% of Australia's total exports in 2018–19 (Australian Bureau of Agricultural and Resource Economics and Sciences [ABARES], 2020). Involvement in the global markets is strongly linked to intense competitive pressure faced by Australian producers. In such a situation, being innovative and productive is important for Australian firms to respond to international competition and to keep up with improvements, technological disruption and industry transformations in other advanced economies (ABARES 2020).

In the Australian agricultural industry, productivity is a core measure of performance. It shows 'how efficiently inputs (labour, capital, land, materials and services) are used to produce outputs (crops, wool and livestock) over time' (Boult & Chancellor 2020, p. 3). A prevailing issue facing the Australian agricultural industry in recent years is a marked slowdown of productivity growth. The average growth rate of agricultural productivity dropped to an average of 0.7% year-on-year since 2005, compared with a 4.2% year-on-year average during the period 1989 to 2005. From 2018 to 2019, agriculture exhibited the largest fall in productivity among all Australian industries, a 10.1% decline in labour productivity and a 9.8% decline in multifactor productivity. This fall is responsible for a quarter of the productivity slowdown in the Australian economy (Productivity Commission 2020). The significant fall and stagnation in productivity growth of the industry are caused mainly by deteriorating seasonal conditions, low efforts in innovation and a decline in technical changes (Boult & Chancellor 2020).

The Agriculture, Forestry and Fishing industry is characterised by a strong attachment to the environment. Unprecedented natural events such as climate change, threats from pests and diseases, water scarcity and widespread bushfires have been the major challenges to firms' survival and performance. In this context, innovation is proposed as a key to developing farming solutions that minimise the impact of the environment on firm performance as well as the impact of business activities on the environment. It is also suggested as the driver of global competitiveness (Caiazza & Stanton 2016) and a means of improving agricultural productivity (Läpple et al. 2016; OECD 2015c). As the ABARES (2019) notes, the adoption of new technologies and innovative solutions has boosted the performance of the industries as a whole, driven profitability and productivity, reduced environmental impacts and improved sustainability. Thus, accelerating productivity growth for the Agriculture, Forestry and Fishing industries, as ABARES (2019) asserts, lies with innovation. Yet, not only are more efforts in innovation required, but the effectiveness of existing innovation investments needs to be improved to ensure to success and long-term productivity growth (ABARES 2019, 2020).

The mining industry forms a significant component of the primary sector and a major contributor to the Australian economy, with $148.8 billion industry value added, 7.6% share of national GDP and 240,000 jobs. Mining is Australia's largest exporter, generating $221 billion resources exports and accounting for 55% share of total exports in 2017–18 (Australian Mining 2019). Australia experienced one of the greatest mining booms in its history during the period 2000–01 to 2015–16. The enormous investments in mining led the Australian mining industry to the forefront of innovation. World-first technologies developed by Australian mining have been implemented globally and have significantly enhanced productivity for mining firms (DIIS 2018b, c). Nevertheless, since the end of the investment phase of the mining boom, productivity of the industry has been declining. The fall in mining investments detracted 4.8 percentage points from GDP growth since the year 2013–14, significantly affecting Australia's economic performance (DIIS 2018a). Further, it is pointed out that, while digitisation is crucial to mining operations, the mining industry performed poorly in terms of the Digitisation Index and the Digital Scores, ranked in the bottom quarter of Australian industries (DIIS 2018b).

Today, with automation, robotics and artificial intelligence becoming more and more important in the mining industry, there is a significant need to encourage more investments in innovation and new technologies in this industry. Like agriculture, mining firms also face strong competition from global markets. As Matysek and Fisher (2016) indicate, innovation is highly important for Australian mining firms to improve their efficiency and sustain their global competitiveness in the long term. As most investments in technologies and innovation in mining are enormously costly, they are mainly conducted by large firms (DIIS 2018b). Although SMEs comprise the majority of the industry, large mining firms are the main contributors to the industry's performance, overwhelmingly surpassing their smaller counterparts. The share of industry value added by large mining firms was 78% compared with 10% by small firms. Large mining firms also accounted for 99.88% of total value of goods exports (small firms: 0.02%) and 70.5% of business expenditure on R&D (small firms: 2%). There is not only a considerable disparity in performance between large firms and SMEs in the mining industry, but also in the productivity gap (DIIS 2018b).

Despite the importance of innovation in productivity in the primary sector, there is very limited empirical research on innovation and productivity in the agricultural industry, particularly in the SME context (Soriano et al. 2019). Moreover, relative empirical research on mining SMEs is significantly lacking. As reviewed in Chapter Two, the focus of prior innovation research in agriculture was almost solely on large firms and on technological innovation. In Australia, available innovation studies on innovation in the primary sector are mostly policy papers conducted by the OECD and industry reports by the ABARES which are primarily conceptual and descriptive in nature. Most academic research also focuses on large farms or agricultural firms as a whole rather than SMEs. The exception is Soriano et al. (2019), who conduct two separate analyses on determinants of small firms (i) in the agriculture, forestry and fishing industry and (ii) two other food-related industries including manufacturing and wholesale trade. Yet Soriano et al.'s (2019) study did not examine the next stage, namely, how innovation influences the productivity of small agriculture, forestry and fishing firms. In addition, no quantitative studies on the innovation–productivity link are found on Australian mining SMEs. Hence, further empirical investigations are needed to inform policy to improve innovation and productivity of firms in this sector, particularly for SMEs, which lag behind in these areas.

3.2.2. Secondary sector

The secondary sector in this study consists of manufacturing firms that use materials which are the output of the primary sector and transform them into products. Manufacturing has a strong connection with both the primary and service sectors via its flow of goods and knowledge throughout the economy (Schafran et al. 2018). Due to Australia's transition into a service-based economy, manufacturing's share of output and employment has fallen significantly over the past three decades (Reserve Bank of Australia 2017). Nonetheless, the manufacturing industry remains a crucial component of the Australian economy. In 2017–18, the industry contributed around $100 billion to national GDP and employed around 900,000 workers, making it the seventh largest industry for employment and the sixth largest for output in Australia (ABS 2019a). Over the past decades, with new technologies such as automation and digitalisation increasingly transforming the industry, manufacturing has become more capital-intensive and less labour-intensive (DIIS 2018b). Manufacturing is also the second largest goods exporter, accounting for nearly a quarter of export volume—just behind the Mining industry (55%) (ABS 2018b). The industry is therefore highly exposed to trade and faces strong international competition. In terms of its components, the

Australian manufacturing industry is predominantly made up of SMEs (99.4%), with only 0.6% being large firms. Nonetheless, the economic contribution of SMEs is not proportional to their large number. SMEs accounted for approximately 46.8% of total industry value added and 63.4% of employment in the industry (ABS 2019a).

Despite the advancements that new technologies have brought to the industry over the past decades, the productivity of Australian manufacturing has been declining. In the year 2018–19, the industry recorded a drop of 5.5% in multifactor productivity compared with 2011–12 or 9% relative to 2003–04 (ABS 2019d). One of the main reasons for this has been skills shortages. This reason has also been cited as the top concern by Australian manufacturing firms insofar as it acts as a major inhibitor of the industry's performance (Australian Industry 2019). Recent research claims that the manufacturing industry is responsible for nearly half of the productivity slowdown of the Australian economy and that the current industry's productivity levels are much weaker than in earlier decades (Productivity Commission 2020). Further, manufacturing also had the lowest proportion of high-growth firms as part of the Australian innovation system (8.7%) (Australian Government 2017c). With the rise of Industry 4.0, the manufacturing industry has a massive opportunity to transform, innovate and grow. Embracing digital technologies and innovation is not only crucial for the sector's performance but it will also prevent Australian manufacturers from being surpassed by international competitors (Advanced Manufacturing Growth Centre [AMGC], 2018).

Knowledge about innovation in manufacturing and its impacts on productivity has been extensively examined in the broader innovation literature, although to a much lesser extent in the SME context (Baumann & Kritikos 2016). Generally, the innovation process in the manufacturing industry is known to be sophisticated, mostly science-based and requiring a high level of technology (Mohnen & Hall 2013; Raymond & Pierre 2010). Prior research shows manufacturing firms typically conduct more technological than non-technological innovation (Aboal & Garda 2016; Raymond & Pierre 2010). Thus, technological innovation is often referred to as the main contributor to manufacturing productivity compared with non-technological innovation (Aboal & Garda 2016; Álvarez et al. 2015). In manufacturing, the outcome of innovation typically results in visible or tangible products and processes. As a tangible product, innovation in manufacturing is easy to measure and often protected by intellectual property rights such as patents or trademarks. R&D is often used as the key measure of innovation input in manufacturing. However, it has also been recognised that

R&D activities are mainly conducted by large manufacturing firms rather than SMEs (Aboal & Garda 2016; Ortega-Argilés et al. 2009), whereas non-R&D innovators are found to be more popular among manufacturing SMEs (Huang et al. 2007; 2010; Rammer et al. 2009). SMEs in manufacturing tend to create a competitive advantage through their human capital's creative potential to develop differentiated products for niche markets (Fuchs et al. 2000; Terziovski 2010). However, in Australia, most manufacturing SMEs are 'simply trying to survive' rather than 'attempting to do something new … such as updating their equipment or introducing new products and services' (AMGC 2017, p. 5). With SMEs accounting for the vast majority of the Australian manufacturing industry, but considerably lagging behind large firms in innovation and economic performance, improving innovation among the broad mass of manufacturing SMEs could lead to big gains for the sector as well as the Australian economy (AMGC 2017).

3.2.3. Service sector

Services have become the largest sector in the global economy and significantly contributed to GDP and employment of both developed and developing countries (World Bank 2017). Like many other advanced economies, Australia is a service-based economy. The service sector contributes more than 75% to Australia's gross value added and 88% of total employment (Australian Government 2019a). Services, as the fastest growing sector in Australia, play a key role in the way the economy has responded to technological progress (Reserve Bank of Australia [RBA], 2017). The value of services trade rose to $198.7 billion in 2018–19 (DFAT 2020). Thus, the performance, productivity and sustained growth of service industries are critical drivers of the overall growth of the Australian economy (Committee for Economic Development of Australia [CEDA] 2017; Sorbe et al. 2018).

International evidence shows that of the service sub-sectors, KIBS plays a significant role in innovation systems and new knowledge-based economies. Firms in KIBS are often referred as innovative and dynamic in upgrading and renewing their knowledge base (Martin-Rios & Ciobanu 2019; Pina & Tether 2016) and in introducing innovation with high levels of novelty (De Fuentes et al. 2019). However, unlike KIBS, the internal capabilities to generate new knowledge of SIS firms are limited. Their innovation activities are mainly based on the acquisition of machinery or equipment and the adoption of technological knowledge created elsewhere in the economy (Castellacci 2008; Malerba 2002). SDS firms commonly lack the internal capability and resources; thus, they exhibit lower levels of innovation among the three service sub-sectors (Martin-Rios & Ciobanu 2019). Innovations in SDS firms primarily depend on the purchase of goods or services and interaction with their suppliers and customers (Aas et al. 2015). Many SDS, for example, Accommodation and Food Services and Arts and Recreation Services, also have a very low level of productivity (Hall & Williams 2019).

While measurement of productivity is well developed in the manufacturing industry, measuring productivity in services remains a key challenge since the outputs of services are mostly intangible and assessed based on their quality, which is heterogeneous as it is perceived by consumers (CEDA 2017; Sorbe et al. 2018). Traditionally, the service sector was often referred to as a passive adopter of technologies developed in the manufacturing sector and a laggard in innovation and productivity growth (Gallouj & Savona 2009; Tether & Howells 2007). However, in recent years, empirical research has refuted this proposition since many service firms are found to be as innovative as manufacturing firms (Álvarez et al. 2015; Zahler et al. 2014) and are no longer technologically backward (Mina et al. 2014). As CEDA (2017, p. 16) emphasises, service industries' productivity is 'growing more strongly than previously thought'. Yet, a recent study on service firms across OECD countries by Sorbe et al. (2018) contends that services are very diverse, leading to variations in performance across service sub-sectors. In Australia, certain service industries (e.g. information and telecommunications or professional and technical services) enjoy high productivity levels and growth rates, while other industries such as accommodation, food and transport (often referred to as tourism industries) are between average to below-average (CEDA 2017) and even negative in the year 2018–19 (Productivity Commission 2020). As Sorbe et al. (2018) show, the productivity levels and growth rates of services as a whole are likely to be weaker than those of manufacturing.

There is consensus in the literature that innovation is a strategic solution to lift productivity levels of the service sector (Sorbe et al. 2018). Understanding the innovative behaviour of service firms and determinants of innovation in services is therefore of the utmost importance to boost their innovation performance and, ultimately, their productivity. Available international evidence shows that innovation patterns and behaviour of service firms are different from those of manufacturing firms (Aboal & Garda 2016; De Fuentes et al. 2019; González-Blanco et al. 2019; Love et al. 2011). Innovations in the service sector are characterised by four distinct features, namely, intangibility, simultaneity, heterogeneity and perishability (de Jong et al. 2003; Savona & Steinmueller 2013). Simultaneity inherent in services makes it difficult to distinguish product and process innovations because the processes are often inseparable from the outcomes they produce (González-Blanco et al. 2019; Mina et al. 2014; Toivonen & Tuominen 2009). While innovations in the primary and manufacturing sectors are mainly technological, innovations in services are not necessarily linked to technology (Toivonen & Tuominen 2009).

Empirical evidence shows that innovation in services is likely to be non-technological (Aboal & Garda 2016; De Fuentes et al. 2015) or less technological (Van Ark et al. 2003; Tether 2005). With services being a labour-intensive sector, innovations tend to focus on organisational and human capital aspects (Gallouj & Savona 2009; Hipp & Grupp 2005). Further, performing R&D is not popular in services. Many service firms, because of their small size, do not have an R&D department (Toivonen & Tuominen 2009). Their innovation often has no R&D expenditure or is less dependent on formal R&D activities (Aboal & Garda 2016; Flikkema et al. 2007; Miles 2008). Instead, as indicated by Álvarez et al. (2015), Cainelli et al. (2006) and Hertog (2010), the innovation process in service firms requires various non-R&D activities, such as investments in ICT or training of employees. Such non-R&D activities have been identified as the driver of numerous successful innovations in services (Trigo 2013).

The Australian service sector is also predominantly made up of SMEs (ABS 2019c). As the OECD (2019f) emphasises, SMEs are the key to improving productivity. However, SMEs, especially in services, face several disadvantages in undertaking innovation. These include economies of scale, resource shortages, limited access to capital markets and inadequate management expertise and organisational capabilities (Tejada & Moreno 2013). Despite the growing interest in innovation in services over the last decade, research on service innovation and firm performance in the SME context remains scarce (Audretsch et al. 2020; Verreynne et al. 2019). Most studies continue to focus on technological aspects of innovation, whereas the role of non-technological innovation has largely been ignored (Geldes et al. 2017; Verreynne et al. 2019). It is argued that technological innovation itself is not sufficient to explain innovation in service-dominated economies (De Fuentes et al. 2019; Geldes et al. 2017). Therefore, recent studies have raised the need for further research to analyse the link between non-technological innovation and productivity in services (Peters et al. 2018), especially in service SMEs (Audretsch et al. 2020). Thus, more empirical investigations are needed to shed light not only on the characteristics of innovators in services and how they innovate, but also on the extent to which technological and non-technological innovation affects firm productivity in service SMEs.

3.3. CHARACTERISTICS OF AUSTRALIAN FIRMS

3.3.1. Firm size

Among firm characteristics, firm size[16] is often considered the most important. Table 4.1 provides information on the total number of firms in Australia, entries, exits and their innovation status by size. Overall, the Australian economy is dominated by SMEs (99.8%). In 2017–18, the number of business entries and exits was highest for firms without employees (i.e. self-employed, sole traders), followed by micro firms, and lowest for large firms. There was a dramatic increase of 65,496 non-employing firms and a considerable decline of 7,732 small firms over the year 2017–18. This indicates that very small businesses often face low barriers to entry. Their operations can be easily established and usually do not require complex procedures and substantial set-up costs. However, these types of businesses are less likely to survive over time compared with larger firms, evident by the highest exit rate of 15.2%.

Innovation activity occurs in Australian firms of all sizes. The data show that at the aggregate level, one in every two Australian firms (49.8%) was innovation-active[17] in 2017–18. Among firm size groups, large firms (73.6%) exhibited the highest proportion of firms undertaking innovative activities, followed by medium firms. In contrast, non-employing and micro firms constituted the smallest proportion of innovation-active businesses (41.7%). The data suggests a declining tendency in the proportion of innovation-active firms as firm size declines. SMEs demonstrated a lower rate of innovation-active firms relative to large firms. This tendency has been observed in most prior studies on innovation. SMEs often face resource shortages, which prevent them from investing in innovation (Lukovszki et al. 2020), whereas larger firms are more likely to innovate because of greater resources and the advantage of economies of scale (Hewitt-Dundas 2006). Mohnen and Hall (2013) add that because larger firms are typically involved in a wider range of activities and projects, they have a higher probability of innovating in at least one of them.

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[16] Firm size is classified by the number of employees. Micro firms: 0 to 4 persons, small firms: 5 to 19 persons, medium firms: 20 to 199 persons and large firms: 200 or more persons (Australian Government 2019b).

[17] Innovation-active businesses are firms that undertook any innovative activity irrespective of whether the innovation was introduced, still in development or abandoned.

Table 3.1: Characteristics of Australian firms

		Non-employing firms	Micro firms	Small firms	Medium firms	Large firms	Total
Operating at start of financial year	no.	1,370,051	608,733	203,351	52,249	3,915	2,238,299
	%	61.21	27.20	9.09	2.33	0.17	100
Entries	no.	259,775	85,247	8,259	1,136	103	354,520
Entry rate	%	19.0	14.0	4.1	2.2	2.6	15.8
Exits	no.	208,717	57,606	11,096	1,958	151	279,528
Exit rate	%	15.2	9.5	5.5	3.7	3.9	12.5
Operating at end of financial year	no.	1,435,547	627,932	195,619	50,338	3,855	2,313,291
	%	62.06	27.14	8.46	2.18	0.17	100
Change	no.	65,496	19,199	–7,732	–1,911	–60	74,992
Innovation-active	%	41.7[18]		60.9	70.6	73.6	49.8

Source: Derived from Count of Australian Businesses (ABS 2019c) and Characteristics of Australian Businesses (ABS 2019b)

3.3.2. Firm age

Firm age is known to have some influence on innovation capability. According to endogenous growth theory, mature firms tend to be more innovative due to their greater organisational learnings, resources, knowledge, experience and ability to handle risks (Cohen & Levinthal 1990). However, most empirical evidence shows that younger firms are more innovative (Rosenbusch et al. 2011). Figure 3.1 illustrates the link between firm age and the proportion of innovation-active SMEs over the period 2011–12 to 2015–16.

As shown in Figure 3.1, the rate of innovation tends to decline with years of operation. An overwhelming proportion of innovation-active business is observed at an early age, with the largest proportion being new entrants (less than one year of operation), 2-year-old firms and 6-year-old firms. Over certain years of operation (i.e. 6 years), the number of Australian firms engaging in innovative activity starts dropping. After 12 years, the proportion of innovation-active businesses is less than non-innovation-active ones. This proportion eventually declines by 17% for firms aged 30 years or more compared with new entrants. This pattern implies that older firms seem less likely to undertake innovative activity.

[18] No published data are available separately for non-employing firms and micro firms.

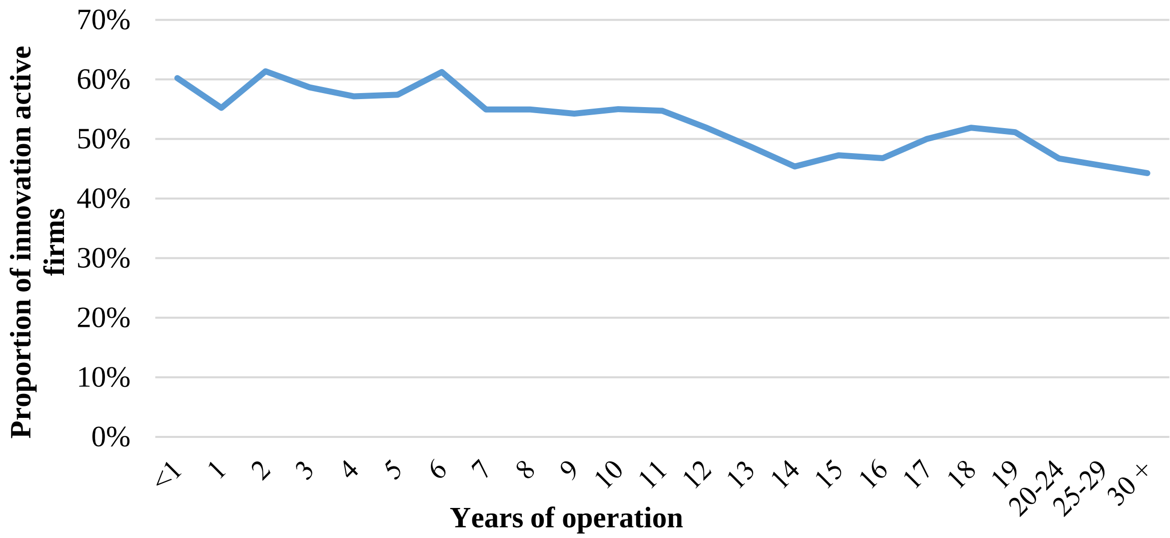

Figure 3.1: SME age by innovation-active status

Source: Business Characteristics 2011–12–2015–16 (ABS 2019f)

A high rate of newly established firms investing in innovation could be related to one of Schumpeter's assumptions that innovations are 'embodied in new firms founded for the purposes' (1939, p. 94) and also to the concept of innovative entrepreneurs—those who change the market by making innovative investments that embody new technologies or resource discoveries. The observed decline in innovation rates by firm age could be because of organisational inertia (Hannan & Freeman 1984). Compared with mature firms, young or newly established firms are much more flexible in setting up their routines and capabilities to better exploit new ideas and market opportunities (Helfat & Peteraf 2003). They are also willing to undertake risky innovative investments, and are thus more eager to innovate than older firms (Coad et al. 2016).

3.3.3. Ownership

Type of ownership is known to have an impact on firms' strategy as well as their business performance. Table 3.2 provides data on the economic activity and share of foreign-owned businesses in selected industries in Australia. It is revealed that foreign-owned firms cover a wide range of industries, but they make up only 0.5% of total operating businesses in Australia. The number of foreign-owned firms is relatively small across all industries. Mining has the largest share of foreign-owned firms, accounting for 5.93% of total mining firms in Australia. In manufacturing, only 1.21% of firms are foreign-owned, while in the services sector, Wholesale Trade has the highest share of foreign-owned firms (2.49%).

Table 3.2: Economic activity of foreign-owned firms in Australia[19]

Industry	Operating business		Employment		Sales of goods/services		Industry value added	
	no.	%	'000	%	$m	%	$m	%
Primary Sector								
Agriculture, Forestry and Fishing	180	0.10	6.0	1.24	12,282.2	14.87	1114.1	3.83
Mining	474	5.93	40.5	22.75	53,793.6	25.21	38975.2	33.08
Manufacturing Sector								
Manufacturing	1,010	1.21	141.3	16.55	126,847.4	33.91	29,345.9	29.49
Service Sector								
Construction	484	0.14	63.6	6.05	50,435.3	13.51	15,375.9	13.34
Wholesale Trade	1,909	2.49	123.0	22.65	209,544.2	43.62	26,432.1	42.83
Retail Trade	396	0.30	66.2	5.12	36,243.3	9.36	8,010.4	11.21
Accommodation and Food Services	131	0.15	72.4	7.53	15,061.2	16.23	5,190.5	13.36
Transport, Postal and Warehousing	369	0.29	67.8	11.92	29,517.4	19.17	11,798.4	16.92
Information Media and Telecommunications	303	1.56	33.1	19.70	9,001.4	11.90	6,563.3	17.69
Rental, Hiring and Real Estate Services	687	0.29	28.3	7.06	22,779.8	19.03	9,607.7	13.46
Professional, Scientific, Technical Services	1,604	0.63	115.7	12.05	55,652.4	28.96	27,592.7	25.77
Administrative and Support Services	356	0.45	98.8	11.80	18,382.0	23.13	19,689.2	36.91
Arts and Recreation Services	60	0.23	11.1	5.44	2,544.3	8.28	887.5	7.27
All industries	*9,946*	*0.5*	*996.2*	*8.7*	*770,395.1*	*24.2*	*221,915.7*	*20.8*

Source: Economic Activity of Foreign-Owned Businesses in Australia, 2014–15 (ABS 2018c)

[19] In this section, foreign ownership refers to majority foreign-owned businesses only (greater than 50% equity ownership). In addition, the figures for 'all industries' in the Australian economy are included, not just the 13 industries in the present thesis.

Despite being a minority group in terms of the number of businesses, foreign-owned firms make a significant contribution to the Australian economy (DFAT 2018). In terms of employment, approximately one-fifth of the workforce in the Mining (22.75%), Wholesale Trade (22.65%) and Information Media and Telecommunications (19.70%) industries were employed by foreign-owned firms. In relation to the sales of goods or services, a substantial contribution of foreign-owned groups was also evident in the Wholesale Trade and Manufacturing industries. While foreign-owned firms accounted for just 2.49% of total Wholesale Trade firms, sales generated from this group made up 43.62% of total industry sales. Similarly, 1.21% of manufacturing firms that are foreign-owned constituted 33.91% of total sales in this industry. The contribution of foreign-owned businesses in industry value added is similar to that of sales of goods or services, with the largest contribution being Wholesale Trade (42.83%), followed by Administrative and Support Services (36.91%) and Mining (33.08%). These figures reflect the economic significance and high performance of foreign-owned firms.

The literature suggests that the nature of firm ownership also has some influences on their innovation performance. Figure 3.2 depicts the proportion of innovation-active SMEs by their ownership type, i.e. (i) wholly Australian-owned and (ii) partly or wholly foreign-owned firms.

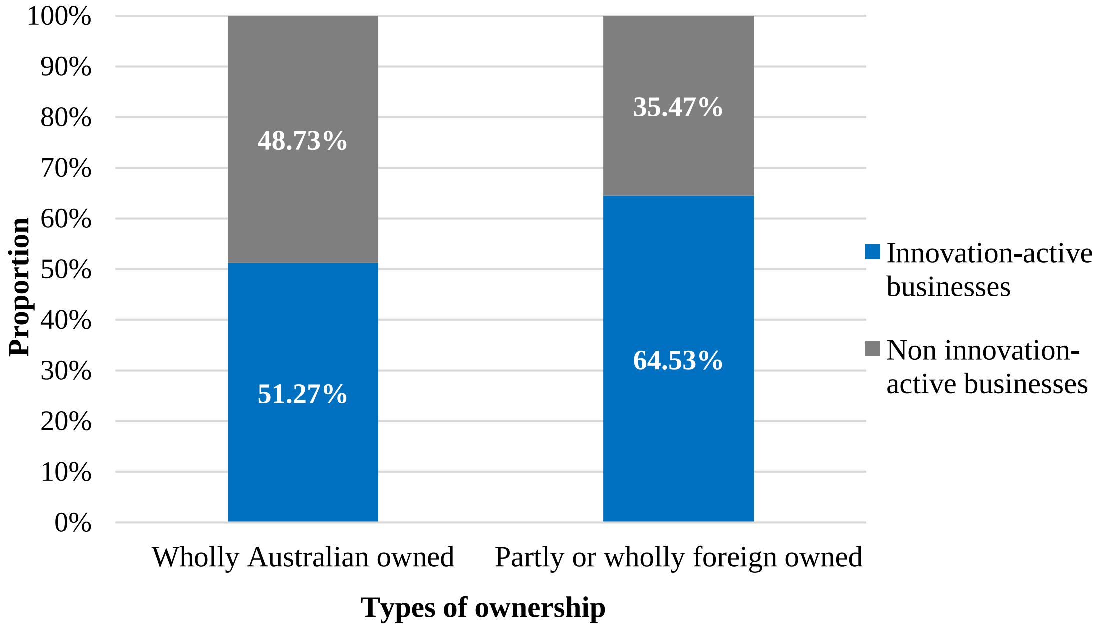

Figure 3.2: Ownership types by innovation status

Source: Business Characteristics 2011–12–2015–16 (ABS 2019f)

Figure 3.2 shows a higher proportion of innovation-active businesses in the case of SMEs with some degree of foreign ownership (64.53%), relative to those that are wholly Australian-owned (51.27%). This implies that foreign-owned firms (partly or wholly) seem more likely to innovate than those that are wholly Australian-owned, which is consistent with prior research (Corsi & Prencipe 2018; Palangkaraya et al. 2010). As reviewed in the literature, a higher rate of innovation among foreign-owned firms could be due to their specific advantages such as better access to resources, new technologies, information and international experience. Further, the transfer of knowledge and management methods from multinational corporations is also more likely enhance the innovative capacity of firms with foreign ownership (Ghazalian & Fakih, 2017; Vahter 2011).

3.3.4. Exports

In the era of globalisation, international trade is a way of increasing market share for the firms' goods and services and to gain export earnings. Australian firms are actively involved in exports. Table 3.3 provides data on value of exports from the key goods and service exporters and the corresponding share of each exporting industry.

Table 3.3: Value of exports in goods and services

Goods exporters (a)	$m	%	Service exporters (b)	$m	%
Primary Sector			***Secondary Sector***		
Agriculture, Forestry and Fishing	3,456	1.19	Manufacturing, maintenance and repair services	49	0.06
Mining	161,368	55.48	***Service Sector***		
Manufacturing Sector			Transport	7,530	8.55
Manufacturing	69,066	23.74	Travel	56,811	64.52
Service Sector			Financial and insurance services	5,127	5.82
Construction	535	0.18	Construction	726	0.82
Wholesale Trade	43,325	14.89	Telecommunications, computer, information services	4,173	4.74
Retail Trade	2,422	0.83	Cultural, recreational, personal services	1,065	1.21
Transport, Postal and Warehousing	2,961	1.02	Other business services	10,297	11.69
Other industries	7,747	2.66	***Others***		
			Government goods and services	1,131	1.28
			Charges for use of intellectual property	1,139	1.29
Total	*290,880*	*100.00*	***Total***	*88,048*	*100.00*

Source: (a) Characteristics of Australian Exporters (ABS 2018b);
(b) International Trade in Services (ABS 2018f)

Trade in goods and services make a significant contribution to the economic growth of the Australian economy. The data show that the primary sector is the most active in relation to goods exports, led by the Mining industry, which made up 55.48% of total goods exported in the year 2017–18. The secondary sector is the second most important, with goods exported by manufacturing firms accounting for nearly a quarter of the total value (23.74%). The service sector also made up a significant proportion of services exporting, with travel and transport being the dominant service export industries, together making up approximately 73% of total service exports in 2017–18.

It is suggested that firms need to innovate to succeed in the global economy (Potecea & Cebuc 2011). Firms that introduce innovative goods or services are likely to capture new markets, increase market share, improve choices and quality of products and gain a competitive advantage in the international market (Agarwal et al. 2017). The relationship between innovation and the export status of Australian SMEs is presented in Figure 3.3.

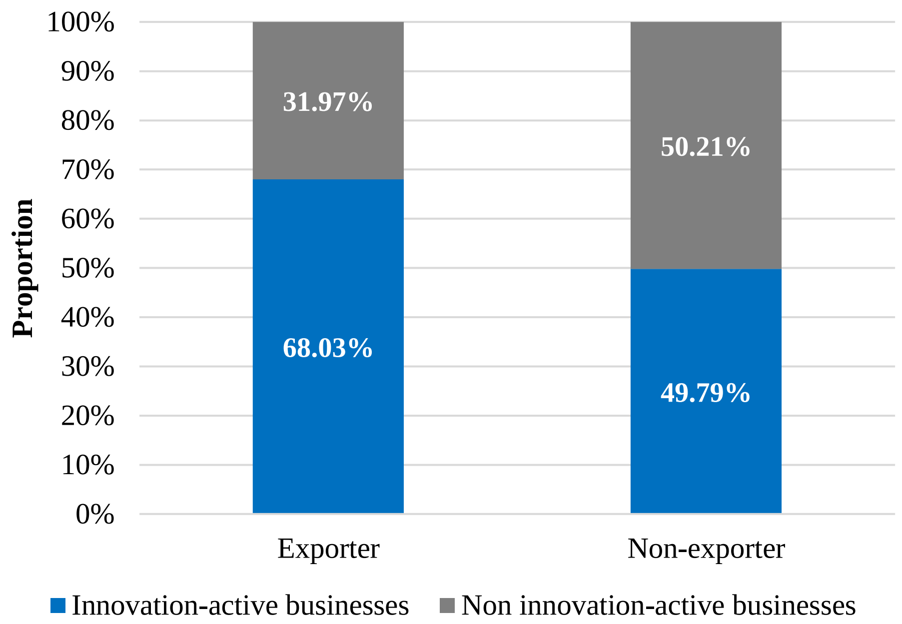

Figure 3.3: Export status by innovation status

Source: Business Characteristics Survey 2011–12–2015–16 (ABS 2019f)

As shown in Figure 3.3, most exporters are innovation-active businesses. Specifically, 68.03% of exporters conducted some form of innovative activity over the period under survey, whereas the proportion of innovative non-exporters is nearly 20% lower (49.79%). This implies that, in the Australian context, SME exporters seem more likely to innovate than non-exporters. The link between exports and innovation can be referred to the learning-by-exporting hypothesis and the international competition effect. On the one hand, exporters have advantages through better access to advanced technologies from overseas, foreign knowledge spillovers, a worldwide pool of information and higher capacity utilisation because of economies of scale (Criscuolo et al. 2010; Park et al. 2010). These advantages, together with knowledge and experience accumulated, while trading in the international markets, could enhance their innovative capability (De Fuentes et al. 2015). On the other hand, through exposure to intense international competition, exporters are urged to innovate to remain competitive over their foreign competitors (Coronado et al. 2008).

To summarise, in terms of firm characteristics, although they are a predominant component of the Australian economy, SMEs seem to be less innovative compared with large firms. The data show that the larger the firm size, the greater the proportion of firms innovating. There is a large number of innovation-active SMEs found in the early years of operation. The proportion of firms investing in innovation tends to decline over time, implying that older SMEs seem less likely to innovate. In relation to ownership, there is a higher percentage of innovation-active firms among foreign-owned SMEs compared with those that are wholly Australian-owned. In addition, SME exporters are observed to be more innovative than non-exporters.

3.4. THE STATE AND PATTERNS OF INNOVATION IN AUSTRALIAN FIRMS

3.4.1. Innovative activity

Table 3.4 presents the innovative activity undertaken by Australian firms across sectors, using the latest available innovation data. An indicator often used to measure innovation performance is the proportion of innovation-active firms (Australian Government 2017c). Evidence shows that Australia has a high proportion of innovation-active firms with 49.8% of firms conducting innovative activity and 43.8% reporting one or more innovations introduced or implemented. Approximately a quarter of Australian firms, in general, had some innovation still in development in the year being surveyed. Likewise, the abandonment rate of innovative activity averaged 7.5% in 2017–18. Inherently, innovative activity is characterised by high risk and uncertainty over its outcome (Leoncini 2016). When firms invest in an innovation project, they might not foresee all the difficulties and unwanted events that might occur or the project’s future profitability (Garcia-Vega & Lopez, 2010). Failure and abandonment of innovative activities are therefore unavoidable in the innovation process. While failures are considered a problem in a firm’s economic activity, they are also seen as motivators likely to trigger future innovation performance (Leoncini 2016; Tsinopoulos et al. 2019).

Table 3.4: Innovative activity of Australian businesses 2017–18

Industry	Businesses with any innovative activity (innovation-active businesses)	Businesses that introduced or implemented innovation	Businesses with innovative activity that was: still in development	abandoned
	%	%	%	%
Employment size				
0–4 employees	41.7	35.3	20.2	7.6
5–19 employees	60.9	55.9	32.6	7.1
20–199 employees	70.6	64.2	41.2	8.6
200 or more employees	73.6	62.6	50.1	6.2
Primary Sector				
Agriculture, Forestry and Fishing	34.7	29.6	15.1	3.9
Mining	41.0	36.2	22.3	4.9
Secondary Sector				
Manufacturing	61.7	55.0	33.7	8.8
Service Sector				
Construction	39.4	34.2	16.7	6.9
Wholesale Trade	63.8	58.7	35.1	10.1
Retail Trade	56.4	49.6	27.0	12.6
Accommodation and Food Services	57.6	48.2	25.9	9.8
Transport, Postal and Warehousing	35.9	32.1	20.6	2.8
Information Media and Telecommunications	59.9	51.3	38.1	15.0
Rental, Hiring and Real Estate Services	51.9	43.5	31.1	5.3
Professional, Scientific and Technical Services	52.5	45.9	29.8	5.6
Administrative and Support Services	42.2	36.1	25.0	7.7
Arts and Recreation Services	55.9	52.4	30.4	9.8
All industries[20]	*49.8*	*43.8*	*25.7*	*7.5*

Source: Characteristics of Australian Businesses 2017–18 (ABS 2019b)

Innovation activity occurs across all categories of firm sizes, increasing as firm size increases, with large firms exhibiting the largest rate of innovation activity (73.6%) compared with SMEs. Micro firms had the lowest proportion of firms engaging in innovation and introducing innovation in 2017–18, followed by small firms. Innovation activity also varies across Australian sectors and industries. In 2017–18, the Wholesale Trade industry, which belongs to the service sector, was the most innovative industry in Australia, with 63.8% of firms being identified as innovation-active and 58.7% reporting some form of innovation. In

[20] The figure for 'All industries' represents all the industries in the Australian economy, not just the 13 industries examined in the present thesis.

addition, several other service industries were among the more innovative industries, with more than 50% of firms being innovation-active. These included Information Media and Telecommunications, Accommodation and Food Services or Retail Trade. Nevertheless, some service industries showed low levels of innovativeness, for example, Transport, Postal and Warehousing (35.9%) and Construction services (39.4%). The secondary sector demonstrated a high level of innovativeness with 61.7% of firms undertaking innovation activity and 55% introducing innovation in 2017–18. Conversely, both industries in the primary sector scored below the national average, making this the least innovative sector in Australia. The lowest was the Agriculture, Forestry and Fishing industry, with only 34.7% of firms engaging in innovative activity and 29.6% introducing or implementing innovation.

3.4.2. Typologies of innovation

3.4.2.1. Technological innovation

Technological innovation refers to the introduction or implementation of a new or significantly improved product or operational process (OECD 2009; Radicic & Djalilov 2019). Tables 3.5 and 3.6 present the incidence and main forms of product innovation and process innovation across industry sectors. Data in Table 3.5 reveal that of the two forms of product innovation (goods and services), Australian firms tend to introduce more service innovation (15.1%) than goods innovation (11%). The dominance of service innovators is reflective of the structure of the Australian economy—a service-based economy. Of the Australian industries, Wholesale Trade is the most innovative in terms of introducing new products (36.7%). The Agriculture, Forestry and Fishing industry appears to be least innovative in introducing new products, with only 13.1% of firms reporting product innovation.

At the sectoral level, the primary sector is the least innovative of the three sectors. There are variations between the two industries in this sector in terms of their innovativeness as well as the forms of product innovation they introduce. Agriculture, Forestry and Fishing firms tend to introduce more goods innovation, but the proportion of goods innovation (6.4%) is just slightly higher than services innovation (5.2%). In contrast, Mining firms are more likely to introduce services innovation (11.6%) compared with goods innovation (5.7%). For the secondary sector, the proportion of firms introducing goods innovation (23.6%) is nearly twice that of service innovation (12.5%). This can be explained by the nature of the manufacturing industry, which produces goods. Nonetheless, due to increasing competition in both international and domestic markets, manufacturing firms increasingly offer new services associated with their products

(Santamaría et al. 2012). Service components are thus also important given their attachment to the delivery and consumption of tangible goods as well as influence on customers' satisfaction.

Table 3.5: Product innovation

Industry	Businesses that introduced product innovation	Forms of product innovation	
		New goods	New services
	%	%	%
Primary Sector			
Agriculture, Forestry and Fishing	10.5	6.4	5.2
Mining	15.4	5.7	11.6
Secondary Sector			
Manufacturing	27.8	23.6	12.5
Service Sector			
Construction	13.1	4.1	10.1
Wholesale Trade	36.7	31.9	9.3
Retail Trade	33.5	31.2	7.6
Accommodation and Food Services	23.2	15.4	12.8
Transport, Postal and Warehousing	18.5	1.9	17.9
Information Media and Telecommunications	31.0	10.5	26.2
Rental, Hiring and Real Estate Services	18.2	6.3	15.0
Professional, Scientific and Technical Services	29.1	7.9	24.4
Administrative and Support Services	17.8	4.2	16.5
Arts and Recreation Services	26.0	9.4	22.1
All industries	*22.7*	*11.0*	*15.1*

Note: Businesses may be counted in more than one category

Source: Characteristics of Australian Businesses 2017–18 (ABS 2019b)

In the service sector, the dominant type of innovation is service innovation, although a higher rate of goods innovation is evident for Wholesale Trade, Retail and Accommodation and Food Services. A large proportion of goods innovation in Wholesale Trade and Retail could be due to the core business activities undertaken in these industries, which are mainly goods-related, i.e. goods-handling and distributive trades (OECD & Eurostat 2005). In Australia, this high share of new goods reported by these two industries need to be viewed with caution given that the Oslo Manual (OECD & Eurostat 2005, p. 57) recommends that "trading of new or improved products is generally not a product innovation for the wholesaler, retail outlet". Thus, the simple resale of new goods should be excluded, which the European CIS does. However, the relevant question in BCS only asked whether the business introduced any new or significantly improved goods whose characteristics or intended uses differ significantly from those previously produced or offered by this business. Unlike the CIS, the BCS does not flag the business to exclude new goods that are simply sold onwards. This could result in a high proportion of firms in Wholesale Trade and Retail reporting goods innovation. In Accommodation and Food Services, the proportion of goods innovation (15.4%) is slightly higher than services innovation (12.8%). A possible explanation for this could be the recent design revolution of Australia's accommodation industry, with new changes and improvements in space and room design that offer hotel guests new and quality accommodation and styles, e.g. bringing nature into hotels or turning rooms into mobile offices (Tourism Accommodation Australia 2018). For food services, new ways of using and combining a variety of ingredients and flavours are likely to create new foods and drinks for customers with different preferences. The cooperation between hotels and restaurants also contributes to the creation of new packages for staying and dining (Rachão et al. 2019). The remaining industries have more services than goods innovation as their activities are mainly service-based.

The second type of technological innovation is process innovation. Process innovation aims to improve the efficiency of the production process and delivery of goods or services. As the Australian Government (2017b) indicates, process innovations typically lead to greater financial benefits from efficiency and quality improvements rather than from product innovations. As evident from Table 3.6, the process innovation leader is the manufacturing industry, with 30.7% of firms reporting process innovation in 2017–18. The least innovative one is Construction, at 13.6%. Of the main forms of process innovation, firms in the primary sector implemented new processes mainly for producing products, namely, 8.8% of Agriculture, Forestry and Fishing firms and 10.2% of Mining firms. In the secondary sector, the most popular form is also new methods of manufacturing or producing products (21.4%), followed by innovation related to supporting activities for business operations (12.7%) and finally, new logistics, delivery or distribution methods (8.1%). In the service sector, innovation in relation to supporting activities for business operations, such as maintenance systems, purchasing, accounting or computing, is the most common process innovation. The only exception is the Transport, Postal and Warehousing industry, which focuses mainly on new processes that improve logistics, delivery or distribution because these are their core activities (15.5%). The observed rate of various forms of process innovation across sectors is understandable. In the primary and secondary sectors, manufacturing and producing products is the main activity; consequently, innovations that improve the efficiency and productivity and reduce the cost of production processes are most important. In contrast, methods of manufacturing are the least popular in the service sector as most industries in this sector offer services rather than manufactured goods.

Table 3.6: Process innovation

Industry	Businesses that implemented process innovation	Forms of process innovation		
		New methods of manufacturing or producing	New logistics, delivery or distribution methods	New supporting activities for business operations
	%	%	%	%
Primary Sector				
Agriculture, Forestry and Fishing	15.7	8.8	2.9	6.5
Mining	20.6	10.2	6.6	10
Secondary Sector				
Manufacturing	30.7	21.4	8.1	12.7
Service Sector				
Construction	13.6	3.4	2.7	8.6
Wholesale Trade	26.1	11.3	11.6	13.6
Retail Trade	17.7	5.7	6.4	9.9
Accommodation and Food Services	20.7	7.4	7.5	8.6
Transport, Postal and Warehousing	21.2	1.0	15.5	9.8
Information Media, Telecommunications	26.0	7.9	6.2	18.8
Rental, Hiring, Real Estate Services	17.9	2.9	3.9	13.0
Professional, Scientific and Technical Services	21.1	6.7	5.4	14.3
Administrative and Support Services	18.0	3.8	5.0	13.2
Arts and Recreation Services	19.5	4.5	3.9	16.1
All industries	*19.4*	*6.4*	*5.7*	*11.6*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

3.4.2.2. Non-technological innovation

Non-technological innovation refers to the implementation of a new or significantly improved organisational process or marketing method (OECD 2009; Radicic & Djalilov 2019). The proportion of Australian firms implementing organisational innovation and related innovation forms is summarised in Table 3.7.

The data reveal that the service sector is the most active in implementing organisational or managerial innovation, henceforth organisational innovation. This is evident by a large proportion of organisational innovation reported by firms in this sector, led by Information Media and Telecommunications (28.5%), Rental, Hiring and Real Estate Services (28.4%) and Wholesale Trade (28.4%). In the secondary sector, 27.4% of manufacturing firms reported organisational innovation in the year under survey. As in the case of product innovation, the Agriculture, Forestry and Fishing industry is also the least innovative in terms of organisational processes (13.2%).

Of the four forms of organisational innovation, new knowledge management processes and new methods of organising work responsibilities and decision-making are the two most popular across all sectors. In the primary sector, new knowledge management processes (9.2%) is most popular in Agriculture, Forestry and Fishing, while new methods of organising work responsibilities and decision-making (13%) is most popular in Mining. In the secondary sector, most organisational innovations reported were new methods of organising work responsibilities and decision-making (16%), followed closely by new knowledge management processes (14.4%). Methods of organising external relations are the third most common form of organisational innovation in both the primary and secondary sectors. In services, there are similarly high percentages of firms reporting new knowledge management processes and new methods of organising work responsibilities and decision-making. Similarly to the other two sectors, innovation in organising external relations scores lowest in the service sector, with Accommodation and Food Services and Retail Trade reporting the smallest proportions of 2.1% and 2.7%, respectively.

Table 3.7: Organisational or managerial innovation

Industry	Businesses that implemented organisational innovation	Forms of organisational innovation			
		New knowledge management processes	New practices for organising procedures	New methods of organising work responsibilities and decision-making	New methods of organising external relations
	%	%	%	%	%
Primary Sector					
Agriculture, Forestry and Fishing	13.2	9.2	4.4	4.2	2.8
Mining	21.6	10.3	9.3	13.0	6.1
Secondary Sector					
Manufacturing	27.4	14.4	11.5	16.0	5.6
Service Sector					
Construction	20.4	10.6	7.7	10.3	7.1
Wholesale Trade	28.4	17.4	14.0	16.0	7.2
Retail Trade	21.6	12.1	8.0	14.5	2.7
Accommodation and Food Services	17.2	7.2	4.7	10.5	2.1
Transport, Postal and Warehousing	19.9	11.0	10.3	11.1	4.2
Information Media and Telecommunications	28.5	18.6	10.5	19.0	7.4
Rental, Hiring and Real Estate Services	28.4	18.8	7.1	13.8	5.9
Professional, Scientific, Technical Services	25.0	15.1	7.9	14.5	5.3
Administrative and Support Services	20.1	12.1	7.0	11.4	5.3
Arts and Recreation Services	26.0	16.8	8.4	16.2	6.0
All industries	*23.2*	*13.5*	*8.1*	*13.4*	*5.2*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

In a highly competitive marketplace, marketing innovation plays an important role in business success. Tables 3.8 demonstrates the proportion of Australian firms reporting various forms of marketing innovation. Of the three sectors, the service sector appears to be the most innovative in marketing, while the primary sector is the least. A quarter of manufacturing firms implemented some form of marketing innovation over the period surveyed. From an industry-specific perspective, the most innovative industries in marketing are Accommodation and Food Services (32%) and Arts and Recreation Services (30%).

Among different forms of marketing innovation, new marketing techniques or media for product promotion are most popular across all Australian industries. Australian firms are facing increasing competition in both international and local markets. The high proportion of marketing innovation, particularly in using media or techniques for product promotion, emphasises the important role of marketing initiatives in driving product demand and responding to advertisements from domestic and global competitors. Thus, higher frequency of innovation in new techniques and media for product promotion over other forms of marketing innovation is empirically expected. The highest proportion of firms reporting new methods of (i) product placement or sales channels is observed in Retail Trade (8.6%), while (ii) design or packaging and (iii) pricing goods or services is in Wholesale Trade at 7.3% and 9.2%, respectively. The remaining innovative marketing forms account for very small percentages.

To conclude, the rates of innovation activity and innovation types of Australian firms vary from sector to sector. The service sector has the representatives of the most innovative industry in product innovation (Wholesale Trade), organisational innovation (Information Media and Telecommunications) and marketing innovation (Accommodation and Food Services), whereas the secondary sector is the most innovative in terms of process innovation (Manufacturing). This leaves the primary sector as the least innovative in the Australian economy, in all types of innovation. Nonetheless, there are variations between industries within the service sector as well as primary sector. In the service sector, while the Wholesale Trade and Information Media and Telecommunications industries have high performance in all types of innovation, some other industries show opposite trends. For example, Transport, Postal and Warehousing and Construction reported much lower proportions in product and marketing innovation, while Accommodation and Food Services had the lowest proportion of organisational innovation. Similarly to the observed innovative activity, Mining also outperforms Agriculture, Forestry and Fishing industry across all innovation types.

Table 3.8: Marketing innovation

Industry	Businesses that implemented marketing innovation	Forms of marketing innovation			
		New changes to the aesthetic design or packaging	New media or techniques for product promotion	New methods of product placement or sales channels	New methods of pricing goods/ services
	%	%	%	%	%
Primary Sector					
Agriculture, Forestry and Fishing	8.6	2.3	5.1	3.1	1.3
Mining	11.8	3.2	8.0	4.0	3.0
Manufacturing Sector					
Manufacturing	25.3	6.4	18.3	6.0	6.7
Service Sector					
Construction	12.8	2.2	9.9	1.4	1.4
Wholesale Trade	29.6	7.3	19.8	8.2	9.2
Retail Trade	27.0	4.1	21.4	8.6	6.5
Accommodation and Food Services	32.0	2.5	27.0	5.1	5.0
Transport, Postal and Warehousing	10.2	1.5	6.4	1.2	3.6
Information Media, Telecommunications	28.6	6.6	22.7	7.1	8.0
Rental, Hiring and Real Estate Services	25.8	6.6	20.6	3.0	4.1
Professional, Scientific, Technical Services	17.9	5.5	13.4	4.6	4.0
Administrative and Support Services	18.4	5.2	13.7	3.1	5.0
Arts and Recreation Services	30.0	4.5	25.1	4.9	5.4
All industries	*20.7*	*4.1*	*16.2*	*4.1*	*4.2*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

3.4.3. Innovation novelty

Innovation novelty refers to the degree of newness and originality of an innovation. At a minimum, 'an innovation must be new to the business' (Australian Government 2016, p 42). The four degrees of novelty, ranging from the lowest to the highest, are (i) new to the business, (ii) new to the industry, (iii) new to the country and (iv) new to the world. Degrees of the novelty of innovations introduced by Australian firms in 2016–17 are depicted in Figure 3.4.

The majority of Australian firms introduced innovations which are *new to the business* only, i.e. more than 90% with organisational and marketing innovation, 87% and 74% with process and product innovation respectively. In relation to *new to the industry*, the proportion of firms introducing product innovations at this degree of novelty is 13%. The corresponding proportions for process, organisational and marking innovation are 8%, 7% and 5% respectively. In addition, 7% of surveyed firms introduced product innovations which are *new to the world*. However, only around 2% of firms reported *new to the world* process and marketing innovation, and just 0.7% implemented organisational innovations at this highest degree of novelty in 2016–17.

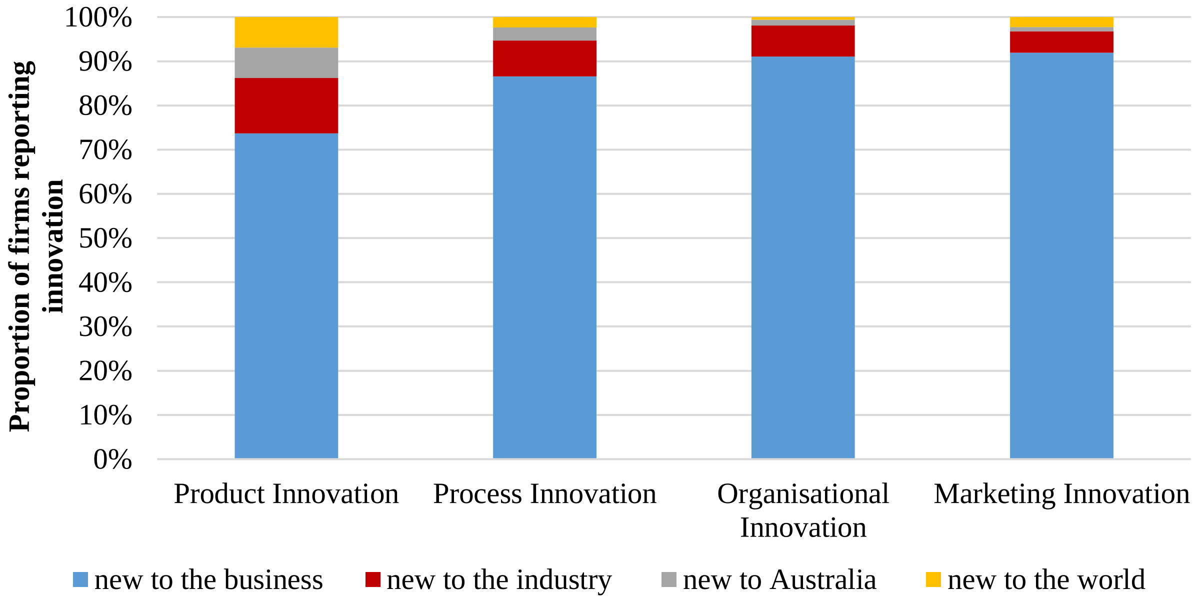

Figure 3.4: Degree of novelty by innovation type

Source: Innovation in Australian Business 2016–17 (2018e)

It has been observed that most Australian firms tend to be domestic modifiers, which has been the case since 2008–09 (Australian Government 2017c). This is a strategy in which Australian firms search for existing innovations that have already been introduced by other Australian or foreign firms. These are then absorbed and modified and eventually commercially deployed onto the market. Domestic modification is reflective of a low degree of innovation novelty; therefore, it is less valuable and has less economic impact (Australian Government 2017c). The relatively low degree of novelty of innovations introduced by Australian firms is likely to affect Australia's international competitiveness. According to the 2018–19 Global Innovation Index, Australia is ranked in the bottom half of OECD countries in terms of innovation output (WIPO 2018, 2019). To enhance Australia's innovation performance by international standards, Australian firms should put more effort into developing innovations with higher degrees of novelty, such as new to the world or new to the country. These types of innovation involve a higher degree of competence, sophistication and knowledge, which would lead to greater economic impacts for the innovating firms as well as the Australian economy.

3.4.4. Patterns of innovation

Figure 3.5 illustrates the proportion of Australian firms reporting innovation over a ten-year period from 2008–09 to 2017–18, separately for each type of innovation[21]. The main aim is to identify if there exists a possible pattern of innovation in the Australian economy.

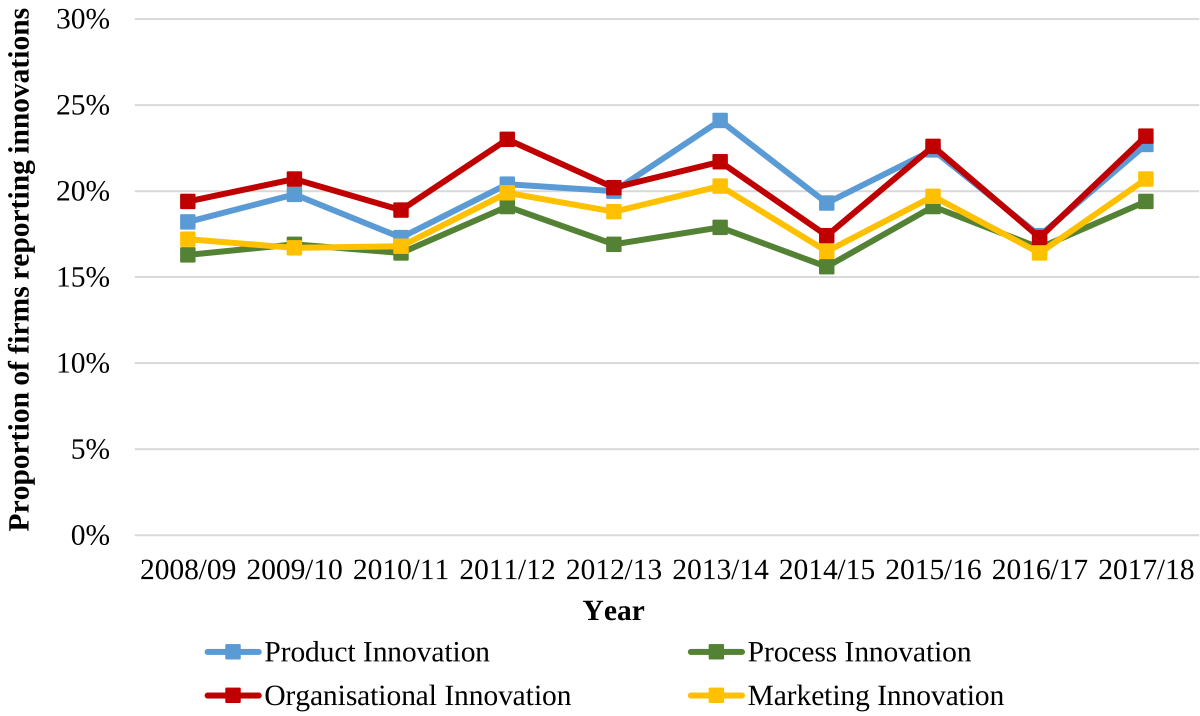

Figure 3.5: Pattern of innovation

Source: Innovation in Australian Businesses 2010–2018 (ABS 2012-19)

[21] The core questions of innovation activities are asked every year in the BCS.

In general, the occurrence of various innovation types varied over the period under examination. From Figure 3.5, it is observed that the proportion of firms reporting innovation has a cyclical pattern over time. The number of innovations increased at the start of the period, then decreased in the following year and increased again in the year after, with the proportionate changes between years being 4% or less. This is apparently the case for all four types of innovation. It is also worth noting that these innovation rates did not show an upward tendency over the 10-year period rather than cyclical fluctuations between 16% and 24%.

Of the four types, the proportion of Australian firms implementing organisational innovation was the highest in the period 2008–09 to 2012–13, while product innovation was the most common from 2012–13 to 2014–15. Since 2014–15, organisational and product innovations shared similar rates. The figure indicates that Australian firms largely concentrated their innovative efforts on organisational and product innovations. Innovation in processes turns out to be the least popular among the four types of innovation over the 10-year period, except for 2016–17, with the proportion of firms reporting process innovation (16.70%) being somewhat higher than marketing innovation (16.40%).

The observed cyclical pattern of innovation in Australia is consistent with empirical studies in the US, UK and G7 countries (e.g. Barlevy 2007; Comin & Gertler 2006; Francois & Lloyd-Ellis 2009; Mand 2019). A consensus from their work is that total innovation expenditure is procyclical. On theoretical grounds, this could be supported, particularly by business cycle and demand-pull theories. There is a proposition that the economic cycles are generated by recurring innovation. The disproportionate and recurrent fluctuations in the rate of innovation and their usage intensities cause business cycles (Kuznets 1940; Schumpeter 1939). Geroski and Walters (1995), examining innovative activity over the business cycle, demonstrate that major innovations and patents have cyclical patterns. However, they also assert that variations in economic activity and demand are the cause of fluctuations in innovation activity. Mand (2019) indicates that the shocks to productivity and government spending cause fluctuations in the business cycle. Business cycle fluctuations result in cyclical R&D activities, which in turn affect productivity growth. Therefore, the economy's productivity is procyclical due to its interrelation with R&D activities (Francois & Lloyd-Ellis 2009). From a demand-pull perspective, the ability that a certain market is able to absorb new products is rather limited at a given time (Judd 1985). Inevitably, a new product entering the market has to compete with numerous existing products, then imitative products. Given the same consumer base in a short period, an increasing number of new products is likely to result in a reduction in profitability for each firm. A flurry of innovation is often observed after its introduction into the market because of the effect of diminishing returns as a source of value, which then causes a rise in the equilibrium unit cost of innovation (Francois & Lloyd-Ellis 2009). Consequently, the incentive to invest in innovative activity will decline as will the flow of innovation to the market (Francois & Lloyd-Ellis 2009; Geroski & Walters 1995). However, the resumption of innovation will then occur when economic growth, caused by innovation and productivity booms, leads to demand expansion, which in turn stimulates firms to invest in new innovations (Mand 2019). This creates a recurring pattern of innovation activity over time.

The literature further indicates that there exist possible associations between different types of innovation. To shed further light on this issue, the following figure presents the incidence of different combinations of innovation occurring during the period 2011–12 to 2015–16.

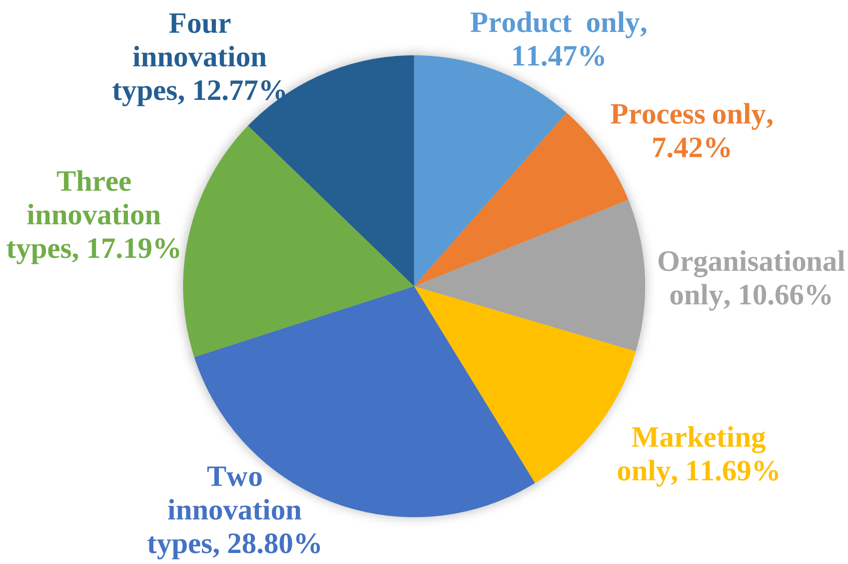

Figure 3.6: Proportion of firms reporting one or more types of innovation

Source: Derived from Microdata: Business Characteristics 201/12 to 2015–16 (ABS 2019f)

Among the innovators, an estimated 41.24% of firms introduced one type of innovation only, whereas 58.76% of firms reported two or more types of innovation. The proportion of innovators that reported two types and three types of innovation are 28.80% and 17.19%, respectively. At the highest level of innovation diversity, 12.77% of Australian innovators introduced all four types of innovation. The results imply that innovative activity in one field tends to involve innovative activity in other fields of business. As discussed in Chapter Two, the introduction of new products may cause the development of new processes or require the establishment of new sales divisions and reorganisation of workflows and responsibilities, or new ways of marketing. Further, the implementation of new processes or technologies in production or distribution may require the reorganisation in business routines or affect the quality of products (Schmidt & Rammer 2007; Tavassoli & Karlsson 2015).

3.4.5. Innovation persistence

Peters (2009) proposes that there might exist a persistence in innovative activities that reflects a firm's continuation of the innovative investments from the previous period to the current period. It has been observed that the positive impact of innovation becomes stronger when firms innovate more frequently (Australian Government 2016). An approximation of persistence over the period 2011–12 to 2015–16 can be obtained from the transition probabilities analysis. Table 3.9 illustrates the probabilities of being innovation-active to past results.

Table 3.9: Transition probabilities

Previous period \ Current period	Non-innovator (%)	Innovator (%)	Total (%)
Non-innovator	75.75	24.25	100.00
Innovator	24.92	75.08	100.00
Total	48.67	51.33	100.00

Source: Derived from Microdata: Business Characteristics (ABS 2019f)

There is a high proportion of SMEs remaining innovation-active over the years. The results show that 75.08% of innovators in the current period continue to invest in innovation activity in the next year. From a theoretical perspective, this could be linked to the past innovation experience or the effect of Arrow's (1962) 'learning-by-doing' and the cumulative and incremental nature of innovation and the development of dynamic capabilities. Firms that generate new knowledge are more likely to generate new additional knowledge at less cost (David 1993). In line with the 'success breeds success' hypothesis, the resources that successful innovators have accumulated over time enhance their innovation capability and motivate them to undertake further innovations in subsequent periods (Cefis & Ciccarelli 2005). Investing in innovative activities requires upfront sunk costs for the establishment of research infrastructure and other long-term investment commitments (Sutton 1991). For firms that have already innovated, they either do not bear set-up costs again or they pay less sunk costs associated with innovative activities due to the availability and readiness of established facilities and internal capabilities (Antonelli et al. 2013; Mañez et al. 2009). This encourages innovative firms to make further innovative investment. The persistence of innovative activity found in the Australian case is consistent with empirical studies in Italy (Antonelli et al. 2012; Bartoloni & Baussola 2018) and Germany (Ganter & Hecker 2013; Peters 2009).

3.5. INPUTS FOR INNOVATION

3.5.1. Human capital

The stock of human capital—knowledge, skills and expertise embedded in the workforce—is decisive in firms' innovation capability (McGuirk et al. 2015). The key provider of knowledge and skills is the education system. Figure 3.7 illustrates the different levels of educational attainment of Australia's workforce across industries.

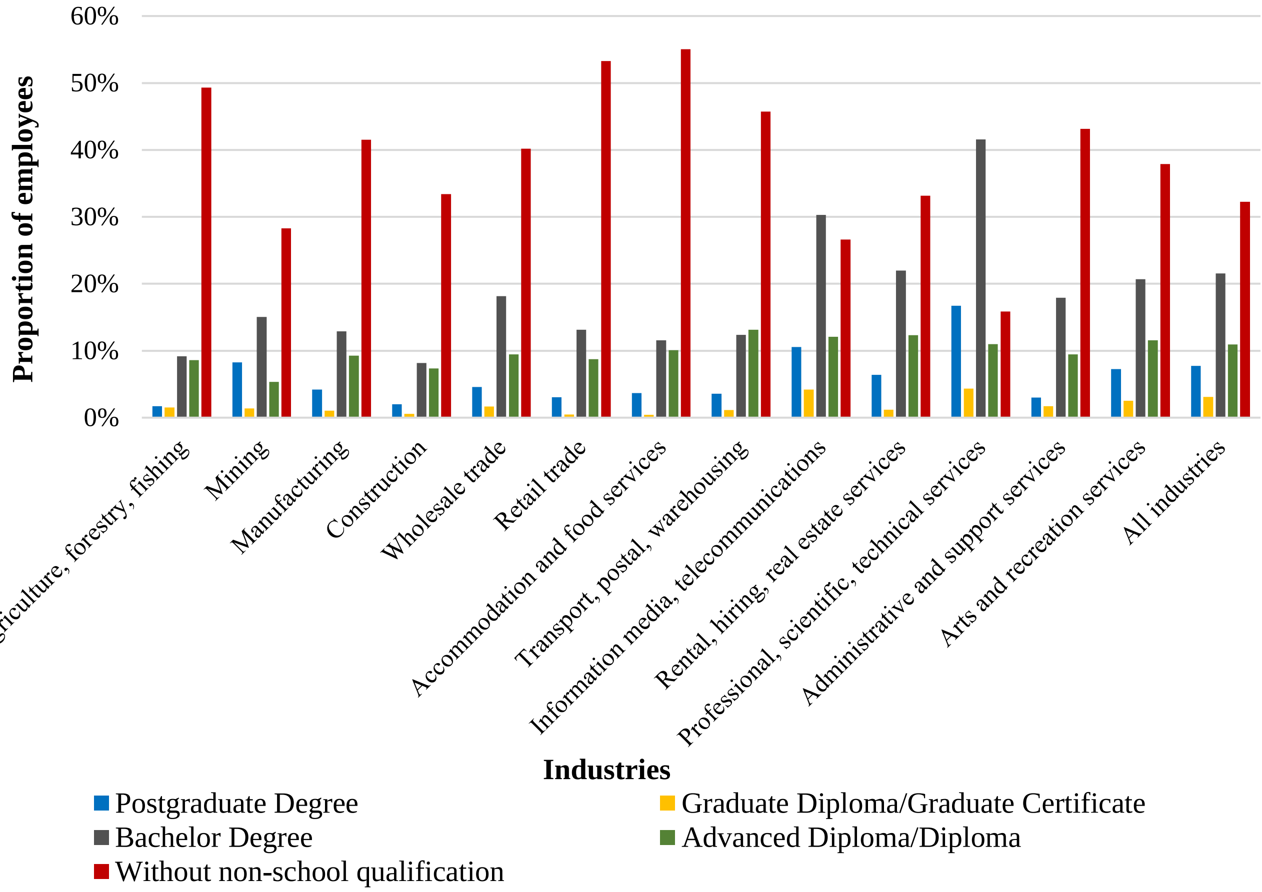

Figure 3.7: Levels of educational attainment

Source: Education and Work, Australia (ABS 2018d)

Overall, most Australians are highly educated, with the proportion of the adult population (aged 25 to 64) having a non-school qualification[22] at 67.74%. An estimated 32.37% of the population has a bachelor's degree or higher, 7.75% of those hold postgraduate degrees and 3.10% have a graduate diploma/graduate certificate.[23] Levels of educational attainment vary considerably across economic sectors as well as within each sector. The largest proportion of employees holding a bachelor's degree or higher is Professional, Scientific and Technical services at 62.62%. The proportions of employees with at least a bachelor's degree in the primary and secondary sectors are lower than the national average. The non-school education system provides workers in-depth knowledge in the field as well as specific technical and business skills, which is a means of enhancing human capital (ISA 2016). Nonetheless, some industries exhibit a relatively low level of educational attainment, e.g. Accommodation and Food Services and Retail Trade, with more than half of the total employees not holding non-school qualifications. This is reflective of the role of these industries as a flexible entry point into the labour market for school leavers, students and part-time workers.

A group of skilled workers crucial for innovation development is R&D personnel.[24] Table 3.10 provides data on business human resources devoted to R&D, as a reference to employment size. In general, human resources devoted to R&D vary not only among the three economic sectors but also within the sector. The largest contributor to total human resources devoted to R&D is the Professional, Scientific and Technical Services industry, at 21,364 person-years of effort (PYE), followed by Manufacturing. In the primary sector, while Mining firms devoted 3,667 PYE to R&D, the figure for Agriculture, Forestry and Fishing firms is just 816 PYE. Of the industries, Accommodation and Food Services is the one with the lowest effort for R&D. The low effort is also found in Arts and Recreation, Transport, Postal and Warehousing and Rental, Hiring and Real Estate Services, implying that R&D seems to be of less concern in these industries. Medium and large firms are the main contributors to R&D. As firm size increases, human resources devoted to R&D also progressively increase in Mining, Manufacturing, Construction, Wholesale Trade, Information Media and Telecommunications and Administrative and Support Services.

[22] Non-school qualifications are educational attainments beyond secondary education (After Year 12).

[23] Levels of educational attainment considered in this study are level 5 and higher based on the Australian Qualifications Framework; levels 1 to 4 are excluded.

[24] R&D personnel include 'all persons engaged directly in R&D, whether employed by the statistical unit or external contributors fully integrated into the statistical unit's R&D activities, as well as those providing direct services for the R&D activities' (OECD 2015a, p. 151).

Table 3.10: Business human resources devoted to R&D

Industries	Employment size				
	0–4 employees	5–19 employees	20–199 employees	200 + employees	Total
	PYE	PYE	PYE	PYE	PYE
Primary Sector					
Agriculture, Forestry and Fishing	88	82	459	187	816
Mining	134	485	591	2,457	3,667
Secondary Sector					
Manufacturing	369	1,593	4,161	8,235	14,358
Service Sector					
Construction	62	314	654	854	1,884
Wholesale Trade	133	825	1,958	1,323	4,240
Retail Trade	73	368	475	247	1,164
Accommodation and Food Services	2	62	71	45	180
Transport, Postal and Warehousing	n/a	n/a	130	354	542
Information Media, Telecommunications	384	483	823	1,259	2,950
Rental, Hiring and Real Estate Services	107	292	203	151	753
Professional, Scientific, Technical Services	1,683	4,874	9,418	5,389	21,364
Administrative and Support Services	90	212	544	634	1,480
Arts and Recreation Services	7	39	112	320	477

Note: n/a: Not available for publication, but included in total where applicable; PYE: person-years of effort

Source: Research and Experimental Development, Businesses, Australia, 2015–16 (ABS 2017b)

3.5.2. Innovation expenditure

In the innovation process, a range of expenditure is incurred for developing, testing and implementing innovation. Among the various types of expenditure, R&D is often the first to be mentioned. There are two main types of R&D expenditure: (i) intramural (in-house) and (ii) extramural (contracting out to or acquiring from other firms or research organisations). Recent research by the ISA (2020) shows that at the national level, only 5.8% of Australian firms reported R&D investment. Table 3.11 presents the proportion of firms that invested in R&D and key forms of R&D expenditure undertaken by Australian firms for innovation purposes. Data show that of Australian innovation-active firms, only 13% reported some forms of R&D over the 2016–17 financial year (ABS 2018e). At the industry level, those with the largest proportion of firms investing in R&D are Professional, Scientific and Technical Services, Mining and Wholesale Trade. For the remaining industries, there is a relatively very small percentage engaging in R&D, with the lowest being Construction (4.9%) and Administrative and Support Services (7.3%). With regards to forms of R&D, Australian firms tend to perform more intramural rather than extramural R&D, except for Transport, Postal and Warehousing firms.

Performing R&D is not sufficient, and it is not the only method of innovating (Arundel et al. 2008; Mohnen & Hall 2013). In Australia, 87% of firms did not conduct any intramural or extramural R&D activities for innovation purposes in the year under survey. Meanwhile, the contemporary literature highlights the growing role of non-R&D[25] activities as a driving force behind numerous successful innovations (Trigo 2013). As emphasised by the ISA (2020, p. 6), 'attention must be given to non-R&D innovation to obtain a holistic view of how Australian businesses innovate today'. There is a range of non-R&D activities firms undertake to pursue innovation such as (i) acquisition of machinery, equipment, technology and software, (ii) reorganisation of existing business models, work practices, decision-making processes, (iii) training, (iv) marketing activities, (v) design, planning and testing of products or processes, (vi) acquisition of licences or patents and (vii) costs for labour. The set of innovation activities might vary considerably, depending on the nature and technological level of the firm's activity, the degree of customer involvement and the intensity of human capital participation during the

[25] Non-R&D innovation as innovation activities that do not stem from a scientific method or involve R&D.

innovation process (Trigo 2013). Table 4.14 presents main types of non-R&D expenditure spent by Australian firms for developing and introducing innovations.

Table 3.11: R&D expenditure for developing or introducing innovation

Industry	Proportion of firms with R&D expenditure	Forms of R&D (% of firms)	
		Intramural	Extramural
Primary Sector			
Agriculture, Forestry and Fishing	11.3	10.1	5.4
Mining	21.1	17.3	6.8
Secondary Sector			
Manufacturing	19.6	18.0	4.1
Service Sector			
Construction	4.9	4.7	1.5
Wholesale Trade	20.6	15.9	11.8
Retail Trade	12.3	10.8	5.6
Accommodation and Food Services	14.5	12.9	8.3
Transport, Postal and Warehousing	10.2	5.7	7.3
Information Media and Telecommunications	19.1	17.5	5.6
Rental, Hiring and Real Estate Services	15.0	12.5	11.0
Professional, Scientific, Technical Services	22.0	18.5	10.2
Administrative and Support Services	7.3	7.3	4.9
Arts and Recreation Services	15.5	14.6	7.2
All industries	*13.0*	*11.1*	*6.1*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

Of the various types of non-R&D expenditure, acquisition of machinery, equipment or technology is the category with the largest percentage of investment by Australian firms across all industries, except for Accommodation and Food Services. As shown in Table 3.12, Agriculture, Forestry and Fishing (58.1%), Rental, Hiring and Real Estate Services (54.9%) and Administrative and Support Services (52.5%) firms invest heavily in machinery, equipment and technology for innovation purposes. The Accommodation and Food Services industry allocated its expenditure mostly to marketing activities (46.3%), then acquisition of machinery, equipment or technology (45.5%). Some other industries, also with high proportions of firms investing in marketing, are Wholesale Trade (43.4%) and Rental, Hiring and Real Estate Services (41.6%). Such large investment emphasises the important role of marketing in innovation development and implementation. Indeed, market research is essential to understand customer demand and preferences for goods or services. Further, advertising or marketing campaigns are also decisive in the successful introduction of new goods or services to customers.

Table 3.12: Non-R&D expenditure for innovation purposes (% of firms)

Industry	Acquisition of machinery, equipment or technology	Reorganisation of existing business models, work practices, decision-making processes	Training	Marketing activities	Design, planning and testing	Acquisition of licences, rights or patents	Other labour costs	Other activities
Primary Sector								
Agriculture, Forestry and Fishing	58.1	21.7	20.4	12.0	7.2	3.9	28.6	7.7
Mining	39.2	21.9	26.8	20.4	20.6	9.7	30.0	3.4
Secondary Sector								
Manufacturing	46.4	30.3	25.0	30.9	25.9	3.4	31.6	2.8
Service Sector								
Construction	46.2	31.2	27.9	24.0	7.9	10.6	17.7	3.1
Wholesale Trade	43.9	31.0	28.1	43.4	29.6	12.5	36.0	2.9
Retail Trade	34.2	24.0	26.7	33.1	18.7	9.2	30.8	3.1
Accommodation and Food Services	45.5	32.8	26.1	46.3	23.7	10.6	23.0	3.9
Transport, Postal and Warehousing	38.3	33.9	31.7	18.9	12.2	10.9	18.6	2.3
Information Media and Telecommunications	40.8	29.0	25.0	33.4	23.3	9.9	31.0	2.9
Rental, Hiring and Real Estate Services	54.9	39.2	49.7	41.6	22.1	13.6	22.9	n/a
Professional, Scientific and Technical Services	38.9	30.5	38.4	29.7	29.4	9.1	32.3	3.9
Administrative and Support Services	52.5	37.5	38.6	31.7	13.9	5.6	38.1	2.9
Arts and Recreation Services	48.1	33.4	28.1	37.4	21.7	13.8	30.0	3.5
All industries	*43.4*	*30.6*	*31.9*	*31.8*	*18.0*	*9.7*	*27.1*	*3.8*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

In addition to marketing activities, the success of innovation, especially in services, also depends on the training of workers who produce the goods or services (Mohnen & Hall 2013). Of the industries, Rental, Hiring and Real Estate Services has the largest proportion of firms (49.7%) investing in training for the development or introduction of innovation, followed by Administrative and Support Services (38.6%) and Professional, Scientific and Technical Services (38.4%). In services, employees are those who deliver the service to customers and also interact with customers the most. Training is crucial to update and renew workforce capabilities and enhance human capital. It also assists employees to understand and become familiar with new products or processes and effectively deliver them in the marketplace. A high-quality workforce is important for innovation development and implementation. Two other non-R&D expenditures popular in Australia are (i) reorganisation of existing business models, work practices, decision-making processes (30.6% on average) and (ii) labour costs (27.1% on average). Design, planning and testing are also common for Wholesale Trade (29.9% and Professional, Scientific and Technical Services (29.4%). There is a relatively low proportion of non-R&D expenditure for the acquisition of licences, rights, patents or other IP.

To summarise, available evidence shows that non-R&D activities are the most popular type of innovation expenditure by Australian firms (87%). This highlights the important role of non-R&D activities in innovation in general, and in a service-based and small business economy in particular. As discussed in Chapter Two, many service firms do not have an R&D department and often innovate on a more informal basis outside the R&D lab (Toivonen & Tuominen 2009). In addition, 99.8% of Australian firms are SMEs; the vast majority of SMEs do not undertake R&D (Hervas-Oliver et al. 2016). Instead, their innovation process involves various non-R&D activities. Of the various non-R&D categories, a significant proportion of firms across all sectors invests heavily in machinery, equipment and technology. Most firms also devote their effort to marketing activities, employee training and reorganisation of existing business models, work practices and decision-making processes.

3.5.3. Collaboration for innovation

The literature indicates the important role of collaboration in innovation development and implementation. Figure 3.8 depicts the proportion of Australian firms engaging in collaboration for innovation. On average, only 17% of Australian firms collaborated for innovation purposes in the year 2017–18. Of these, the Information Media and Telecommunications industry is the most collaborative at 30.1%, followed by Mining, Administrative and Support Services and

Arts and Recreation Services at 26.4%, 25.5% and 25.4%, respectively. The industries with the lowest percentage of firms engaging in collaboration are Accommodation and Food Services (10.5%), Construction (13.5%) and Rental, Hiring and Real Estate Services (13.8%).

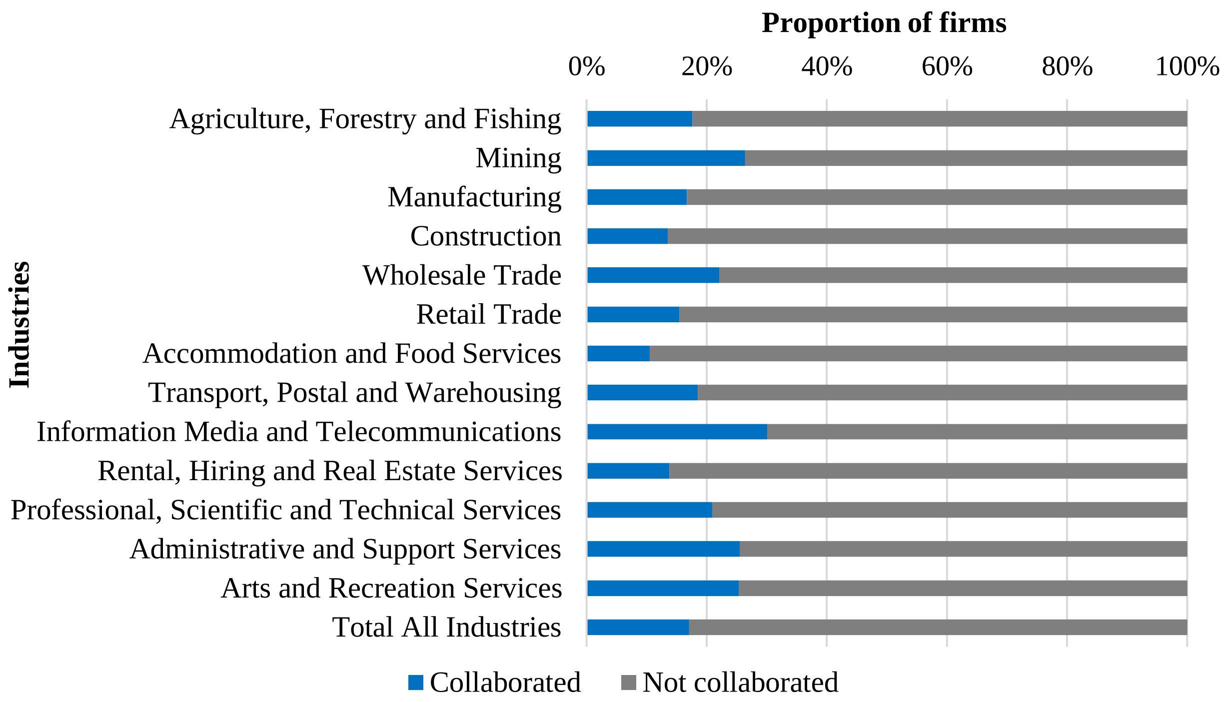

Figure 3.8: Collaboration for innovation purposes, all firms

Source: Innovation in Australian Businesses 2017–18 (ABS 2019e)

The majority of Australian firms (83%) did not engage in collaboration for innovation, indicating 'a weakly networked innovation system' in Australia (Australian Government 2016, p. 59). It also explains the poor ranking of Australia against other OECD countries in most collaboration indicators.[26] Previous research has shown that collaboration enables firms to access resources, share knowledge and experience, minimise risk and maximise innovation performance. Nonetheless, the low degree of collaboration is an indication that Australian firms have undervalued the role and benefits that collaboration could bring to their business, especially for SMEs with limited resources (Australian Government 2017c).

[26] It should be noted that an issue with the international comparisons is that the Australian data has a single reference year while most OECD countries employ a three year reference period (ABS 2017a). The longer reference period is more likely to increase the likelihood that a business collaborates for innovation. Thus, international comparisons on this variable need to be treated with caution.

Table 3.13 presents the common types of organisation to which Australian firms collaborate with. For those firms that engage in collaboration, their main collaboration partners are customers and suppliers. Collaborating with customers is most popular for Transport, Postal, Warehousing and Administrative and Support Services. Firms in Retail and Accommodation and Food Services collaborate mostly with their suppliers, probably due to their business operations depending largely on the supply of materials, goods or equipment. Collaboration with competitors is highest among Accommodation and Food Services firms. Besides customers and suppliers, collaboration-active firms in Agriculture, Forestry and Fishing, Arts and Recreation, Accommodation and Food and Rental, Hiring and Real Estate Services prefer to collaborate with consultants.

By international standards, Australia ranks poorly in both (i) business to business collaboration and (ii) business to research collaboration (Australian Government 2017c). Rauter et al. (2018) advocate that expert knowledge from universities and research institutions is a valuable resource that businesses could exploit to trigger innovation and to strengthen their innovation performance. Collaboration with universities via contract research or consulting projects helps businesses advance their scientific understanding and access to technologies, which is likely to result in radical inventions or higher quality inventions (Walsh et al. 2016). Nonetheless, evidence shows that universities and research institutions are the least preferred collaboration partner for Australian firms. Except for Arts and Recreation Services and Mining, other industries hardly have any collaboration with the research sector.

In the Australian case, firms that collaborated with universities or research institutions such as the Commonwealth Scientific and Industrial Research Organisation (CSIRO) have experienced increases in annual productivity and other performance measures (Australian Government 2016). The weak connection between the business sector and the research sector is an indication that Australia is missing out on the benefits of such collaboration. Although encouraging signs of collaboration between Australia's research base and industry have begun to emerge, these are coming from a low base; thus, much more needs to be done (DIIS 2018b). The poor performance and low ranking of Australia across a range of collaboration metrics, compared with its OECD counterparts, suggests that collaboration is an important aspect of the innovation system that needs to be improved across all sectors of the Australian economy.

Table 3.13: Collaboration within Australia, by type of organisation collaborated with (% of firms)

Industry	Another business owned by the same company	Clients	Suppliers	Competitors	Consultants	Universities/ higher education institutions	Research institutions			Government agencies
							Private non-profit	Government/ public	Commercial	
Primary Sector										
Agriculture, Forestry and Fishing	16.2	11.8	23.7	19.9	46.3	8.4	n/a	0.0	n/a	n/a
Mining	20.3	28.4	39.5	23.0	36.2	16.5	n/a	n/a	8.3	0.0*
Manufacturing Sector										
Manufacturing	24.2	47.0	33.7	13.6	18.9	3.7	0.2	3.1	0.1	6.4
Service Sector										
Construction	43.3	40.0	36.5	8.1	25.8	0.0*	n/a	0.0*	n/a	n/a
Wholesale Trade	30.6	38.3	45.0	23.6	10.2	3.3	0.0*	0.0*	3.4	9.7
Retail Trade	30.0	39.2	65.8	11.0	25.1	0.0*	0.0*	0.0*	n/a	0.0
Accommodation and Food Services	25.4	24.5	56.6	56.9	41.4	0.0*	n/a	n/a	n/a	n/a
Transport, Postal and Warehousing	25.4	53.8	21.8	30.8	5.6	n/a	0.0*	0.0*	0.0*	17.8
Information Media, Telecommunications	18.8	43.4	34.4	20.0	36.1	3.4	n/a	n/a	n/a	2.1
Rental, Hiring and Real Estate Services	23.0	45.0	46.9	23.1	41.0	0.0*	n/a	0.0*	n/a	13.3
Professional, Scientific and Technical Services	18.0	31.5	19.3	26.2	34.0	5.5	2.8	0.0*	n/a	n/a
Administrative and Support Services	23.8	52.4	29.6	35.4	29.3	n/a	0.0*	0.0*	n/a	0.0*
Arts and Recreation Services	20.9	37.4	37.4	34.5	44.0	13.6	n/a	10.2	n/a	13.7
All industries	*25.1*	*36.5*	*35.5*	*23.5*	*30.7*	*4.8*	*3.7*	*1.7*	*2.9*	*4.9*

*Note: Businesses may be counted in more than one category, n/a: not available for publication but included in totals where applicable, *: nil or rounded to zero (including null cells)*

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

3.5.4. Business use of information and communication technology

The development of ICT, or Information Technology (IT), has significantly influenced various business aspects such as operations, management, internal and external communication and marketing (OECD 2017b). ICT helps reduce operational costs and enhances process efficiency (Toivonen & Tuominen 2009); it also facilitates coordination and communication without geographical constraints (Arvanitis & Loukis 2015; OECD 2017b). A strong and advanced ICT platform is therefore crucial for innovation. Table 3.14 shows the proportion of Australian businesses that adopted IT in 2017–18 by firm size and by industry. There are five basic forms of IT adoption, including Internet access, web presence, social media presence, Internet ordering and Internet receiving.[27]

As can be seen in Table 3.14, the proportion of Australian firms with Internet access—the most basic form of IT adoption—is relatively similar among the four firm sizes. However, there is a lower proportion of SMEs with a web presence, social media presence, Internet ordering and receiving compared with large firms. The pattern observed is that the smaller the firm size, the lower the number of firms adopting these types of IT applications. The largest differences are found between firms with 0 to 4 employees and large firms. For example, just 44.1% of the former had a web presence in comparison with 95.8% of the latter in 2017–18. The proportion of firms with 0 to 4 employees (35.4%) having social media is less than half of large firms (85.7%). This pattern in general indicates a low level of IT adoption by smaller firms.

[27] Adoption of other advanced ICT/digital technologies, such as cloud technology, artificial intelligence, Internet of Things, is outside the scope of this study given the unavailability of sectoral data.

Table 3.14: Proportion of firms adopting Information Technology

Industry	Forms of IT adoption				
	Internet access	Web presence	Social media presence	Placed orders via the Internet	Received orders via the Internet
	%	%	%	%	%
Employment size					
0–4 persons	96.3	44.1	35.4	55.5	36.5
5–19 persons	97.3	67.1	59.1	71.9	48.5
20–199 persons	99.8	85.6	68.4	77.6	49.5
200 or more persons	97.8	95.8	85.7	86.1	64.5
Primary Sector					
Agriculture, Forestry and Fishing	93.2	16.8	17.0	50.1	24.8
Mining	97.9	67.1	36.2	64.6	34.2
Manufacturing Sector					
Manufacturing	97.0	72.2	50.1	74.5	65.4
Service Sector					
Construction	99.2	40.4	34.7	58.0	40.0
Wholesale Trade	97.3	72.3	46.5	75.1	64.3
Retail Trade	93.6	63.2	60.5	71.2	54.5
Accommodation and Food Services	90.1	59.3	67.4	53.7	40.1
Transport, Postal and Warehousing	95.0	33.1	23.5	46.4	32.4
Information Media, Telecommunications	99.1	76.5	69.9	75.5	57.4
Rental, Hiring, Real Estate Services	94.8	61.4	52.4	58.6	28.1
Professional, Scientific, Technical Services	99.5	61.4	43.8	68.0	38.5
Administrative and Support Services	98.2	53.7	42.0	55.6	37.2
Arts and Recreation Services	93.7	74.8	74.8	69.9	55.7
All industries	*96.8*	*54.4*	*45.2*	*62.2*	*41.2*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2017–18 (ABS 2019e)

Overall, the majority of Australian firms have Internet access (96.8%), but the other forms of IT adoption have much lower percentages. Just over half of Australian firms have a web presence (54.4%) and 62.2% of firms place orders via the Internet. Less than half of Australian firms have a social media presence (45.2%) or receive orders via the Internet (41.2%). At the sectoral level, more than 90% of firms across all industries have access to the Internet. Nonetheless, there are significant variations in relation to the adoption of other forms of IT among industries. The Agriculture, Forestry and Fishing industry has the smallest proportion of firms with a web presence (16.8%) or social media presence (17%) among all Australian industries. Despite being in the same sector, Mining shows a much higher proportion, with 67.1% of firms having a web presence and 36.2% having a social media presence. The secondary sector has relatively larger proportions of firms with IT adoption compared with the primary sector as well as the national average across all categories. The proportion of IT adoption varied among service industries. The largest proportion of firms having Internet access is recorded in Professional, Scientific, Technical Services (99.5%). Web presence and placing orders online are most popular in Information Media, Telecommunications, while a social media presence is most adopted in Arts and Recreation Services. The lowest percentages of firms having a web presence, social media and placing orders online are recorded in the Transport, Postal and Warehousing industry.

Table 3.15 demonstrates the proportion of Australian businesses that adopted IT in 2017–18, classified by innovation status. Overall, the proportion of innovation-active firms adopting IT is greater than non-innovation-active firms across all categories and industries. On average 98.4% of innovation-active businesses has Internet access, compared to 95.3% for non-innovation-active firms. The lowest proportion of firms with Internet access is found among non-innovation-active businesses in Accommodation and Food Services. In terms of web presence, the percentage of innovation-active firms with a web presence is substantially greater than that of non-innovation-active firms across all industries. Agriculture, Forestry and Fishing firms have a low web presence and social media presence. Arts and Recreation Services have the highest percentage of innovation-active firms using social media, at 88.7%, whereas Transport, Postal and Warehousing industry has the lowest percentage of non-innovation-active firms employing this form. The Information Media and Telecommunications industry has the largest proportion of innovation-active firms having an online ordering system (85.3%) and Arts and Recreation Services has the highest percentage of firms receiving orders via the Internet (72.2%).

Table 3.15: Proportion of firms adopting Information Technology, by innovation status

Industry	Innovation-active businesses					Non-innovation-active businesses				
	Internet access	**Web presence**	**Social media presence**	**Placed orders via the Internet**	**Received orders via the Internet**	**Internet access**	**Web presence**	**Social media presence**	**Placed orders via the Internet**	**Received orders via the Internet**
Primary Sector										
Agriculture, Forestry and Fishing	99.2	29.1	28.4	70.9	38.8	90.0	10.2	10.9	39.1	17.4
Mining	100.0	80.9	47.8	76.7	44.2	96.5	57.5	28.1	56.2	27.2
Manufacturing Sector										
Manufacturing	97.7	80.5	61.6	78.9	69.6	95.9	58.9	31.5	67.4	58.6
Service Sector										
Construction	98.9	58.9	51.1	73.1	54.5	99.4	28.4	24.0	48.1	30.6
Wholesale Trade	100.0	79.3	55.1	82.9	69.9	92.7	60.0	31.4	61.4	54.3
Retail Trade	96.1	71.6	71.9	81.4	65.0	90.4	52.4	45.8	57.8	40.8
Accommodation and Food Services	95.0	67.8	79.7	62.8	51.2	83.5	47.9	50.5	41.3	25.0
Transport, Postal and Warehousing	98.5	61.0	46.1	69.3	51.3	93.0	17.5	10.8	33.6	21.8
Information Media, Telecommunications	100.0	88.1	81.4	85.3	67.9	97.6	59.2	52.7	60.9	41.8
Rental, Hiring, Real Estate Services	99.1	82.0	73.7	74.1	38.0	90.2	39.1	29.5	41.9	17.4
Professional, Scientific, Technical Services	99.5	78.3	62.2	74.5	46.3	99.4	42.9	23.4	60.9	29.9
Administrative and Support Services	100.0	71.3	58.8	70.4	48.9	96.8	40.9	29.6	44.7	28.6
Arts and Recreation Services	98.2	87.9	88.7	84.3	72.2	88.0	58.2	57.1	51.5	34.8
All industries	*98.4*	*71.0*	*62.5*	*75.0*	*52.9*	*95.3*	*37.9*	*28.1*	*49.6*	*29.6*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2017–18 (ABS 2019e)

Given the substantially higher proportion of innovation-active businesses across all forms of IT adoption and all industries, one might infer that IT use has some bearing on innovation status. Evidence suggests that firms that engage more in IT seem more likely to be innovation-active. In recent years, Australian businesses have been increasingly embracing digital technology. Income generated over the Internet has experienced a dramatic increase from $285.5 billion in 2014–15 to $394.2 billion 2016–17 (ABS 2018g). Investments into appropriate IT platforms could thus drive business innovation and productivity.

3.5.5. Financial support for innovation

The act of undertaking innovation often requires large amounts of financial resources to invest, develop and implement the innovation (Hall & Lerner 2010). There are two main sources of financial assistance: (i) public funding from the government through grants, subsidies, soft loans, tax concessions or rebates and (ii) private funding in the form of debt or equity. Table 3.16 provides data on financial assistance from the Australian government in support of innovative activities and from debt or equity finance, particularly for innovation-active businesses in 2016–17.

As the literature suggests, small size is often associated with lack of finance. Therefore, small firms are disadvantaged in conducting innovative activities, while large firms are in 'a better position to carry out research and innovate with little external support' (Aboal & Garda 2016, p. 436). However, as can be seen in Table 3.16, a very small percentage of small firms received government financial support for their innovation activities, namely, 3% of micro firms and 3.7% of small firms. In contrast, the proportion of medium firms and large firms receiving this support was approximately three times greater, at 11% and 9.4%, respectively.

From an industry-specific perspective, Australian firms seem not receive much financial assistance from the government for their innovation activities. Except for Arts and Recreation Services (13.8%) and Mining (11%), there were only very small percentages of firms in the remaining industries that received government support. It is worth noting that the Wholesale Trade industry, which has the largest proportion of innovation-active businesses in Australia (63.8%), is among the industries with the least government financial assistance for innovation (0.6%). In terms of sources of support, for those that received government financial assistance, the majority of funding came from the Federal government, except for Administrative and Support Services, Transport, Postal and Warehousing and Arts and Recreation Services, which received funding mainly from the state/territory or local government.

Table 3.16: Proportion of firms receiving financial support for innovation activities

	Government financial assistance	Sources of government support		Debt or equity finance
		Federal	State/territory/local government	
	%	%	%	%
Employment size				
0–4 persons	3.0	66.9	38.5	14.9
5–19 persons	3.7	63.4	40.1	15.3
20–199 persons	11.0	54.8	49.9	14.6
200 or more persons	9.4	68.4	67.4	14.9
Primary Sector				
Agriculture, Forestry and Fishing	6.4	64.9	35.1	15.2
Mining	11.4	76.8	31.6	19.4
Manufacturing Sector				
Manufacturing	6.8	75.9	24.2	16.3
Service Sector				
Construction	4.5	72.5	27.5	5.0
Wholesale Trade	0.6	99.2	n/a	21.8
Retail Trade	n/a	0.0	n/a	11.7
Accommodation and Food Services	n/a	0.0	n/a	13.7
Transport, Postal and Warehousing	2.9	17.8	90.5	21.8
Information Media and Telecommunications	8.0	64.7	43.2	27.8
Rental, Hiring and Real Estate Services	3.6	n/a	n/a	25.8
Professional, Scientific and Technical Services	4.6	78.6	29.8	23.1
Administrative and Support Services	1.7	n/a	98.1	0.0*
Arts and Recreation Services	13.8	46.7	86.7	16.2
All industries	*4.1*	*62.5*	*42.5*	*15.1*

*Note: Businesses may be counted in more than one category, n/a: not available for publication but included in totals where applicable, *: nil or rounded to zero (including null cells)*

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

Another option to finance innovation projects is by seeking private finance. Firms seek private finance to address their financial needs for various activities: operation, expansion, export, R&D and introduction of new products. Finance used to purchase or upgrade machinery, equipment and software is also considered an innovation input (Mohnen & Hall 2013). As far as firm size is concerned, the proportions of firms seeking private finance for innovation activities are relatively equal among the four firm size groups (around 15%). Of the industries, more than one-fifth of innovation-active firms in the Information Media and Telecommunications, Rental, Hiring and Real Estate Services, Wholesale Trade and Transport, Postal and Warehousing industries sought debt or equity to finance innovation. In the case of Administrative and Support Services, the figure is nearly zero. This is probably due to the small scale of innovation projects in this industry.[28] The types of finance that firms seek depend largely on the risk profile and collateral available within the firm. Although debt financing is found to be 'ill-suited' for newer, innovative and fast-growing firms, with a higher risk return profile (OECD 2015d, p. 11), 90.6% of Australian firms sought this type of finance. In the case of SMEs, they face stricter conditions and higher interest rates when seeking bank finance compared with large firms and are more disadvantaged when attracting alternative sources of finance (OECD 2017a).

In conclusion, although finance is often mentioned as a key factor affecting innovation, only a very small percentage of Australian firms received government financial assistance for their innovation projects. The lack of funding available for firms to invest and support innovation activity is a prevailing obstacle to the development and implementation of innovation among Australian firms, especially among small businesses. In the early stages of the innovation process, in particular, the lack of finance significantly limits the growth potential of innovative firms in Australia (Australian Government 2017c). This implies a need for policy intervention.

3.6. MARKET COMPETITION

The degree of market competition is known to have an impact on business innovation. It is suggested that the intensity of market competition is one of the key driving forces of innovation (Pirnar et al. 2012). However, the impact of competition on innovation is still inconclusive. Figure 3.9 provides data on the degree of competition at the aggregate level, while Table 3.17 shows the number of competitors for each industry, classified by innovation status.

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[28] More than 90% of firms in Administrative and Support Services spent between $0 to less than $50,000 on their innovation projects (ABS 2018e).

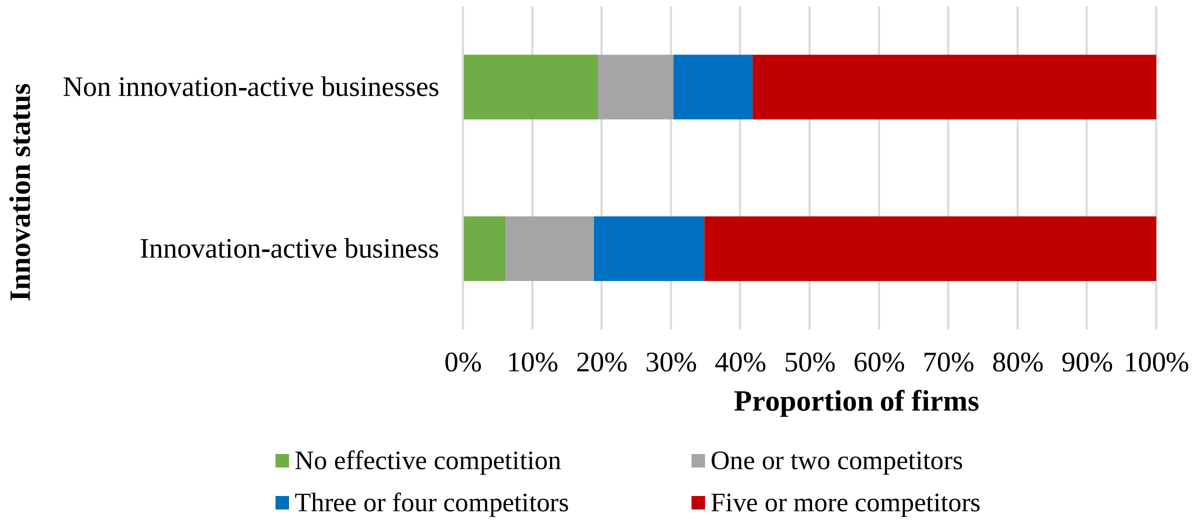

Figure 3.9: Degree of competition in the market

Source: Characteristics of Australian Business (ABS 2019b)

As shown in Figure 3.9, where no effective competition exists (i.e. captive market), there is a significantly higher number of non-innovation-active businesses compared with innovation-active businesses. This could imply that the absence of competition discourages firms from innovating. The opposite pattern is observed for the remaining categories, when firms face some level of competition, (i.e. there are more innovation-active businesses than non-innovative ones). Among innovation-active businesses, 65.2% of firms face five or more competitors, while for non-innovation-active businesses, 58.2% face this high level of competition.

As far as industries are concerned, in the absence of competition, the proportion of non-innovation-active businesses is higher than innovation-active businesses across all industries. The largest difference by innovation status is found in the case of Rental, Hiring and Real Estate Services, with 37.2% of non-innovation-active businesses operating in a captive market compared with just 6.5% of innovation-active businesses. In contrast, firms operating in a highly competitive market are likely to be innovative. For example, among innovation-active firms in the manufacturing industry, 58.1% faced five or more competitors, whereas the relative proportion was 10% lower for non-innovation-active group. The observed pattern suggests that competition seems to motivate firms to conduct innovative activity. As discussed in Chapter Two, intense competition puts firms under pressure to reduce costs, improve existing products or introduce new ones to maintain their competitive position.

Table 3.17: Number of competitors

Industry	Innovation-active businesses				Non-innovation-active businesses			
	None	One or two	Three or four	Five or more	None	One or two	Three or four	Five or more
	%	%	%	%	%	%	%	%
Primary Sector								
Agriculture, Forestry and Fishing	14.6	12.7	13.7	58.9	33.8	7.7	5.1	53.4
Mining	7.0	16.8	20.0	56.1	27.1	11.8	13.1	48.0
Secondary Sector								
Manufacturing	3.4	17.1	21.4	58.1	9.7	21.8	20.3	48.2
Service Sector								
Construction	4.1	10.0	10.3	75.6	11.2	11.8	10.7	66.3
Wholesale Trade	2.5	10.5	16.0	71.0	9.6	11.2	16.3	62.8
Retail Trade	n/a	n/a	23.0	60.1	11.3	20.5	14.3	54.0
Accommodation and Food Services	4.4	17.5	21.5	56.6	16.3	10.2	16.7	56.9
Transport, Postal and Warehousing	11.7	12.4	17.1	58.8	28.2	10.6	11.2	50.1
Information Media and Telecommunications	9.8	18.4	13.9	57.9	18.7	12.8	9.4	59.1
Rental, Hiring and Real Estate Services	6.5	10.8	9.5	73.2	37.2	7.2	5.9	49.8
Professional, Scientific and Technical Services	10.1	9.3	13.8	66.8	24.4	6.4	9.6	59.5
Administrative and Support Services	6.9	8.2	13.0	71.9	25.6	8.1	8.4	57.9
Arts and Recreation Services	10.7	14.0	16.8	58.5	22.6	17.2	9.3	50.9
All industries	*6.1*	*12.7*	*15.9*	*65.2*	*19.6*	*10.9*	*11.4*	*58.2*

Source: Characteristics of Australian Businesses 2017–18 (ABS 2019b)

3.7. BENEFITS OF AND BARRIERS TO INNOVATION

3.7.1. Benefits of innovation

The literature indicates that a firm's incentive to develop innovation is to increase profit, market share and achieve a monopoly position (Schumpeter 1934). To explore the impact of innovation, Figure 3.10 depicts the share of innovation-active and non-innovation active SMEs that report increased business performance.

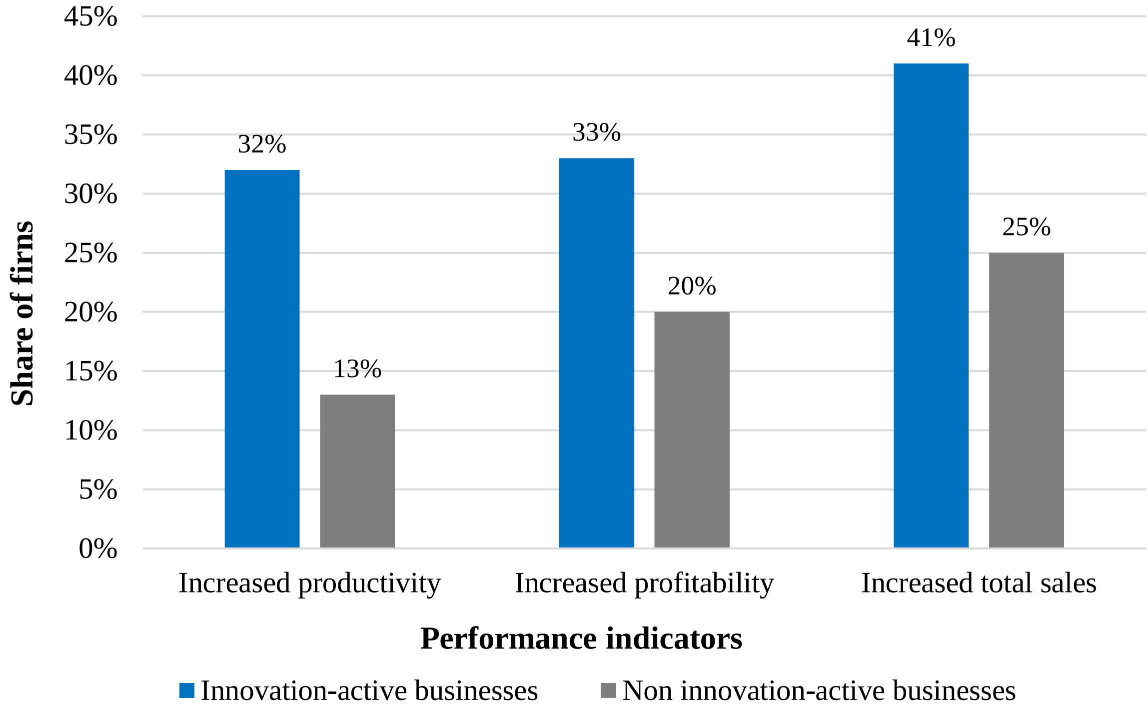

Figure 3.10: Business performance by innovation status

Source: Business Characteristics 2011–12–2015–16 (ABS 2019f)

As shown in Figure 3.10, the share of innovation-active businesses that reported improved performance is greater than that of non innovation-active firms across all indicators: productivity, profitability and sales. Specifically, 32% of innovation-active businesses gained productivity increases, whereas the corresponding share of non innovation-active businesses is considerably lower, at just 13%. Similarly, there is also a larger share of innovation-active businesses (33%) reporting increased profitability in comparison with 20% of non innovation-active businesses that achieved higher profit. With regards to total sales, 41% of innovation-active businesses and 25% of non innovation-active businesses reported sales increases compared to the previous year. The markedly greater share of innovation-active businesses experiencing increases in the three business performance indicators, compared with non innovation-active businesses implies that businesses which engage in innovation seem more likely to achieve better economic performance compared to those that do not undertake innovation activities.

As a sectoral study, the benefits of innovation are also examined from an industrial perspective. Table 3.18 provides further data on the extent to which Australian firms experienced various benefits from innovation across industry sectors. Overall, on average, 86.5% of firms experienced the benefits of introduced innovation in 2016–17. Of the industries, Agriculture, Forestry and Fishing (95.3%), Administrative and Support Services (94.7%), Wholesale Trade and Information Media and Telecommunications (91.9%) enjoy the greatest benefits from innovation. The four main types of benefits that innovation brings about are (i) increased revenue, (ii) reduction in costs, (iii) gained a competitive edge and (iv) improved customer service.

At the aggregate level, increased revenue and improved customer service are the two most frequently cited benefits of innovation. At the sectoral level, there was a high proportion of innovators in the primary sector reporting increased revenue (44%). Those in the secondary sector mostly experienced improvement in customer service (37.3%). In relation to services, there are variations due to a variety of sub-industries in this sector. Nonetheless, increased revenue and improved customer service are also the two most widely cited benefits of innovation. Finally, approximately a quarter of Australian firms believed it was too early to measure the benefits of introduced innovation at the time of being surveyed. This view could be explained by the time lag of innovation due to the opportunity cost and time taken from development to implementation of the innovation (Peters et al. 2017). Thus, there is a generally held view that the impact of innovation investments is not always immediate (Rochina-Barrachina et al. 2010).

Table 3.18: Benefits of introduced innovation

Industry	Businesses experienced benefits	Types of benefits: Increased revenue	Reduction in costs	Gained a competitive edge	Improved customer service	Other benefits	Too early to measure
	%	%	%	%	%	%	%
Primary Sector							
Agriculture, Forestry and Fishing	95.3	44.0	32.1	21.1	17.3	6.8	26.8
Mining	88.0	29.2	22.7	24.9	24.5	7.2	31.7
Manufacturing Sector							
Manufacturing	86.0	34.9	28.8	25.8	37.3	7.2	23.6
Service Sector							
Construction	81.6	35.0	16.2	12.6	35.2	5.4	28.8
Wholesale Trade	91.9	50.2	20.1	33.3	41.8	2.8	18.7
Retail Trade	85.3	42.4	19.3	23.6	41.2	2.7	19.6
Accommodation and Food Services	80.2	34.1	18.1	19.9	40.4	2.3	21.3
Transport, Postal and Warehousing	77.0	27.7	24.4	21.5	39.3	n/a	10.1
Information Media and Telecommunications	91.9	45.8	20.3	28.1	30.2	2.0	29.2
Rental, Hiring and Real Estate Services	88.6	43.9	18.2	27.5	44.2	7.3	17.2
Professional, Scientific and Technical Services	85.4	37.5	14.7	25.6	35.9	4.9	27.4
Administrative and Support Services	94.7	26.0	20.4	21.2	34.9	6.0	36.8
Arts and Recreation Services	84.5	34.2	21.3	25.8	35.0	6.1	27.7
All industries	*86.5*	*38.3*	*17.9*	*22.3*	*37.9*	*4.2*	*24.7*

Note: Businesses may be counted in more than one category; (n/a) Not available for publication but included in totals where applicable

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

3.7.2. Barriers to innovation

The barriers to innovation are crucial to a firm's decision to either engage in innovation or avoid innovative activity altogether (Santiagoa et al. 2017). A better understanding of the obstacles to innovation is important for developing appropriate policies to address prevailing problems in the innovation frontier and boost innovation performance. The major barriers to innovation that Australian firms confront are summarised in Table 3.19.

An estimated 55.5% of Australian innovation-active firms experienced barriers to innovation during the surveyed period. The major barriers are funding, skilled personnel, knowledge, demand and regulation. Data reveals that financial constraints, particularly lack of funds and high costs associated with innovation activities, are among the main barriers. This is the case for all industries (30.7% on average). The highest proportion of innovation-active firms reporting lack of access to additional funds as a main factor discouraging them from undertaking innovation is from the Arts and Recreation Services industry (41.7%). For the remaining industries, the proportion of firms experiencing this barrier was also significantly high, ranging from 26.2% to 36.2%. Extensive literature has emphasised financial constraints as a key barrier affecting innovation (Santiago et al. 2017). Investment in innovation often requires large amounts of financial resources, and internal finance may not be sufficient. A firm's capability to access additional funds is essential to keep it engaged in innovation activities (Pierre & Fernandez 2018).

As discussed previously, innovation is costly. Hence, the cost of development, introduction or implementation of innovation is also a major concern. These costs occur in various stages of the innovation process, for example, idea generation and selection, market analysis, experiment and development of new goods, services or processes, or prototype testing (Hoegl et al. 2008). The substantial cost of innovation development and implementation is an obstacle that prevents firms from devoting their efforts to innovate in the first place. On average, one-fifth of innovation-active firms across all industries firms reported this barrier.

Another major factor hampering innovation is the lack of personnel with appropriate skills and knowledge to develop and implement innovation. Approximately a quarter of innovation-active firms in Australia faced this issue. This barrier was mostly reported by the two service industries, Information Media and Telecommunications (29.5%) and Transport, Postal and Warehousing (27.4%). Although human capital is widely acknowledged as a crucial factor in innovation, there is a serious shortage of skilled personnel facing Australian firms across all industries. According to the Australian Government (2017), lack of access to skilled persons is one of the most often cited barriers to innovation in Australia, and this relates to all skill types—not just scientific, technical or engineering. While this labour force issue has long been recognised in industry and policy circles, it remains unresolved.

Innovation activity is characterised by high risk and uncertainty of success. It is a time-consuming process, starting from idea generation to development and introduction or implementation into the market. This uncertainty means that there are no guarantees that the innovation will be successful and bring profits to the business. On average, 16.6% of Australian innovation-active firms report that the uncertainty of demands for new goods or services, identified as a market-related barrier, acts as an important factor in discouraging them from pursuing innovation ideas. Retail Trade was the industry with the highest proportion of firms reporting this barrier, at 25.6%, followed by Professional, Scientific and Technical Services, Wholesale Trade and Manufacturing industries at 23.6%, 20.9% and 20.5%, respectively. Finally, 11.2% of innovation-active firms mentioned government regulations or compliance, 6.5% cited lack of access to knowledge or technology and 3.9% reported adherence to standards as other barriers to investing in innovation.

D'Este et al. (2012) propose that perceptions of innovative and non-innovative firms on innovation barriers are generally not the same. While innovative firms perceive such barriers as challenges to be overcome, non-innovative firms view them as barriers which deter them from undertaking innovation investments. Compared to innovative firms, there is limited survey-based research that investigates obstacles encountered by non-innovative firms (Amara et al. 2016). Taking this into account, table 3.20 presents barriers to innovation reported by non innovation-active firms in the Australian context.

Table 3.19: Barriers to innovation by innovation-active businesses

Industry	Businesses experiencing barriers	Lack of access to additional funds	Lack of skilled personnel	Cost of development/ introduction/ implementation	Lack of access to knowledge or technology	Government regulations and compliance	Adherence to standards	Uncertain demand for new goods or services
	%	%	%	%	%	%	%	%
Primary Sector								
Agriculture, Forestry and Fishing	58.3	34.9	18.9	27.2	3.3	15.5	4.8	18.0
Mining	56.8	35.4	18.5	23.5	11.6	15.0	5.3	19.1
Manufacturing Sector								
Manufacturing	57.1	26.2	26.3	18.2	7.9	13.6	2.1	20.5
Service Sector								
Construction	53.2	28.5	26.9	15.5	7.2	13.5	4.2	11.6
Wholesale Trade	58.6	28.5	26.8	21.5	4.7	8.7	4.0	20.9
Retail Trade	59.0	36.1	20.1	19.1	5.4	7.3	5.9	25.6
Accommodation and Food Services	51.8	32.2	26.8	14.6	5.0	12.7	2.9	14.5
Transport, Postal and Warehousing	58.5	27.0	27.4	18.0	6.1	18.1	1.8	9.4
Information Media, Telecommunications	61.3	36.2	29.5	18.9	6.6	6.7	1.2	16.3
Rental, Hiring and Real Estate Services	55.1	31.7	22.0	17.7	2.3	7.1	2.8	10.3
Professional, Scientific, Technical Services	57.2	30.0	22.6	26.2	7.1	7.7	4.3	23.6
Administrative and Support Services	50.6	33.0	21.8	20.5	10.7	13.4	3.3	10.2
Arts and Recreation Services	57.4	41.7	21.0	23.3	11.9	9.2	1.4	13.0
Total All Industries	*55.5*	*30.7*	*24.3*	*20.1*	*6.5*	*11.2*	*3.9*	*16.6*

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

Table 3.20: Barriers to innovation by non innovation-active businesses

Industry	Businesses experiencing barriers	Lack of access to additional funds	Lack of skilled personnel	Cost of development/ introduction/ implementation	Lack of access to knowledge or technology	Government regulations and compliance	Adherence to standards	Uncertain demand for new goods or services
	%	%	%	%	%	%	%	%
Primary Sector								
Agriculture, Forestry and Fishing	24.2	8.5	6.8	8.0	0.5	10.5	3.6	6.6
Mining	32.1	13.8	6.0	6.9	n/a	11.3	3.4	9.1
Manufacturing Sector								
Manufacturing	31.9	13.4	17.5	10.4	1.5	6.2	1.2	10.7
Service Sector								
Construction	26.7	10.0	12.8	5.1	1.2	5.7	2.0	7.0
Wholesale Trade	30.3	8.6	12.3	4.9	3.7	8.9	1.1	13.5
Retail Trade	21.0	12.4	7.3	4.6	2.4	2.7	n/a	4.4
Accommodation and Food Services	31.4	13.1	11.5	6.1	4.1	7.6	0.0	7.9
Transport, Postal and Warehousing	19.5	6.9	9.1	4.0	1.6	9.5	n/a	2.5
Information Media, Telecommunications	25.7	12.1	7.1	8.2	4.7	5.9	n/a	12.0
Rental, Hiring and Real Estate Services	26.6	11.8	8.5	4.2	n/a	6.9	2.6	8.1
Professional, Scientific, Technical Services	19.6	7.0	7.9	4.7	0.8	5.4	2.8	6.6
Administrative and Support Services	18.6	7.2	10.0	3.7	n/a	5.9	n/a	5.5
Arts and Recreation Services	22.8	13.8	8.0	7.1	4.0	4.0	n/a	5.9
Total All Industries	*24.4*	*9.7*	*10.6*	*5.5*	*1.5*	*6.7*	*2.0*	*6.7*

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

As shown in table 3.20, with respect to the industry average, only a quarter of non innovation-active firms reported that they experienced some innovation barriers. This proportion is 30% below the proportion of innovation-active firms experiencing barriers (55.5%). Similar to innovation-active firms, lack of skilled personnel and lack of access to additional funds are also the two most reported barriers by non innovation-active firms. However, the proportion of non innovation-active firms reported these barriers is considerably smaller, at approximately 10%. For the remaining five types of barriers, less than 7% of non innovation-active firms referred to them as obstacles to innovation. These percentage are also relatively low across all industries. The highest proportion of non innovation-active firms that reported lack of access to additional funds was Mining and Arts and Recreation Services, at 13.8%. The Manufacturing industry had the highest proportion of firms that reported a lack of skilled personnel (17.5%) and cost of development/introduction/implementation (10.4%) as the major barriers preventing them from innovating. Among non innovation-active firms, barriers related to government regulations and compliance are highest among Mining firms (11.3%), while uncertain demand for new goods or services is the most reported by firms in the Wholesale Trade industry (13.5%). Finally, a very small (to zero) proportion of non innovation-active firms across all industries mentioned lack of access to knowledge or technology and adherence to standards as barriers.

To summarise, there is a markedly smaller proportion of non innovation-active firms that reported innovation barriers compared with innovation-active firms across all types of barriers.This could be because firms that engage in innovation activities are more likely to face more barriers to innovation and are more aware of the associated difficulties (such as development costs or skilled personnel) than those who do not undertake innovation (Amara et al. 2016; D'Este et al. 2012). According to Galia and Legros (2004, p. 1189), "… certain problems are not effectively encountered until firms face them. [...] innovative firms face problems and more innovative firms have more problems". Thus, firms that do not engage in innovative activities may not recognise such barriers (D'Este et al. 2012). Hence, firms that decide not to innovate could be due to their lack of interest in innovation, rather than facing innovation barriers (Pellegrino 2018).

It is often claimed that firm size has an influence on innovation strategy and capability. Table 3.21 provides data in relation to barriers to innovation reported by businesses grouped via firm size.

Table 3.21: Barriers to innovation by firm size

Barriers	Micro firms	Small firms	Medium firms	Large firms	Total
	%	%	%	%	%
Lack of access to additional funds	32.1	32.2	19.0	13.1	*30.7*
Cost of development/introduction/implementation	20.7	19.3	20.6	18.0	*20.1*
Lack of skilled persons	21.6	27.8	24.7	18.0	*24.3*
Lack of access to knowledge or technology	6.2	6.8	6.7	8.4	*6.5*
Government regulations and compliance	11.5	11.4	8.7	12.8	*11.2*
Adherence to standards	3.2	4.7	3.7	4.1	*3.9*
Uncertain demands for new goods/services	17.8	15.1	17.1	8.3	*16.6*
Total businesses experiencing barriers	56.8	55.6	50.2	38.3	*55.5*

Note: Businesses may be counted in more than one category

Source: Innovation in Australian Businesses 2016–17 (ABS 2018e)

As shown in Table 3.21, micro and small firms face the greatest barriers. The data show that 56.8% of micro firms experienced difficulties in conducting innovation, followed by small firms and medium firms at 55.6% and 50.2%, respectively. The percentage of large firms reporting barriers to innovation is 38.3%. These facts support the generally held view that SMEs, because of their limited resources, experience more barriers to innovate compared with large firms (Rosenbusch et al. 2011).

The most frequently cited barrier by micro and small firms (over 32%) is the lack of access to additional funds for innovation. The figures for medium and large firms are much lower. A lack of skilled persons to develop and implement innovation is the second major barrier, mostly cited by small firms (27.8%), whereas only 18% of large firms referred to this as a barrier. These results reflect major disadvantages faced by small firms in terms of their capability to access financial and human resources for innovation. In terms of cost of development or introduction/implementation, there are relatively similar proportions of firms reporting this barrier across all sizes; however, more SMEs also faced this obstacle than large firms. Similarly, uncertain demand for new goods or services is the barrier faced mostly by SMEs (15.1% to 17.8%) compared with large firms (8.3%). Finally, government regulations and compliance, lack of access to knowledge or technology and adherence to standards are also reported as barriers, preventing firms from making innovation efforts; yet the numbers are relatively similar across firm size groups.

To sum up, although Australian innovation-active firms enjoy substantial benefits of introduced innovations, such as improvements in business performance, many firms face several barriers hampering their innovative activity. Indeed, financial constraints, such as lack of funds and high costs associated with innovation activities, are among the main barriers experienced by firms across all sectors. Another issue faced by a quarter of innovation-active firms in Australia is the shortage of workers with appropriate skills, qualifications and knowledge to develop and implement innovation. These issues are more severe in the case of SMEs, which are often known as less innovative groups. The presence of various barriers to innovation is likely to hinder innovation incentives and capabilities of Australian firms, particularly SMEs. Identification of the major barriers affecting firms in each sector is an important step to be undertaken. Given this, an appropriate innovation policy could be developed and implemented to address prevailing obstacles in the innovation frontier and boost innovation performance for Australia firms.

3.8. DISCUSSION OF FINDINGS

The information and analysis presented in this chapter addressed the first research question of the thesis: *What is the state of innovation in Australia's three economic sectors (i.e. primary, secondary and service)?*

3.8.1. The state of innovation

At the aggregate level, nearly half of all businesses in Australia conducted some form of innovative activity, i.e. 49.8% in 2017-18 or 46.2% over the period 2011–16. At the sectoral level, the primary sector is the least innovative sector. Currently, the primary sector experiences a lack of critical mass in innovation, evidenced by the Agricultural, Forestry and Fishing industry exhibiting the lowest proportion of innovation-active firms in Australia (34.7%) and Mining (41%), both appreciably lower than the national average. Consequently, the number of firms with innovation implemented is also considerably low across technological and non-technological innovations. However, it should be noted that the Mining industry has a relatively higher proportion of firms engaging in innovative activity as well as implementing innovations, both technological and non-technological, compared with the Agriculture, Forestry and Fishing industry.

The secondary sector is quite innovative, with 61.7% of manufacturing firms engaging in innovation, which is 12% higher than the national average. They are innovative across all types of innovation. In terms of innovation types, there is a higher proportion of manufacturing firms implementing technological innovation than non-technological innovation. Manufacturing also had the highest proportion of firms implementing process innovation among the 13 Australian industries under study. This is understandable given that their business activities are mainly technology-related and that improvements in processes that reduce production and delivery costs, while increasing output and efficiency are considerably important to firms in the manufacturing industry (Mañez et al. 2013; Rochina-Barrachina et al. 2010).

The Australian economy is dominated by its service sector. There were variations within the sector due to the diversity of industries constituting this sector. Overall, the majority of firms in this sector actively engaged in innovative activity, with seven out of ten service industries showing a greater proportion of innovation-active firms relative to the national average. An important finding was the innovation performance of the Wholesale Trade industry. This service industry had the largest proportion of innovation-active firms as well as innovation implemented among the 13 Australian industries under study. These findings imply that the service sector is not a laggard in the innovation race. Further, service firms actively implemented both technological and non-technological innovation. Some service industries, such as Wholesale Trade, Retail Trade, Information Media and Telecommunications and Professional, Scientific and Technical Services, even introduced more product innovation than the manufacturing industry. Therefore, service firms can also be as innovative as manufacturing firms in technological aspects and should no longer be considered technologically backward (Álvarez et al. 2015; Mina et al. 2014). Nevertheless, there remain three industries, namely, Construction, Transport, Postal and Warehousing and Administrative and Support Services, that show lower innovation performance compared with the national average.

3.8.2. Inputs used for innovation

This chapter also conducted a preliminary analysis of potential inputs used for innovation by Australian firms across sectors. The innovation literature has long focused on R&D as the key input into the innovation process. However, data showed that firms in Australia invested heavily in non-R&D rather than R&D activities. This could be because of the nature of the Australian economy, which is predominantly made up of SMEs with the vast majority of them operating in the service sector. Given this, the ISA (2020) emphasises the need to pay more attention to non-R&D innovation activities to better reflect how Australian firms innovate in today’s economy.

Of the non-R&D inputs for innovation, human capital is often cited as the most important (McGuirk et al. 2015). Levels of educational attainment of the Australian workforce vary across economic sectors as well as within each sector. Of the industries under studies, only two service industries—Professional, Scientific and Technical Services and Information Media and Telecommunications—and the Mining industry in the primary sector, demonstrated higher proportions of workforce with qualifications beyond secondary education compared with the national average. In Australia, the lack of skilled workers has been reported as a major barrier to innovation faced by SMEs across all sectors. This ongoing skill shortage issue in Australia is likely to hamper SMEs' capability to innovate and grow (OECD 2018c).

Financial support is perceived as crucial to innovation, especially for SMEs with limited resources. However, nationally only 4.1% of Australian firms received financial support from the government for their innovation activities in the year under study. Except for Arts and Recreation Services (13.8%) and Mining (11%), the proportion of firms obtaining government financial support was relatively very low across all industries. This issue is even more severe for SMEs since only 3% of micro firms and 3.7% of small firms received government financial support for innovation. Consequently, lack of access to additional funds is a major barrier to innovation among Australian SMEs. This could possibly be a reason for the small proportion of Australian SMEs undertaking innovative activity.

Collaboration, as indicated by the literature, is a means of accessing external resources and enhancing innovation performance through knowledge and resource sharing. However, on average only 13% of Australian firms engaged in collaboration for their innovation projects. The poor state of collaboration for innovation is observed in all sectors, except for the Information Media and Telecommunications industry, with 30.1% of innovation-active firms involved in some form of collaboration. The role of collaboration with universities and research institutions has been internationally recognised, and these entities are viewed as important innovation partners given their cutting-edge knowledge, technology and skilled personnel (Lee & Miozzo 2019; Rauter et al. 2018). However, less than 5% of Australian firms engaged in this type of collaboration, ranking Australia the lowest of all OECD economies in this collaboration category (ABARES 2019). This raises the question of whether Australian firms miss out on the benefits of collaboration in their innovation projects.

The adoption of ICT is critical in innovation development and implementation (OECD 2017b). At the national level, the majority of Australian firms has Internet access (96.8%) and 62.2% also places orders via the Internet. However, just over half of Australian firms has a web presence, while less than half has a social media presence or receives orders online. This reflects a relatively low level of IT adoption by Australian firms in general. As the OECD (2019b) indicates, Australia's ICT investment scores are below the OECD average. The state of IT adoption varies among sectors. Agriculture, Forestry and Fishing firms are least active in adopting IT of all Australian industries. Compared with the primary sector, the secondary sector has a larger proportion of firms with IT adoption across all categories. There are variations in the rates and forms of IT adoption among service industries, which is due to the heterogeneity in characteristics of industries in this sector. It is noted that the proportion of innovation-active firms adopting IT is much larger than that of non-innovation-active firms. This pattern is true for all forms of IT adoption across all industries and sectors, implying a possible link between IT adoption and firms' innovation status. Further, except for Internet access, there is a declining tendency of adoption for the remaining IT forms as firm size decreases.

3.8.3. Characteristics of innovation-active firms in Australia

This chapter also discussed the characteristics of Australian firms, aiming to identify potential characteristics of innovative firms. In terms of firm size, the proportion of firms undertaking innovative activity increases as firm size increases. This could be an indication that larger firms have higher innovation propensity than smaller firms. Regarding firm age, the number of firms that conducted innovation had a declining tendency as their years of operation increased, implying that younger firms seem to be more innovative than older firms. International involvement also demonstrated some links to innovation. A greater proportion of innovation-active firms was observed in firms with foreign ownership over wholly Australian-owned firms and in exporters over non-exporters, suggesting that firms with foreign ownership and involved in exports might be more likely to conduct innovation activity. Finally, the proportion of innovation-active firms is much higher than non-innovation-active firms in the competitive markets, implying that competition stimulates firms to innovate. Yet, conclusions on the impact of size, age, foreign ownership, exports and market competition, as identified above, cannot be drawn unless empirically tested by econometric models.

3.9. SUMMARY

The aim of this chapter was to answer the first research question and provide a contextual background for the key issues addressed in this thesis overall, and to set the foundation for the econometric analysis to be conducted in the next chapter. This chapter provided an overview of the three Australian economic sectors, the state of innovation and the inputs used for innovation across sectors. It also presented potential links between firm characteristics and market competition and firm innovation status. The quantification of the various issues highlighted in this chapter is formally carried out using econometric modelling in the next chapter. Further, the differences in the innovation behaviour and performance among the three sectors suggest that these sectors should not be analysed solely via aggregation. Therefore, examination of the innovation process should begin with an aggregate analysis of the economy, then each economic sector should be analysed independently, bearing in mind the nature of the sector. The findings from the empirical model (Chapter Five) and the barriers faced by Australian firms, particularly SMEs, identified in this chapter, provide a useful empirical premise for policy discussion in Chapter Six.

CHAPTER FOUR:
RESEARCH METHOD

4.1. INTRODUCTION

This chapter presents the research method used for the empirical analysis. The chapter begins with a review of commonly used methods in empirical research on innovation and productivity. The next section provides information on the data used for the empirical analysis, its sources and features and measurements of variables. The conceptual framework is then developed and research hypotheses are proposed. Given the relevance of reviewed methods, the availability of Australian innovation data and the conceptual framework, an appropriate method for the present study is justified. This is followed by specifications of the empirical model, estimation technique and the modelling strategy.

4.2. REVIEW OF RESEARCH METHODS

4.2.1. The knowledge production function approach

The first attempt to investigate the innovation input–output relationship was conducted by Griliches (1979), who developed the knowledge production function (KPF). The KPF illustrates the process that transforms R&D (broadly defined as innovation inputs) to innovation outputs (patents). Griliches considered a stock of knowledge created by R&D investments as an additional input, along with conventional inputs such as physical capital, labour and materials, into the firm's production function. The model is presented as follows:

$$Y = F(X, K, u) \quad (4.1)$$

where

Y denotes the production function connecting some measure of output

X stands for an index of conventional inputs (e.g. labour, capital)

K is a measure of the current state of technical knowledge or stock of knowledge capital

u stands for all other unmeasured determinants of output and productivity

K, as assumed by Griliches (1979, p. 95), is determined by W(B)R, an index of 'current and past levels of R&D expenditures', explaining the relative contribution of past and current R&D levels to the current state of technical knowledge, B is 'the lag operator' and v is 'another set of unmeasured influences on the accumulated level of knowledge'.

This is shown below:

$$K = G[W(B)R, v] \tag{4.2}$$

The total factor productivity measure is specified.

$$A = Y/X = DX^{\alpha+\beta-1}K^{\gamma}e^{\lambda t+u} \tag{4.3}$$

where

A is total factor productivity

D is a constant

K is research capital

Y is a measure of output

X is a measure of inputs

t is a time index

e is the base of natural logarithms

α, β, γ and λ are the parameters of interest, non-constant returns to scale ($\alpha + \beta \neq 1$)

u is the random factor.

Following Griliches (1979), a large number of empirical studies have estimated the impact of R&D investment on firm productivity, output or profits using the KPF framework. The core concept in the KPF framework that has attracted interest from scholars is the partial derivative of output in terms of the knowledge stock, estimated as either the elasticity of output or the marginal product of the knowledge stock. The marginal product of the knowledge stock offers 'a measure of the return to the firm's investment in R&D and has been the primary focus of the empirical innovation literature' (Peters et al. 2017, p. 410). Most of the empirical research examining the R&D–productivity relationship was built around Griliches's KPF (e.g. Hall & Mairesse 1995; Harhoff et al. 2003; Mairesse & Mohen 2002). Over 40 years, the KPF model has undergone several extensions, for instance, encompassing R&D spillovers across industries, incorporating innovation outcomes as an intermediate step between R&D investment and output or using the market value of the firm as a measure of long-run output. The KPF framework/model placed an initial step for numerous studies investigating the R&D and productivity relationship.

4.2.2. The CDM model approach

The original CDM model

Inspired by the work of Griliches (1979), Crépon, Duguet and Mairesse (1998) extended the KPF framework in several ways. In their seminal paper, *Research, Innovation and Productivity: An Econometric Analysis at the Firm Level,* Crépon, Duguet and Mairesse (1998) developed the CDM model. The model links R&D, innovation and productivity, informed by the core idea that 'firms invest in research in order to develop process and product innovations, which in turn may contribute to their productivity and other economic performances' (Crépon et al. 1998, p. 2). The model comprises four equations reflecting the main stages of the innovation process: (i) the firm's engagement in research activities, (ii) the intensity of these research activities, (iii) the innovation equation and (iv) the productivity equation. The first equation, namely, the research equation, presents the firm's decision to engage in research activities.

$$g_i^* = x_{1i}b_1 + u_1 \qquad (4.4)$$

where

g_i^* is the latent dependent variable expressing some decision criterion

x_{1i} is a vector of explanatory variables

b_1 is the corresponding coefficient vector

u_1 is an error term.

The second equation specifies the intensity of the research activities.

$$k_i^* = x_{2i}b_2 + u_2 \qquad (4.5)$$

where

k_i^* is the latent dependent variable expressing the intensity of research

x_{2i} is a vector of explanatory variables

b_2 is the corresponding coefficient vector

u_2 is a disturbance summarising omitted determinants and other sources of unobserved heterogeneity.

In the two equations above, the explanatory variables include most of those considered in the literature on R&D determinants, namely, those from the Schumpeterian tradition such as firm size, market share, diversification, demand conditions and technological opportunities.

The third equation in the CDM model is the innovation equation, where the innovation output is measured either by the number of patents or innovative sales. Here, the exogenous variables have the same notations as in the research equations except for market share and diversification, which are assumed to indirectly affect innovation through research. The patent equation is specified below.

$$n_i^* = E(n_i | k_i^*, x_{3i}, u_{3i}; \alpha_K b_3) = \exp\,(\alpha_K k_i^* + x_{3i} b_3 + u_{3i}) \qquad (4.6)$$

where

n_i^* is the dependent variable

k_i^* is the latent research variable

x_{3i} is a vector of explanatory variables (supposedly exogenous)

u_{3i} is the error or heterogeneity term.

The innovative sales equation is presented below.

$$t_i^* = \alpha_k k_i^* + x_{3i} b_3 + u_{3i} \qquad (4.7)$$

where

t_i^* is the underlying true share expressed in logarithm

α_k is the elasticity of the expected patent numbers relative to research capital

k_i^* is the latent research variable

x_{3i} is a vector of explanatory variables (same as the patent equation)

u_{3i} is the error or heterogeneity term.

The fourth equation is the productivity equation. In this equation, labour productivity is the dependent variable, where the factors of productivity include innovation output, physical capital and shares of engineers and administrators (considered skilled labours) in the total of employees. The productivity equation, an augmented Cobb–Douglas production, is specified below.

$$q_i = \alpha_I \ln\,(n_i^*) + x_{4i} b_4 + u_{4i} \qquad (4.8)$$

or

$$q_i = \alpha_I t_i^* + x_{4i} b_4 + u_{4i} \qquad (4.9)$$

where

q_i is the logarithm of labour productivity

$\ln\,(n_i^*)$ is expected patents per employee

t_i^* is the latent share of innovative sales

x_{4i} is the vector of the factors of productivity, other than innovation output

α_I is the elasticity of total factor productivity

b_4 is the associated coefficient

u_{4i} is the error term.

The general structure of the CDM model is presented in Figure 4.1.

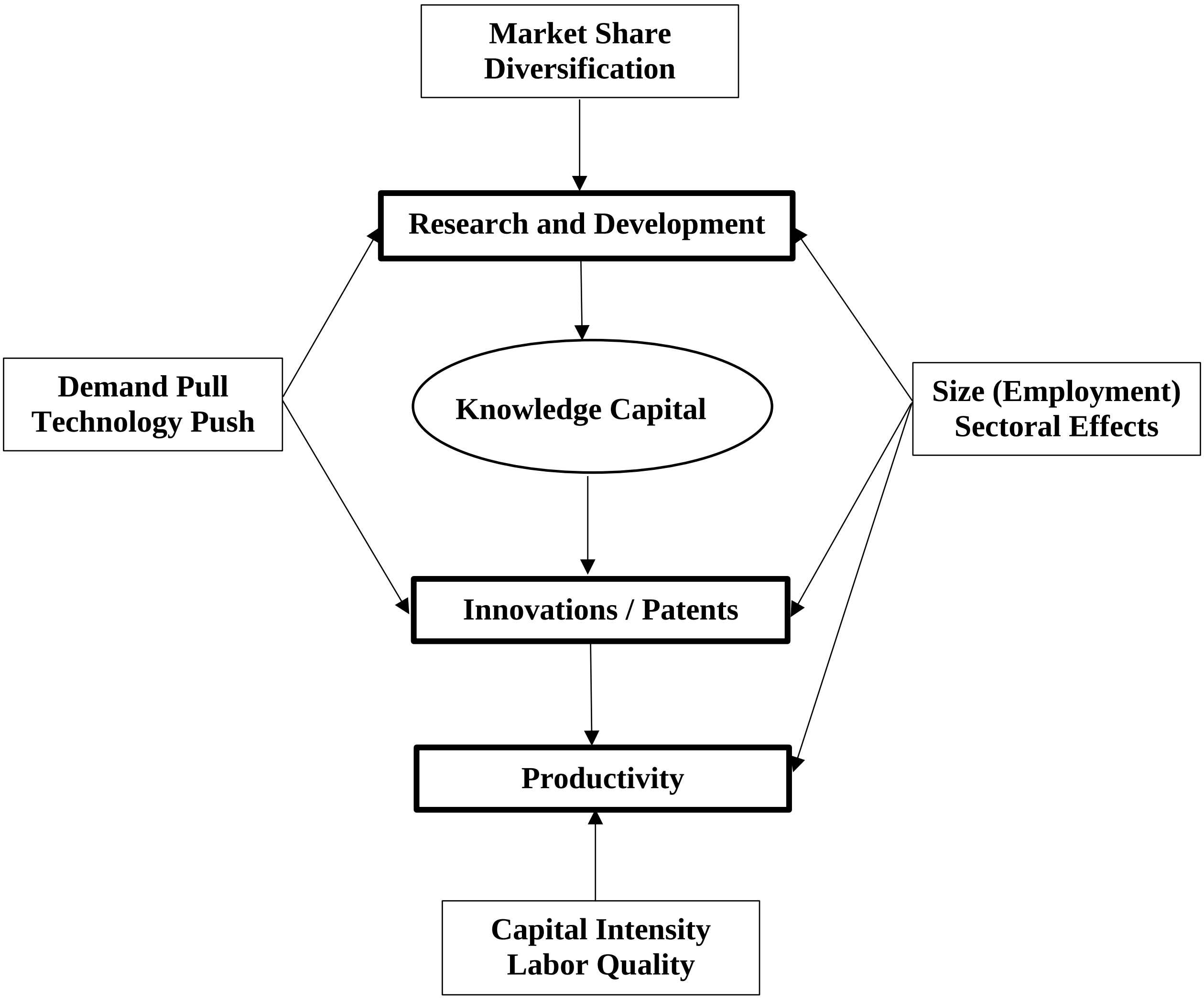

Figure 4.1: The original CDM model

Source: Crépon et al. 1998, p. 22

The CDM model was fitted into a French manufacturing dataset containing innovation, R&D and accounting data. Two samples were used for the analysis—a full sample of 6,145 firms in which data were obtained from different sources and a subsample of 4,164 firms drawn from the Innovation Survey during the 1986 to 1990 period. The econometric results show that the likelihood of engaging in research increases with firm size, market share and diversification as well as the demand-pull and technology push factors. The research effort (R&D capital intensity) of a firm is also positively correlated with the same variables, except for firm size. A firm's research effort, along with demand-pull and technology push indicators, increases innovation output—either directly or indirectly through their effect on research. Finally, a positive association is found between firm productivity and a higher innovation output, even when controlling for the skill composition of labour and physical capital intensity (Crépon et al. 1998).

The development and subsequent empirical application of the CDM

Over the 20 years since its introduction, different versions of the CDM have been applied to data in various countries. Major studies include Klomp and Van Leeuwen (2001), Kemp et al. (2003) and Van Leeuwen and Klomp (2006), who fitted the CDM into Dutch manufacturing data. Criscuolo and Haskel (2003) used CIS data and the CDM to analyse innovative behaviours of UK firms, while Lööf and Heshmati (2002, 2006) used it for Swedish manufacturing firms. Janz et al. (2004) used the model for German and Swedish manufacturing firms, Parisi et al. (2006) for Italian manufacturing firms, Benavente (2006) for Chilean firms, Mairesse and Mohnen (2005) and Mohnen et al. (2006) for French firms, Jefferson et al. (2006) for Chinese firms, Wong et. al. (2007) for Australian firms and Morris (2018) for manufacturing and service firms in 43 countries. In the SME literature, Hall et al. (2009) employed the CDM model for Italian manufacturing SMEs and Beneki et al. (2012) for Greek SMEs. As can be seen, the vast majority of previous studies were conducted in European countries, using CIS data.

The key advantage of the CDM model is its capacity to 'integrate the innovation process and business productivity from an empirical perspective' (García-Pozo et al. 2018, p. 1051). Today, the CDM model has become 'the workhorse in the empirical literature on innovation and productivity and been applied to micro data of over 40 countries' (Lööf et al. 2017, p. 1). It is referred to as the most appropriate framework/model to 'analyse innovation survey data based on the Oslo Manual' (Lööf et al. 2017, pp. 1–2). Most studies rely on the four equations of the original CDM model. Nonetheless, there are variations and diversification in terms of the innovation inputs and outputs examined among studies. For example, Janz et al. (2004) include firm size, physical capital, public funding, age, cooperation, sources of information and market demand as the independent variables in the innovation output equation. Griffith et al. (2006) consider R&D intensity, investment intensity, innovation protection, sources of innovation, demand-pull, firm size and industry. In the SME context, Hall et al. (2009) included R&D intensity, investment per employee, firm size and firm age, while Beneki et al. (2012) considered the number of researchers, public sector expenditure and private sector expenditure on R&D as the determinants of innovation output. Product and process innovations are the two main types of innovation output in almost all studies, while labour productivity is the most widely used proxy for firm productivity.

The CDM has also been applied in the service sector, although not as extensively as in the manufacturing sector (Beneki et al. 2012). Of the available studies, Musolesi and Huiban (2010), using French microdata, find that innovation has a positive effect on productivity in knowledge-intensive business services (KIBS). Masso and Vahter (2012) indicate that non-technological innovation plays a positive role in KIBS. Similarly to manufacturing firms, a positive effect of technological innovation on labour productivity is also found in service firms. In addition to the CDM equations, Masso and Vahter (2012, p. 2537) added an export equation, arguing that 'the effects of innovation on productivity may also work through the effects of innovation on exports'. García-Pozo et al. (2018) use the CDM model to examine the relationships between R&D investment, innovation output and labour productivity in Spanish service firms. They conclude that the key determinants of innovation are internal R&D expenditure, suppliers, customers, trade fairs, training expenditure, size, competition and region. Further, innovative firms gain increased labour productivity compared with non-innovative firms. The findings of studies on innovation in services are comparably consistent with those in manufacturing with respect to the positive link between innovation and labour productivity. Several factors have been identified as the determinants of innovation processes in various sectors.

In terms of measurements and estimations, different measures of innovation input and output have been used. These variables are either continuous, discrete or binary data. Several estimation methods have also been employed to estimate the innovation and productivity link. Some common methods are two-stage least squares, three-stage least squares and maximum likelihood. Among those, maximum likelihood seems to be the most widely used method. A significant number of scholars have used probit and logit regression to estimate the relationship between innovation input and innovation output. This is due to the widespread use of the CIS in which innovation is measured by a binary variable (i.e. whether the firm introduced or implemented a particular type of innovation). Another significant feature of the CDM model is that it originally was a static model used on cross-sectional data, whereas now it has been extended to panel data, dynamic models and applications on multiple types of innovative activities and firm performance measures (Lööf et al. 2017).

4.2.3. Dynamic model approach

Although the utility of the CDM model is widely acknowledged, one of the limitations of the original CDM paper and 'nearly all CDM studies on manufacturing and services' is 'the cross-sectional nature of the data and estimates' (Audretsch et al. 2020, p. 1002; Baum et al. 2017, p. 122). Most prior research adopting the CDM used cross-sectional data, which was unable to examine the dynamic linkages between innovation and productivity as well as unobserved firm heterogeneity (Morris 2018; Raymond et al. 2015). As suggested by Raymond et al. (2015), a dynamic model is necessary to capture this complex interrelation. Due to the opportunity cost and time taken from idea generation to innovation development and the uncertainty inherent to the innovation process, there might exist a time lag between a firm's decision to invest in innovation, the related R&D outlays and the innovation success (Majd & Pindyck 1987). The time lag is also a focus of the KPF literature, which concerns how R&D affects productivity and output in the subsequent periods (Peters et al. 2017). A firm that has successfully innovated is more likely to experience innovation success in the future compared with a non-innovating firm (Geroskietal 1997; Peters 2009). Innovating firms are likely to demonstrate persistence in their economic performance (Baily et al. 1992; Fariñas & Ruano 2005). Bhattacharya and Ritter (1983) suggest that because of information asymmetry, firms may prefer to use their retained earnings rather than seek external funding for their future innovation investment. This is referred to as a feedback effect from productivity to innovation; in other words, R&D investment affects the firm's discounted sum of expected future profits, creating an incentive to invest in R&D in the future (Peters et al. 2017).

To investigate the dynamic aspects, Raymond et al. (2015) proposed a dynamic model comprising a KPF and an augmented production function. The KPF representing the relationship between innovation output and R&D and other explanatory factors is specified as follows:

$$y^*_{1it} = \vartheta_{11} y_{1i,t-1} + \vartheta_{13} y_{3i,t-1} + \beta'_1 x_{1\,it} + \alpha_{1i} + \varepsilon_{1\,it} \qquad (4.10)$$

where

y^*_{1it} is a latent variable denoting the firm's propensity to introduce product innovations at period t

$y_{1i,t-1}$ is the past observed occurrence of product innovations

$y_{3i,t-1}$ is past labour productivity

$x_{1\,it}$ is past R&D and other firm- and market-specific characteristics

α_{1i} is unobserved firm heterogeneity

ϑ_{11}, ϑ_{13}, β'_1 are corresponding coefficients

$\varepsilon_{1\,it}$ denotes idiosyncratic errors encompassing other time-varying unobserved variables that affect y^*_{1it}.

Another equation considers innovative sales as the dependent variable. The function is represented below.

$$y^*_{2it} = \vartheta_{22}y_{2i,t-1} + \vartheta_{23}y_{3i,t-1} + \beta'_2 x_{2\,it} + \alpha_{2i} + \varepsilon_{2\,it} \qquad (4.11)$$

where

y^*_{2it} is a latent variable denoting the firm's share of innovative sales or potential innovation intensity at period *t*

$y_{2i,t-1}$ is past observed innovation intensity

$y_{3i,t-1}$ is past labour productivity

$x_{2\,it}$ is past R&D and other firm- and market-specific characteristics

α_{2i} is firm-specific effect

ϑ_{22}, ϑ_{23}, β'_2 are corresponding coefficients

$\varepsilon_{2\,it}$ denotes idiosyncratic errors.

In terms of the productivity function, "the most ubiquitous form in the theoretical and empirical analyses of grow and productivity" is the Cobb-Douglas production function (Felipe & Adams 2005, p. 428). This function is central to much of the empirical work on economic growth, technological change, innovation, and productivity. As a production function, it defines the economic output that can be produced for a given level of inputs, i.e. labour and capital, at a given level of technology. The Cobb-Douglas function is the core of the Solow-Swan model (see section 2.3.1.1 for model specifications). The two main features of the Cobb-Douglas production function are constant returns to scale and decreasing marginal returns to factor accumulation (Cobb & Douglas 1928). Contemporary research has redefined the traditional Cobb-Douglas production function to explicitly incorporate a measure of technical progress and also capture the time trend. As Miller (2008, p. 7) recommends, the major strengths of this function are "… its ease of use and its seemingly good empirical fit across many datasets". Further, an augmented Cobb-Douglas production function can be used for both cross section and panel data

(Black & Lynch 2001). Given its usefulness, several empirical studies have applied the Cobb-Douglas production function to examine the innovation and productivity relationship, for example, Crépon et al. (1998) in their seminal paper on the CDM model, Calza et al. (2019), Parisi et al. (2006), Raffo et al. (2008), Siedschlag and Zhang (2015), and Taveira et al. (2019).

As in the vast majority of work in this area, Raymond et al. (2015) apply the augmented Cobb–Douglas production function to represent the link between productivity and innovation output and other production related factors, controlling for industry and time effects. The function is specified as follows:

$$y_{3it} = \vartheta_{33} y_{3i,t-1} + \beta'_3 x_{3\,it} + \gamma_j y^*_{jit} + \alpha_{3i} + \varepsilon_{3\,it} \quad (4.12)$$

$$y_{3it} = \vartheta_{33} y_{3i,t-1} + \beta'_3 x_{3\,it} + \gamma_j y_{jit} + \alpha_{3i} + \varepsilon_{3\,it} \quad (4.13)$$

where

y_{3it} is labour productivity at period *t*

$y_{3i,t-1}$ is past labour productivity

$x_{3\,it}$ is past R&D and other firm- and market-specific characteristics

$j = 1$ or 2, y^*_{1it} is innovation propensity or y^*_{2it} where the potential innovation propensity explains labour productivity in equation (4.12), $y_{1it}$is innovation occurrence or y_{2it} where the observed innovation intensity explains labour productivity in equation (4.13)

$\vartheta_{33}, \beta'_3, \gamma_j$ are corresponding coefficients

α_{3i} is time-invariant firm effects

ε_{3it} denotes idiosyncratic errors.

The model was then fitted into the Dutch and French CIS data on manufacturing firms over three time periods: 1994 to 1996, 1998 to 2000 and 2002 to 2004. The model results indicate that (i) product innovations are determined by R&D activities undertaken continuously during the previous two to four years and the intensity of these activities, (ii) labour productivity is significantly influenced by the occurrence and the intensity of product innovation, but not past productivity, rejecting the hypothesised feedback effect (Raymond et al. 2015).

The dynamic aspects of the innovation process have also been examined in Peters et al. (2017), who developed a dynamic, structural model of discrete R&D investment and quantified R&D cost and long-run benefits among German manufacturing firms. The model linked R&D choice, product and process innovations and future productivity and profits. It took advantage of the CDM framework to specify the firm's decision to invest in R&D as a solution to a dynamic optimisation problem that takes into account the costs incurred and the expected long-run benefit resulting from the innovative investment. The results revealed that, while firms investing in R&D had a higher probability of product or process innovation, R&D investment was 'neither necessary nor sufficient for firm innovation' (Peters et al. 2017, p. 410). Innovation increases future productivity, but product innovations are more important in high-tech industries, whereas process innovations are more important in low-tech industries since innovation cost is smaller for small firms.

4.2.4. The generalised structural equation model approach

Baum et al. (2017) proposed a new approach to estimate the R&D–innovation–productivity relationship. They employed a generalised structural equation model using the full-information maximum likelihood estimator. This approach allows the entire CDM model to be estimated as one system with the parameter estimates differing across technology and knowledge sectors. It also takes into account the possible cross-equation correlations of the errors. A selection equation is first implemented to analyse the likelihood that a firm will undertake innovative activities. This is then combined with three linear regression equations. Another important focus of the present research is on whether heterogeneity exists across sectors. The empirical model is specified below.

$$PRP2_{it} = \beta_{0s} + \beta_{1s} logL_{it} + \beta_{2s} logk_{it} + \beta_{3s} Ms_{it} + \beta_{4s} Mf_{it} + \beta_{5s} Smr_{it} + \beta_{6s} logIm_{it} + \beta_{7s} SD_{it} + \mathcal{L}_{it} + \varepsilon_{it} \quad (4.14)$$

where

PRP2 is the observed dichotomous indicator for the probability to be a P2 firm

logL is the firm size (number of employees)

log_k is the physical capital per employee

Ms is the market share

Mf is a dummy variable for presence in foreign markets

Smr is a dummy variable for location

log_{Im} is imports per employee

SD are sector indicators

$\mathcal{L}$ is a latent variable capturing unobserved factors.

$$logrd_{it} = \gamma_{0s} + \gamma_{1s} logIp_{i,t-1} + \gamma_{2s} logk_{it} + \gamma_{3s} Pat_{i,t-1} + \gamma_{4s} Ms_{it} + \gamma_{5s} Mf_{it} + \gamma_{6s} Smr_{it} + \gamma_{7s} ImG7_{it} + \gamma_{8s} \mathcal{L}_{it} + \gamma_{st} + \epsilon_{it} \quad (4.15)$$

where

log_{rd} is innovation input (R&D expenditures)

lp is the labour productivity

Pat is an indicator of positive number of patent applications in each year

ImG7 is the import fraction from G7 countries

logk, Ms, Mf, Smr, $\mathcal{L}$ are defined as in equation (4.14).

$$\text{log}is_{it} = \delta_{0s} + \delta_{1s} \text{log}rd_{it} + \delta_{2s} k_{it} + \beta_{3s} Ms_{it} + \beta_{4s} Smr_{it} + \delta_{5s} \mathcal{L}_{it} + \delta_{st} + v_{it} \quad (4.16)$$

where

log_{is} is innovation output, i.e. innovation sales

logrd_{it}, k_{it}, Ms_{it}, Smr_{it}, $\mathcal{L}_{it}$ as defined in equation (4.14) and (4.15)

$$logIp_{i,t} = \lambda_{0s} + \lambda_{1s} logis_{it} + \lambda_{2s} logL_{it} + \lambda_{3s} logK_{it} + \lambda_{4s} hc_{it} + \lambda_{5s} Ms_{it} + \lambda_{6s} Smr_{it} + \lambda_{7s} Own_{it} + \lambda_{st} + \zeta_{it} \quad (4.17)$$

where

log_{Ip} is labour productivity

hc is human capital

logK is physical capital

Own is corporate ownership structure

log_{is} as defined in equation (4.16), *logL, Ms, Smr* as defined in equation (4.14).

For all equations, *i* refers to firm, *s* to sector and *t* to time; β, γ, δ, λ are corresponding coefficients; ε, ϵ, v, ζ are error terms; γ_{st}, δ_{st}, λ_{st} are sector–year fixed effects. Lagged labour productivity $logIp_{i,t-1}$ in equation (4.15) represents the feedback from firm performance (equation 4.17) to the firm's innovation efforts.

A panel of 7,083 Swedish manufacturing and service firms in the period of 2008 to 2012 was fitted into the model. The results revealed that firm size, market share, foreign market presence and imports positively affected innovation probability. The positive impact of lagged labour productivity was evident across all sectors. Domestic market share and location were found to affect innovation performance. In addition, while the elasticity estimates for R&D expenditure were positive and significant in all sectors, the effect of capital intensity varied among sectors. The effect of human capital, market share and location also varied across sectors. The results provide evidence of sectoral heterogeneity, due to the differences in technology and knowledge intensity across economic sectors (Baum et al. 2017). The findings of Baum et al. (2017) and Peters et al. (2017) suggest the need to consider sectoral differences and dynamic aspects of the interrelationship between R&D–Innovation–Productivity.

4.2.5. Choice of approach

As reviewed in previous sections, a growing body of empirical literature has investigated the innovation–productivity relationship, with several methods and approaches being developed. Of most importance, the CDM model (Crépon et al. 1998), inspired by the KPF model (Griliches, 1979), has been recognised worldwide (Lööf et al. 2017). Its flexibility in exploiting unique features of various countries' data in a comparable setting and its capacity to integrate the innovation process and firm productivity from an empirical perspective have been proven (García-Pozo et al. 2018; Roberts & Vuong, 2013). Therefore, the CDM model is considered 'the workhorse in the empirical literature on innovation and productivity' at the firm level using innovation survey data (Lööf et al. 2017, pp. 1–2).

In recent years, some new models/approaches have been proposed to analyse the innovation and productivity relationship. These include dynamic models, for example, Raymond et al. (2015) (section 4.2.3), or generalised structural equation models, for example, Baum et al. (2017) (section 4.2.4). These models were built upon the CDM model, while considering the dynamic aspects and improving its estimation to apply for panel data, rather than just cross-sectional estimation. It should be emphasised that the CDM model/framework remains the backbone in almost every study analysing the innovation and productivity relationship, with subsequent approaches improving and advancing the CDM model. Given its significance and worldwide recognition in empirical innovation research, the CDM model approach is adopted as a method for identifying key variables and the relationship between innovation and productivity. This also facilitates the development of the conceptual framework in the next section and subsequently the econometric model for the present study in chapter 5.

4.3. CONCEPTUAL FRAMEWORK

As discussed in previous sections, the CDM framework developed by Crépon et al. (1998) has proven its significance in empirical innovation research. Therefore, the CDM framework was used as a foundation to develop the conceptual framework in the present study. Given this foundation, the framework for studying SMEs' innovation process in this study is built upon the existing literature, taking into account the availability of the variables provided in the database and the distinct nature of SMEs. As discussed in section 3.2.2, the original CDM framework used R&D as the key innovation input determining innovation outcome. However, in the case of SMEs, the vast majority of firms do not undertake or report R&D (Czarnitzki & Hottenrott 2011; Hervas-Oliver et al. 2011, 2016), especially in Australia (ISA 2020). Thus, based on the reviewed literature, this study proposes other innovation inputs relevant to SMEs rather than using R&D. These inputs include training, collaboration, ICT investment, financial support and innovation focus. In addition to innovation inputs, the framework also incorporates two other groups of factors that are likely to influence innovation outputs. These include (i) firm characteristics, i.e., firm size,[29] firm age, ownership and exports and (ii) external environment, i.e., market competition and sectoral effect.

Innovation outcomes in the original CDM are measured by patents or innovative sales (Crépon et al. 1998). These concepts are for technological innovation and more relevant for the manufacturing context in which the CDM framework was developed. However, with SMEs' distinct nature, characterised by flexibility, market proximity and resource scarcity, non-technological innovation has recently been found to be of great importance (Expósito & Sanchis-Llopis 2018; Radicic & Djalilov 2019). Thus, in this study, innovation outputs are not only technological innovation (new or significantly improved products or processes); they are also extended to involve non-technological innovation (new or significantly improved organisational processes or marketing methods). This coverage provides a compatible foundation for analyses across the three economic sectors (i.e. primary, manufacturing and service), rather than just focusing on manufacturing. The final stage of the CDM framework remains the same—innovations impact firm productivity. The conceptual framework for the present study is depicted in Figure 4.2. This framework is aligned with the second and third objectives of the thesis, which are

[29] Firm size was the only firm characteristic variable in the original CDM framework.

(i) to identify and quantify the determinants of SME innovation outputs and (ii) to estimate the impacts of innovation outputs on SME productivity across sectors.

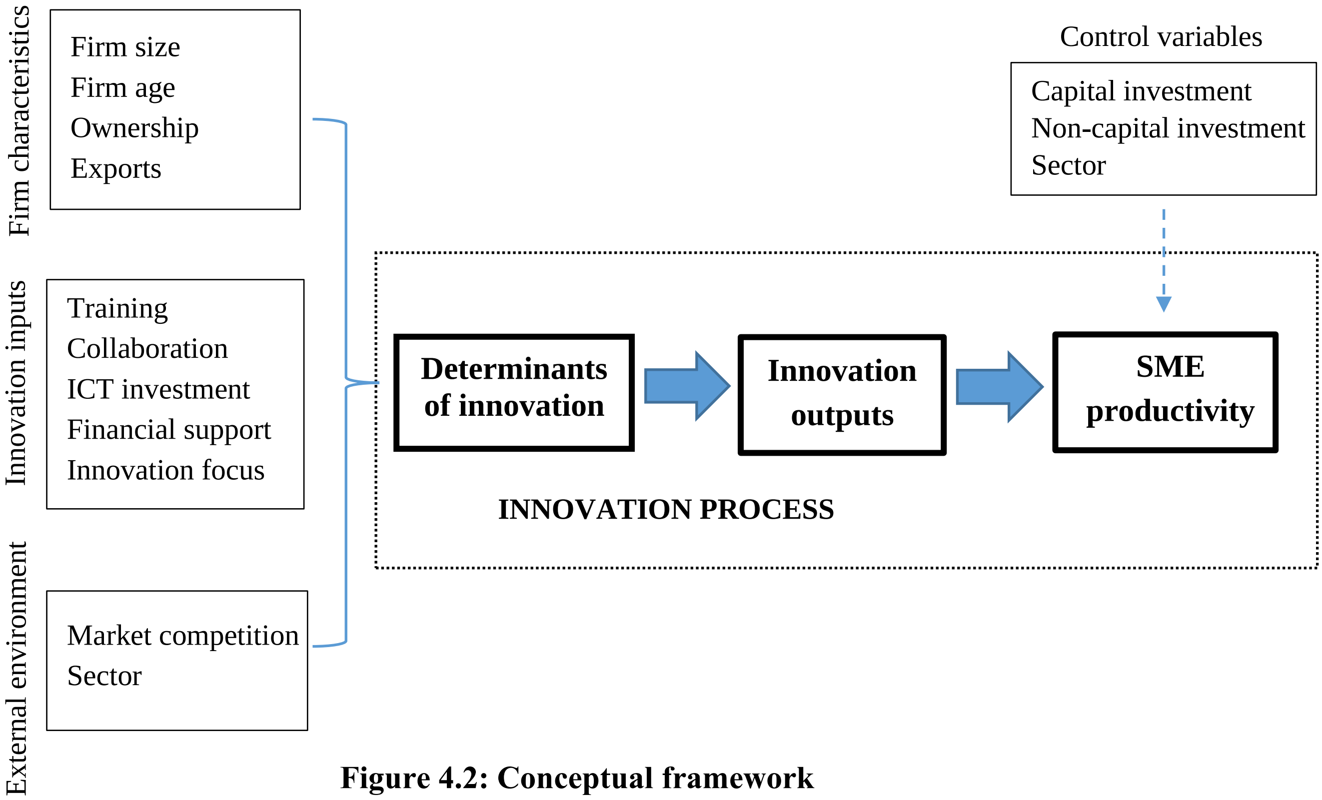

Figure 4.2: Conceptual framework

To summarise, the above framework includes two stages. In the first stage, SMEs invest in innovation inputs with the aim of generating innovation outputs. In addition to innovation inputs, firm characteristics and external environment might also be the determinants which concurrently influence SME innovation outputs. The innovation process is the transformation from innovation inputs into innovation outputs, which can be technological or non-technological innovations, bearing the influence of firm characteristics and external environment. In the second stage, the introduction or implementation of innovation outputs is likely to increase productivity for SMEs. Along with innovation outputs, capital and non-capital investments might affect SME productivity. Sectoral differences are also likely to affect the productivity of SMEs across sectors. This conceptual framework lays a foundation for developing the econometric model in section 5.4.1.

4.4. RESEARCH HYPOTHESES

Based on the framework and the objectives of the study, the general research hypotheses are developed. These hypotheses are used to test the aggregate dataset model. At the sectoral level, the significance, sign of the hypothesised factors and the magnitude of their impact could be heterogeneous from sector to sector due to the possibility of sectoral differences.

4.4.1. Innovation inputs and innovation output

Human capital has long been recognised as one of the most valuable resources of a firm. Investments in education and training for employees are ways to increase the stock of human capital (Morris 2018). In the SME context, available evidence shows formal training leads to improved innovation performance (McGuirk et al. 2015; Sheehan 2013). The review of prior research has revealed that training for employees is more likely to enhance the firm's innovation capability. Therefore, the following hypothesis is proposed:

H1: *Training has a positive effect on SME innovation outputs.*

Collaboration allows firms to gain access to resources and technologies which are important to SMEs constrained by resource scarcity. It further enables firms to acquire knowledge, experience and information from their partners (Chesbrough 2017) and reduce the costs of innovation development and risks of failure (Hagedoorn 1993). As Greco et al. (2015) and Vahter et al. (2014) find, collaboration is associated with higher innovation performance in SMEs. Given its substantial benefits, collaboration would be a contributor to innovation output in SMEs. This forms the basis for the following hypothesis:

H2: *Collaboration for innovation has a positive effect on SME innovation outputs.*

The use of ICT has been recognised as key to innovation capability (Giotopoulos et al. 2017) and SMEs' survival and competitiveness (Higón 2011; Parker & Castelman 2007). ICT investment fosters SME innovation by enhancing process efficiency and facilitating flexibility in business structures (Higón 2011). ICTs creates substantial opportunities for re-engineering, facilitates communication and coordination and enables e-commerce (Koellinger 2005). Therefore, an increase in ICT investment would facilitate SME innovation. Accordingly, the following hypothesis is postulated:

H3: *ICT investment has a positive effect on SME innovation outputs.*

The act of undertaking innovation often requires large amounts of financial resources (Hall & Lerner 2010; Hashi & Stojcic 2013). However, SMEs are known to have limited finance, which acts as a major obstacle in conducting innovation (Antonioli & Torre 2016; Savignac 2008). Empirical evidence shows that receiving financial support is crucial to SMEs' innovation performance (Divisekera & Nguyen 2018a, b; Romero-Martínez et al. 2010). Finance is, therefore, a crucial input to innovation development and implementation in SMEs. This leads to the following hypothesis:

H4: *Financial support has a positive effect on SME innovation outputs.*

A firm's strategy or culture that encourages and supports new ideas, experimentation and creative processes is a prerequisite for innovation to occur (Aksoy 2017; Halim et al. 2015). As De Jong (2011) asserts, a firm's strategic focus on innovation prioritises new developments as a key goal in the organisation. They encourage new ideas and dedicate resources and effort to develop innovation (Branzei & Vertinsky 2006). For SMEs, this focus provides an effective response to overcome liabilities associated with their smallness (Rosenbusch et al. 2011). Thus, the following hypothesis is proposed:

H5: *Innovation focus has a positive effect on SME innovation outputs.*

4.4.2. Firm characteristics and innovation outputs

Firm size reflects access to financial and human resources (Crespi et al. 2016; Skuras et al. 2008). Small firms have limited resources and time, which prevents them from investing in innovation (Hjalager 2010; Rosenbusch et al. 2011). In contrast, larger firms often have higher innovation capability because of greater resources, economies of scale in technology and learning and better management expertise (Hewitt-Dundas 2006). Further, larger firms also have more opportunities to innovate as they are involved in a wider range of activities and projects (Mohnen and Hall 2013). Given the substantial advantages associated with larger firms, the following hypothesis is formulated:

H6: *Firm size has a positive influence on SME innovation outputs.*

The effect of firm age on innovation is mixed (OECD & Eurostat 2018). On theoretical grounds, a higher innovation capability by mature firms occurs given their larger stock of knowledge and experience accumulated over time (Arrow 1962; Romer 1986). Yet, available empirical research in the SME context shows younger SMEs are more flexible in creating new processes and pursuing innovation opportunities (Rosenbusch et al. 2011; Salavou et al. 2004). Informed by prior empirical research on SME innovation, the present study proposes to test the following hypothesis:

H7: *Firm age has a negative influence on SME innovation outputs.*

Foreign ownership is likely to influence innovation due to their advantages in accessing advanced technologies, resources, worldwide information, market opportunities and international experience (Nordman & Tolstoy 2016). Foreign-owned firms tend to be more innovative than domestic firms (Gërguri-Rashiti et al. 2017). Corsi and Prencipe (2018) also report a positive influence of foreign ownership on SME innovation. Given the advantages of foreign ownership, the following hypothesis is proposed:

H8: *Foreign ownership has a positive influence on SME innovation outputs.*

Exports have been found to affect firm innovation (Gërguri-Rashiti et al. 2017). Exporters possess a range of advantages such as access to advanced technologies, foreign knowledge spillovers, international network and higher capacity utilisation because of economies of scale (Criscuolo et al. 2010). Studies by McMahon (2001) and Tuhin (2016) in the SME context demonstrate higher innovation performance by exporters compared with non-exporters. Thus, the following hypothesis is proposed:

H9: *Exports have a positive influence on SME innovation outputs.*

4.4.3. External environment and innovation output

The relationship between market competition and innovation has long been debated in the literature. The present study favours a positive impact of competition. Several studies confirm that the intensity of competition in the market is a driving force of innovation (Pirnar et al. 2012; Soames et al. 2011). Intense competition puts firms under pressure to introduce new products or implement more cost-effective processes (Aghion & Howitt 2009; Soames et al. 2011). Thus, competition is likely to stimulate SMEs to innovate to stay ahead of their competitors. These arguments lead to the following hypothesis:

H10: *Market competition has a positive impact on SME innovation outputs.*

As proposed by evolutionary theorists, sectoral differences are likely to influence innovation (Malerba 2006; Nelson & Winter 1974). Of the limited available sectoral studies, Damanpour (1996), Gallego et al. (2015) and De Fuentes et al. (2019) contend that there are differences in innovation patterns between the manufacturing and service sectors. Empirical evidence in the SME case is scant. Based on findings from previous studies in the broader innovation literature, the following hypothesis is proposed:

H11: *Sector has an impact on SME innovation outputs.*

4.4.4. Innovation outputs and firm productivity

According to Schumpeter (1934), innovation yields income, reorganises production processes, enabling firms to lower costs and to achieve greater efficiency and productivity. The broader innovation literature found a positive relationship between innovation and firm productivity (e.g. Chudnovsky et al. 2006; Crespi & Zuniga 2012; Lee & Kang 2007). Evidence in the SME context is limited and mainly focuses on technological innovation, neglecting non-technological innovation. A positive impact of technological innovation on productivity of manufacturing SMEs was found by Van Auken et al. (2008), Mañez et al. (2013), Hall et al. (2009) and Calza et al. (2019), while Aboal and Garda (2016) reported the effect of non-technological innovation to be positive for small service firms. Given these findings in relation to SMEs, the following hypotheses are proposed:

H12a: *Technological innovation has a positive impact on SME productivity.*

H12b: *Non-technological innovation has a positive impact on SME productivity.*

4.5. SUMMARY

The main aim of this chapter was to review common approaches and methods used to analyse the innovation and productivity relationship, in order to select the most appropriate approach and develop a conceptual framework for the present study. The review of prior research on innovation and productivity highlighted the significance and appropriateness of the CDM framework in empirical innovation literature. Using the CDM as a foundation, the conceptual framework for the study was built, taking into account the research objectives and availability of innovation data in Australia and the features of the Australian economy. The framework illustrates the two core stages of the innovation process: (i) innovation inputs influencing innovation outputs and (ii) innovation outputs affecting SME productivity. Based on the conceptual framework developed in this chapter and the literature in Chapter Two, research hypotheses were proposed for testing in Chapter Six.

CHAPTER FIVE:
DATA AND THE MODEL

5.1. INTRODUCTION

The aim of this chapter is to present the key sources of innovation data, the model and estimation approach employed for econometric analysis in chapter six. The chapter begins with an overview of the Community Innovation Survey (CIS), which is the most commonly used innovation survey at the international level. This is followed by the presentation and discussion of the Business Characteristics Survey (BCS) used to collect innovation data in Australia. The next section provides details of the panel data used for the econometric analysis in this thesis, measurements of variables and descriptions of the sample. The empirical model is then specified, followed by discussion of commonly used approaches to estimate the relationship between innovation and productivity. Finally, the modelling strategy is presented.

5.2. INNOVATION DATA

5.2.1. The Community Innovation Survey

The CIS is a series of surveys focussing on firms' innovation activities across different sectors and regions in Europe. This harmonised innovation survey is conducted every two years across the European Union (EU), European Free Trade Association as well as EU candidate countries. Microdata collected from the CIS is broken down by countries, business size, types of innovators, and economic activities. CIS data enables estimates on innovation related indicators of businesses in the 28 countries in the EU (ABS 2017a). It is seen as an important vehicle enhancing a better understanding of firms' innovation process and the impacts of innovation, which facilitates Europe's development, particularly in innovation aspects. Results from the CIS can be linked to other economic variables such as competitiveness, employment and economic growth of the country. For comparability purposes across countries, the Eurostat in cooperation with EU countries developed a standard core questionnaire accompanied by a set of definitions and methodological recommendations. The statistical concepts and core methodology used in the CIS are based on the *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data* (OECD & Eurostat 2005). As discussed in chapter two, the Oslo Manual is the most widely used and internationally recognised guideline for collecting innovation data.

In terms of CIS's characteristics, it is a standalone innovation questionnaire in which only questions regarding innovation are asked, apart from some basic demographic questions (ABS 2017a). Various editions of the CIS have been carried out with the first CIS being CIS1 in 1992 and the latest development being CIS 2014.[30] The current CIS provides a range of information on the characteristics of innovation activities at the firm level, on different types of innovation, i.e. product, process, organisational and marketing, and numerous aspects of innovation development, such as objectives, sources of information, R&D activities, public financial support, innovation expenditures, co-operation for innovation activities, and intellectual property rights and licensing. Further information on business activities may be covered on a voluntary basis in national datasets according to the countries' interests.

The target population of the CIS is non-government organisations, including all businesses within the relevant countries, with at least 10 employees. Stratified sampling is conducted in most countries, with a few countries using a census or a mix of census and sample survey to collect data. The target population is broken down into strata based on size and economic activity classifications (Eurostat 2016). The CIS classifies businesses using the International Standard Industrial Classification of All Economic Activities (United Nations Statistics Division, 2017). Businesses are also divided into three size categories according to the number of employees (Eurostat 2016).

(i) Small businesses with 10-49 employees

(ii) Medium-size businesses with 50-249 employees

(iii) Large businesses with 250 employees or more

The main data collection methods are via online or mail surveys. A few countries also collect data using face to face interviews. Participation in the CIS varies across countries since it is conducted on a voluntary basis in some countries, yet with large businesses being mandatory respondents such as Austria or United Kingdom, or on a 100 percent

[30] All CIS versions can be found at https://circabc.europa.eu/ui/group/47133480-29c1-4c23-9199-72a631f4fd96/library/bfcf3592-83a3-4066-ab70-f9a5cf492253

voluntary basis (ABS, 2017). The reference period used in the CIS is three calendar years, i.e. businesses report innovation or activities that took place over a three-year period, rather than each year. Due to this feature, analyses using CIS data is limited to a cross-sectional setting and that "firm-level data cannot be longitudinally merged" (Damijan 2017, p. 586). Nevertheless, given the large scale and substantial information it provides, CISs are the most widely used survey data in empirical innovation research (ABS, 2017).

5.2.2. The Business Characteristics Survey

The BCS is an annual survey, conducted by the ABS. The BCS collects key measures on characteristics of Australian businesses and data related to innovation activities and information technology, enabling the production of Characteristics of Australian businesses, Innovation in Australian Business, and Business Use of Information Technology Survey. The BCS provide firm-level information on a large economy scale, which facilitates a better understanding of the business characteristics, practices, behaviours and strategies that affect innovation and firm performance. Given the extensive information it provides, the BCS is regarded as a vehicle for assisting government and industry bodies to develop and implement more relevant and effective policies to support Australian businesses, particularly SMEs (ABS, 2017).

The first BCS was conducted in 2004-05 to collect data on business characteristics only. In 2005-06, the ABS carried out the first integrated BCS survey, combining information on general business characteristics with other items collected in the Business Use of Information Technology Survey and in the Survey of Innovation in Australian Business (ABS 2014). The 2006-07 BCS survey collected more detailed innovation data while the core IT and business characteristics content remained comparatively unchanged since 2006-07. The consistent set of core questions in the BCS allow comparison over time. Unlike the CIS that only gathers information on innovation and some basic demographics, the coverage by the BCS includes a wide range of information such as business structure and arrangements, general business activities, government financial assistance, finance sought, collaborative arrangements, IT usage, markets and competition, innovation activities, barriers to innovation, and performance measures.

For innovation-related questions, the BCS, similar to the CIS, adopts statistical concepts and main methodology defined by the Oslo Manual: *Guidelines for Collecting and Interpreting Innovation Data* (OECD & Eurostat, 2005). However, the reference period used in the BCS is one financial year, whereas the CIS uses three calendar years. Although the two surveys use different reference period, they both adhere with Oslo Manual recommendation that "the observation period for innovation surveys should not exceed three years or be less than one year" *Data* (OECD & Eurostat, 2005, p. 61). One advantage of the one year reference period used in the BCS is that it allows observations of innovation activities and its impact over times, which enables longitudinal analyses.

The focus of the BCS is on the market sector of the economy, including all business sizes, rather than excluding firms with less than 10 employees as the CIS. The reason for including firms with 0 to 9 employees[31] is to reflect the importance of small businesses in the Australian economy and depict a better picture of innovation activities in Australia (ABS 2017a). Data is collected via online forms or mail-out questionnaires. The survey sample is stratified by industry and an employment-based size indicator. Participation in the BCS is "compulsory for all selected business entities", which results in high response rates (ABS, 2017, p. 9). Businesses in the Australian population are classified based on the Australian and New Zealand Standard Industrial Classification (ANZSIC, 2006). In terms of firm size, businesses are categorised based on a stratification derived from employment size as follows (ABS 2019c):

(i) Small businesses are those employing fewer than 20 persons, comprising:
- non-employing businesses (sole proprietorships and partnerships without employees)
- micro businesses (businesses with 1 to 4 employees)
- other small businesses (businesses with 5 to 19 employees).

(ii) Medium businesses are those with 20 to 199 employees.

(iii) Large businesses are those with 200 or more employees.

The data collected from the BCS is the key input to the BLD. The scope of the BLD is actively trading businesses in the Australian economy which are registered for an Australian Business Number and remit Goods and Services Tax. The BLD includes both non-employing and employing businesses, but exclude large businesses which employ 200 persons or more (ABS, 2019f). The reason for this exclusion is to ensure the confidentialisation process since large businesses are more likely to be identified easily

[31] According to the ABS (2017), firms with 0 to 9 employees constitute around 18% of firms in scope for the BCS.

compared with smaller ones. The BLD also excludes some industries, which are primarily dominated by government organisations or categorised as non-profit institutions serving households, which are less important from an industry policy standpoint. The industries are as follows (ABS, 2019f).

- Electricity, Gas and Water (Division D)
- Financial and Insurance Services (Division K)
- Public Administration and Safety (Division O)
- Education and Training (Division P)
- Health Care and Social Assistance (Division Q)
- Other Services (Division S, Group 954, 955 and Sub-division 96)

The dataset is populated from administrative data provided to the ABS by government agencies for statistical and research purposes. The database is designed for longitudinal and micro-level comparisons, with each dataset comprising data from the same businesses over a period of five years. As the ABS (2019) notes, the BLD sample is "… not allocated to enable the creation of population or cross-sectional estimates with any reasonable accuracy". As its aim is to facilitate longitudinal analysis, the BLD design ensures enough sample is included in each panel and that sufficient live sample remains in each stratum at the end of the five-year period. The sample size is approximately 2,000- 2,500 businesses per panel. Given the substantial firm-level data and large number of SMEs included in the BLD, this database is the most appropriate available longitudinal dataset to be used in this present study.

5.3. DATA AND SOURCES FOR THE PRESENT STUDY

5.3.1. The five-year panel data: Business Characteristics 2011–12 to 2015–16

The econometric analysis for the current study uses the BLD Confidentialised Unit Record File (CURF) dataset, particularly the *Microdata: Business Characteristics, Australia, 2011–12 to 2015–16*, released in 2019 by the ABS. As aforementioned, the key input to the database is the BCS, which collects data on innovation activities undertaken by Australian firms across various industries and economic sectors. This database also contains characteristics of businesses such as business structure and operations, market and competition, finance and firm performance (ABS, 2019f). Given the extensive information the database provides, it is appropriate to analyse the innovation processes across Australian sectors.

The sample was selected from a survey frame created by the ABS in June 2012. A total of 926,088 firms were eligible for the sample selection. The sample for the dataset used in this study includes 1,967 SMEs. This dataset contains a set of five reference periods of data, i.e. 2011-12, 2012-13, 2013-14, 2014-15 and 2015-16. As per the ABS(2019f), the questions and measures of variables in this BLD are held the same over this five-year period in order to enable longitudinal and micro-level comparisons.

The dataset used comprises 13 Australian industries classified based on the ANZSIC (2006), excluding six industry divisions as stated previously in section 5.2.2. These thirteen industries are grouped into three economic sectors for sectoral analysis purposes in this thesis. In terms of service industry classification, service firms can be classified based on the specific features of their economic activities and knowledge base (Castellacci 2008; De Fuentes et al. 2019; Martin-Rios & Ciobanu 2019). Accordingly, the three service industry divisions are: (i) Knowledge-Intensive Business Services (KIBS), (ii) Supporting Infrastructure Services (SIS) and (iii) Supplier-Dominated Services (SDS). This classification is used for econometric analysis in Chapter Six. The three economic sectors under study are classified as follows:

1. Primary Sector: Agriculture, Forestry, Fishing; and Mining
2. Secondary Sector: Manufacturing
3. Service Sector:
    i. KIBS: Professional, Scientific and Technical Services; Administrative and Support Services
    ii. SIS: Wholesale Trade; Transport, Postal and Warehousing; Information Media and Telecommunications; Rental, Hiring and Real Estate Services
    iii. SDS: Construction Services; Retail Trade; Accommodation and Food Services; and Arts and Recreation Services.

It should be noted that R&D-related data were excluded from the Microdata: Business Characteristics by the ABS, and were thus unavailable to university researchers.[32] However, as pointed out in Chapter Two, R&D activities are typically conducted by large firms, whereas the vast majority of SMEs and service firms do not invest in R&D

[32] R&D data are available only for authorised government employees, government contractors and individuals sponsored by the government for specific projects.

expenditures (Aboal & Garda 2016; Ortega-Argilés et al. 2009). As the ISA (2020) emphasises, SMEs in Australia invest heavily in non-R&D innovation rather than R&D. Since the majority of SMEs do not undertake R&D (Czarnitzki & Hottenrott 2011; Hervas-Oliver et al. 2016), the innovation process in SMEs can be explained using non-R&D variables (Hervas-Oliver et al. 2011; Rammer et al. 2009).

5.3.2. Variable treatment and definition

The concepts and definitions used to measure innovation in the BCS/BLD are in accordance with the 3rd Oslo Manual (OECD & Eurostat, 2005). The choice of variables for empirical analysis was not only driven by the reviewed literature but governed by the availability of the data and their relevance to the research objectives. The extracted BCS questionnaire is included in the Appendix. Table 5.1 provides definitions and measurements of variables used in the empirical analysis in Chapter Six. The following explains how the variables used for the econometric analysis are treated.

Most of the items included in the BCS/BLD are categorical in nature, i.e. require a yes/no response. It should be noted that missing values and businesses which selected 'not applicable' are excluded from the dataset since these provide no meaningful information for any analyses. This treatment applies to all variables. Innovation output variables are all binary variables, taking the value of 1 if the firm introduced/implemented a given type of innovation, e.g. product (good or service), process, organisational, or marketing, and 0 if they did not. As discussed in chapter 2, product and process innovation can be grouped as technological innovation, while organisational and marketing innovation are classified as non-technological innovation (Aboal and Garda 2016; De Fuentes et al. 2019; Gallego et al. 2015; Geldes et al. 2017; Mothe and Nguyen 2012; OECD 2009; Peters et al. 2018). Accordingly, two new binary variables are created, (i) technological innovation, taking the value of 1 if the firm introduced product and/or process innovation, and 0 if otherwise, and (ii) non-technological innovation, taking the value of 1 if the firm implemented organisational and/or marketing innovation, and 0 if otherwise.

Table 5.1: Variable definitions

Variables	Definitions
Technological innovation	Binary variable, 1 = product and/or process innovation, 0 = otherwise
Non-technological innovation	Binary variable, 1 = organisational and/or marketing innovation, 0 = otherwise
Productivity	Binary variable, 1 = productivity increased compared with the previous year, 0 = otherwise
Firm size	Number of employees: 0 = non-employer, 1 = less than 5 employees, 2 = 5–19 employees, 3 = 20–199 employees
Firm age	Years of operation under current ownership
Ownership	Binary variable, 1 = some degree of foreign ownership, 0 = wholly Australian-owned
Exports	Binary variable, 1 = exporter, 0 = non-exporter
Financial support	Binary variable, 1 = received financial assistance from Australian government or private financing institutions, 0 = otherwise
ICT investment	Binary variable, 1 = increased IT expenditure, 0 = otherwise
Training	Binary variable, 1 = increased structured or formal training for employees, 0 = otherwise
Collaboration	Binary variable, 1 = engaged in collaboration for innovation purposes, 0 = no collaboration
Innovation focus	Binary variable, 1 = major focus on innovation, 0 = otherwise
Market competition	Degree of competition: 0 = no competition, 1 = 1–2 competitors, 2 = 3–4 competitors, 3 = 5 or more competitors
Sector	Economic sectors, 1 = primary, 2 = secondary, 3 = service
Capital investment	Amount (in AUD million) of capital expenditure
Non-capital investment	Amount (in AUD million) of non-capital expenditure

Source: Microdata: Business Characteristics, Business Longitudinal Database (ABS 2019f)

Of ordinal level questions, productivity, ICT investment, training and innovation focus variables were modified. Productivity, ICT investment and training are measured on the basis of 'increased', 'stayed the same' or 'decreased'. The aim of the analysis is to identify the drivers of improved/increased productivity. Thus, "productivity" is transformed into a binary variable, taking the value of 1 if the firm reported 'increased' productivity, and 0 if otherwise, implying that their productivity did not increase, i.e. 'decreased' or 'stayed the same'. Further, the empirical analysis' intent is to examine if increased investments in innovation inputs, i.e. ICT investment and training, result in innovation outputs. Hence, ICT investment and training are also transformed to binary variables, taking the value of 1 if the firm reported ‘increased’, and 0 if otherwise (either ‘stayed the same’ or ‘decreased’). These treatments are the same as that of Reeson and Rudd (2016) who also used the BLD data. The innovation focus variable is transformed to a binary variable, taking the value of 1 if the business’s focus on innovation to ‘a major extent’, and 0 if otherwise (e.g. ‘not at all’, ‘a small extent’ or ‘a moderate extent’). This treatment accords with Majeed et al. (2021) whose analyses also used the BLD data. Measures of other variables such as firm size, firm age, ownership, exports, financial support and market competition remain the same as in the BCS/BLD (see table 5.1).

To enable sectoral analyses, a ‘sector’ variable is created, taking the value of 1 = Primary Sector, 2 = Secondary Sector and 3 = Service Sector. This enables the creation of three separate datasets corresponding to the three economic sectors. In each sector dataset, except for the Secondary sector which contains only Manufacturing firms, a variable, namely ‘industry’, is created to control for the industry effect. In the Primary dataset, the ‘industry’ variable takes the value of 1 if the firm is in the Agriculture, Forestry, Fishing industry and 2 if it is in the Mining industry. In the Service dataset, the ‘industry’ variable takes the value of 1 = Knowledge-Intensive Business Services (KIBS), 2 = Supporting Infrastructure Services (SIS) and 3 = Supplier-Dominated Services (SDS).

5.3.3. Descriptive statistics of the sample

The dataset consists of 1,967 SMEs, with: (i) 268 (14 percent of the sample) firms in the primary sector (agriculture, forestry and fishing, and mining); (ii) 126 firms (6 percent) in the secondary sector; and (iii) 1,573 firms (80 percent) in the service sector. In Australia, the service sector represents over 70 percent of Australia’s GDP, employs 80 percent of the Australian workforce, and accounts for approximately 88 percent of total businesses in 2018–19 (ABS 2019a). In this study, service firms comprise 80 percent of the sample, which closely reflects the structure of the Australian economy as it is dominated by the service sector. Descriptive statistics of the aggregate sample are provided in table 5.2.

As shown in Table 5.2, non-employer firms account for 11.29 percent of the sample, 30.96 percent of firms have less than 5 employees, 30.18 percent have 5-19 employees and 27.57 percent are medium firms who employ 20-199 persons. Over the period under study, 32.60 percent of surveyed SMEs reported technological innovation and 34.88 percent reported non-technological innovation. In terms of productivity performance, 22.63 percent of SMEs in the sample gained increased productivity compared with the previous year. Further summary statistics, i.e. mean and standard deviation, for each variable used in each analysis are provided later in chapter six.

Table 5.2: Descriptive statistics of the sample

Variables		Variables	
Innovation inputs		**Firm characteristics**	
Employee training (%)	11.00	Firm size (%)	
Collaboration for innovation (%)	10.57	*Non-employer*	11.29
ICT investment (%)	19.28	*Less than 5 employees*	30.96
Government financial support (%)	15.20	*5–19 employees*	30.18
Debt or equity	17.30	*20–199 employees*	27.57
Major focus on innovation (%)	42.79	Firm age (mean)	11.92
		Foreign ownership (%)	5.47
Innovation outputs		Exporters (%)	12.61
Technological innovation (%)	32.60	**External environment**	
Non-technological innovation (%)	34.88	Competition (%)	
		No competition	12.86
Firm productivity		*1–2 competitors*	11.95
Productivity increases (%)	22.63	*3–4 competitors*	14.48
		5 or more competitors	60.71
Physical capital investment		Sectors (%)	
Capital expenditure ($m AUD) (mean)	0.14	*Primary*	13.62
Non-capital expenditure ($m AUD) (mean)	2.67	*Manufacturing*	6.41
		Service	79.97

Source: Derived from the Microdata: Business Characteristics (ABS 2019f)

The following table provides the correlation matrix for the independent variables used for the econometric analysis in the next chapter. As a general rule of thumb, if the correlation coefficient between two independent variables is larger than 0.8 or 0.9, there is a serious problem of multicollinearity (Midi et al. 2010; Senaviratna & Cooray 2019). Table 5.3 shows that the correlation coefficients for all pairs of independent variables are relatively low, with the highest being 0.3 which is between ICT and Training. This result confirms that none of the independent variables are highly correlated. Hence, there is no issue of multicollinearity among independent variables.

Table 5.3: Correlation matrix for independent variables

	Firm size	Firm age	Foreign ownership	Export	Financial support	Training	ICT	Collaboration	Innovation focus	Competition	Sector	Capital	Non-capital
Firm size	1												
Firm age	0.1231	1											
Foreign ownership	0.0966	-0.0467	1										
Export	0.0161	0.0507	0.2197	1									
Financial support	0.2264	0.0215	0.0412	0.0683	1								
Training	0.1777	-0.0235	0.0503	0.0575	0.1517	1							
ICT	0.1627	-0.0131	0.0481	0.0878	0.1466	0.3353	1						
Collaboration	0.0859	-0.0219	0.0913	0.1145	0.0751	0.1339	0.1700	1					
Innovation focus	0.1878	-0.0444	0.0394	0.1069	0.1255	0.1781	0.2326	0.1839	1				
Competition	0.1228	-0.0483	-0.0446	0.0223	0.0713	0.0660	0.1124	0.0369	0.1362	1			
Sector	-0.1075	-0.1109	-0.1119	-0.0723	-0.1018	0.0156	0.0189	0.0226	-0.0079	0.0791	1		
Capital	0.0865	0.0375	0.1177	0.0780	0.1016	0.0883	0.0703	0.0508	0.0609	-0.0094	-0.0391	1	
Noncapital	0.2724	0.0927	0.1711	0.1508	0.0895	0.1422	0.1605	0.0657	0.1190	0.0816	-0.1260	0.1571	1

Source: Derived from the Microdata: Business Characteristics (ABS 2019f)

5.4. THE MODEL AND ESTIMATION APPROACH

5.4.1. The empirical model and its specifications

Based on the research objectives and the conceptual framework developed in section 4.3, the study focuses on two equations of the CDM model: the innovation output equation and the productivity equation. The model is first fitted into the aggregate dataset. Then it is fitted into sector-specific datasets (i.e. primary, secondary and service). This is done to identify and quantify the determinants of innovation outputs (technological and non-technological) and estimate the impact of innovation outputs on firm productivity in the Australian economy and in each economic sector. The vast majority of empirical studies adopting the CDM model use cross-sectional data, except for recent studies such as those of Raymond et al. (2015), Baum et al. (2017), Morris (2018) and Taveira et al. (2019). The model developed for the present study also moves beyond the cross-sectional estimation by using a longitudinal panel dataset of Australian SMEs.

The present study uses the five-year panel dataset available from the ABS. As specified in previous section, all the dependent variables used in the analysis (i.e. technological innovation, non-technological innovation and firm productivity) are binary, taking the value of either 0 or 1. Given the panel structure and binary nature of the dependent variables, the study employs random effects probit regressions, as used by Palangkaraya et al. (2016) and Taveira et al. (2019). Random effects probit model is useful when analysing panel data with a binary dependent variable (Bland & Cook 2019). The model provides estimates for both time-invariant and time-varying covariates in the longitudinal case. As opposed to a pooled Probit, the specification of random effects is able to capture unobserved individual-specific factors that influence the likelihood of innovation outputs not captured in the regressors (Boto-García 2020). The likelihood ratio test, which compares the pooled estimator (probit) with the panel estimator, is also conducted for each model (aggregate, primary, secondary and service sectors) to assess whether the panel-level variance component is important. The use of such panel data model can account for unobserved firm heterogeneity, which cross-sectional analysis is unable to do (Morris 2018; Taveira et al. 2019). The use of longitudinal panel data analysis can account for unobserved firm heterogeneity, which cross-sectional analysis is unable to do (Morris 2018; Taveira et al. 2019).

The random effects probit regressions employed in this study estimate (i) the probability that a firm reported a given type of innovation output and (ii) the probability that a firm reported increased productivity compared with the previous year. The general form of the model is presented as follows.

For panel, i = , …, N indicating the individual firms, and t = 1, …, 5 indicating the time periods, the random effects probit regressions of the innovation outputs on their determinants, which take the value of 1 if the firm reported a form of innovation output and 0 if otherwise, is specified below.

For technological innovation:

$$y^*_{1it} = \beta_1 x_{1it} + \epsilon_{1it} + u_{1i} \tag{5.1a}$$

$$y_{1it} = \begin{cases} 1 \; if \; y^*_{1it} > 0 \\ 0 \; else \end{cases} \tag{5.1b}$$

For non-technological innovation:

$$y^*_{2it} = \beta_2 x_{2it} + \epsilon_{2it} + u_{2i} \tag{5.2a}$$

$$y_{2it} = \begin{cases} 1 \; if \; y^*_{2it} > 0 \\ 0 \; else \end{cases} \tag{5.2b}$$

where

y^*_{1it} and y^*_{2it} are unobserved latent variables; y_{1it} and y_{2it} are observed binary dependent variables representing technological and non-technological innovation, respectively

x_{1it} and x_{2it} are vectors of explanatory variables that determine innovation outputs

β_1 and β_2 are corresponding unknown parameters

u_{1i} and u_{2i} are the random effects, which are multivariate normal with mean 0 and covariance $\sum_u$

ϵ_{1it} and ϵ_{2it} are observation-level error terms, which are multivariate normal with mean 0 and covariance $\sum_\epsilon$.

The random effects probit regression of firm productivity on innovation outputs, which takes the value of 1 if the firm reported increased productivity and 0 if otherwise, is specified below.

$$y^*_{3i(t+1)} = \beta_3 \, y^*_{1it} + \beta_4 \, y^*_{2it} + \gamma x_{3it} + \epsilon_{3it} + u_{3i} \tag{5.3a}$$

$$y_{3i(t+1)} = \begin{cases} 1\ if\ y^*_{3it} > 0 \\ 0\ else \end{cases} \tag{5.3b}$$

where

$y^*_{3i(t+1)}$ is an unobserved latent variable

$y_{3i(t+1)}$ an observed binary dependent variable, representing firm productivity

y^*_{1it} and y^*_{2it} are from equation (5.1a) and (5.2a)

x_{3it} is a vector of control variables, namely, capital, non-capital investment and sector

β_3, β_4 and γ are corresponding unknown parameters

u_{3i} is the random effect, which is multivariate normal with mean 0 and covariance $\sum_u$,

ϵ_{3it} is an observation-level error term, which is multivariate normal with mean 0 and covariance $\sum_\epsilon$.

There is a generally held view that the impact of innovation is not always immediate (Rochina-Barrachina et al. 2010). It is suggested that innovation is likely to result in productivity growth, yet with some delay (Soames et al. 2011), proposing a time lag in the innovation and productivity relationship (Mohnen 2019). As reviewed in chapter two, most previous studies on innovation and productivity are based on cross-sectional data. Therefore, their analyses are unable to account for the time lag of innovation (Audretsch et al. 2020; Peters et al. 2017). Given this limitation, Audretsch et al. (2020) emphasise the need for longitudinal data to produce a more robust conclusion on a causal relationship between innovation and productivity. Taking the advantage of the BLD panel data, the present study is able to use a one year lag of the productivity measure to account for the time lag in the analysis of the innovation and productivity relationship. The specifications in equations 5.3a, b indicate that innovation outputs (in year *t*) are proposed to impact productivity of SMEs in the following year (*t + 1*).

It should be noted that most studies on this topic use an objective measure of firm productivity that is a continuous variable—real sales per worker (labour productivity) (e.g. Morris 2018; Taveira et al. 2019). However, relative sales data of Australian SMEs and their number of workers are not available in the BLD data. Consequently, firm productivity used in this study is measured by the ABS, based on a firm's subjective assessment of their performance. The dependent variable in equation (3.20b) is self-reported productivity by Australian SMEs' entrepreneurs or owners whether their firm productivity increased or not. The binary nature of the productivity variable and the panel structure of the dataset lead to the use of the random effects probit regression to estimate the impact of innovation on SME productivity, as specified above.

Self-reported productivity in the BCS questions has long been used in Australia. Numerous studies by academics, the ABS, Productivity Commission, and Australian Government using the BLD data have employed this measure of productivity in their studies. For example, the series of Australian innovation system reports from 2010 to 2017 by Australian Government, and empirical research on innovation and productivity by Reeson and Rudd (2016), Nguyen et al. (2021), and Soames and Brunker (2011). Subjective measures of firm performance (e.g. profit, income, productivity) are commonly used in business research, allowing researchers to obtain the necessary data on a firm's performance without the need to directly disclose sensitive business information (Runyan et al. 2008; Singh et al. 2016). While this measure is unable to capture the depth of the incidents investigated as objective measure, it is useful for sectoral studies because 'objective performance measures of different companies across a variety of industries/sectors (manufacturing, service) may not be directly comparable' (Singh et al. 2016, p. 220). In this regard, subjective measure data are more generalisable and has also been proved to be reliable and effective in measuring firm performance (Droge et al. 2004; Singh et al. 2016; Wall et al. 2004). Subjective measures of firm performance have also been employed in SME innovation studies (e.g. Kim & Shim, 2018; Torrent-Sellens et al. 2016; Verreynne et al. 2019).

5.4.2. Estimation approach

5.4.2.1. A review of existing estimation techniques

Using the CDM framework as a foundation, a number of studies have employed a range of econometric models to explore various aspects of the innovation process. Among the most influential studies is that of Griffith et al. (2006), who examine innovation and productivity using data from the internationally harmonised CIS for four European countries—France, Germany, Spain and the UK. They propose a three-step estimation for analysing the linkages in the CDM. In the first step, the generalised Tobit model is employed to estimate (i) the selection equation describing whether the firm is undertaking R&D or not and (ii) the intensity of R&D activities equation. In the second step, the KPF is estimated using two separate probit equations—one for product innovation and the other for process innovation, using the predicted value of innovative effort from the first step. Finally, the predicted values from the second step are used to estimate the productivity equation—knowledge is considered an input into the output production function. Labour productivity, measured by log output per worker, is used as a measure of production output.

A considerable number of studies have followed Griffith et al.'s (2006) method to estimate the relationship between R&D intensity, innovation and productivity in various countries. These include Raffo et al. (2008) in Europe and Latin America, Crespi and Zuniga (2012) and Crespi et al. (2016) in Latin America. In the SME context, Hall et al. (2009) in the case of Italian manufacturing SMEs and Baumann and Kritikos (2016) in German manufacturing SMEs also followed Griffith et al.'s (2006) method, although their estimation technique was different. They used bivariate probit models to simultaneously estimate (i) the relationship between innovative effort and its determinants and (ii) the probability of having a product or process innovation. Further, the productivity function was estimated using the ordinary least squares (OLS) method. The dependent variable—labour productivity—was a continuous variable, measured by log sales per full-time employees.

In Australia, most existing innovation studies are industry research papers, conducted by the ABS, taking advantage of the BCS. These studies often used probit, Tobit and OLS models. For example, Wong et al. (2007) employed the probit model to estimate the three innovation output equations in which the dependent variables were binary; that is whether the firm introduced innovation or not. The Tobit model is used to estimate the innovative sales equation and the OLS method is used to assess the impact of innovation on productivity. Palangkaraya et al. (2010) employed the bivariate probit to estimate the effects of various factors on the likelihood of undertaking R&D. Soames et al. (2011) applied a binary probit model to analyse a firm's propensity to innovate, a multivariate probit model to predict the conditional probability of a firm displaying any combination of innovation outcomes and an ordered probit model to examine the conditional likelihood of an innovating firm having a given highest level of novelty or introducing a number of innovation types. Using longitudinal panel data, Palangkaraya et al. (2016) employed the random effects probit model to estimate the probability of an Australian firm to introduce a given type of innovation, taking into account unobserved firm heterogeneity.

A review of the literature reveals that the three most widely used models are probit, Tobit and OLS. The choice of an approach is mainly governed by the research objective and the availability and nature of the data. For example, OLS is used when dependent variables are continuous, such as new product sales (Buckley et al. 2002; Wang & Kafouros 2009) or sometimes an ordinal scale such as level of innovation (0 = no innovation, 4 = totally new in the sector) (Camisón & Montfort-Mir 2012; Martínez-Ros & Orfila-Sintes 2012). This method is also used to analyse the link between innovation and firm performance where the performance indicators (e.g. sales, profit and productivity) are measured by continuous variables, for example, log sales per worker (Baumanna & Kritikos 2016; Wong et al. 2007). When the dependent variable is dichotomous or binary and takes one of only two values, representing either success or failure (e.g. 1 = if the firm introduced innovation and 0 = otherwise), probit or logit regressions are most appropriate.

To summarise, Probit estimation is commonly used in empirical innovation literature since most of the available data are collected from sample surveys, for example, CIS or BCS, in which innovation output is measured by a binary variable, which takes the value of 1 if the firm introduced a given type of innovation and 0 if otherwise. The application of a probit model to estimate the innovation output equation can be found in various studies, such as those of Baumann and Kritikos (2016), Divisekera and Nguyen (2018a), Hall et al. (2009), Montresor and Vezzani (2016), Palangkaraya et al. (2010), Soames et al. (2011), Sundbo et al. (2007) and Wong et al. (2007). For innovation studies using panel data, random effects probit models are often used, as in, for example, Anzola-Román et al. (2018), Martínez-Ros and Labeaga (2009), Palangkaraya et al. (2016) and Taveira et al. (2019).

5.4.2.2. Estimation technique for the empirical model

Econometric analysis of the relationship between innovation and productivity often faces endogeneity or simultaneity problems (Hashi & Stojcic 2013; Mohnen 2019; Morris 2018). The unobserved factors that influence SMEs' innovation outputs are suspected to correlate with the unobserved factors that influence their productivity, which means the random effect u_{3i} could be correlated with the random effects u_{1i} and u_{2i}. Moreover, the observation-level errors could be correlated as well. In this case, technological and non-technological innovation outputs should be treated as endogenous covariates in the productivity equation.

The literature proposes two estimation approaches that are often used to handle the endogeneity issue. The first is the simultaneous estimation employed in the original CDM paper (Crépon et al. 1998) and subsequent studies such as Benavente (2006), Hashi and Stojcic (2013) and Lööf and Heshmati (2006). The second is the sequential approach, known as the three-step estimation, which estimates the productivity equation using the predicted values from the knowledge production function equations (i.e., innovation output equations). This approach is initiated by Griffith et al. (2006), and later followed by Chudnovsky et al. (2006), Hall et al. (2009) and Siedschlag and Zhang (2015). As stated by Taveira et al. (2019, p. 3636), both approaches 'accommodate simultaneity and reverse causality bias'. The approach employed in the present study is closely related to the former strand. Accordingly, the two innovation output equations and the productivity equation are estimated simultaneously as one system. This is done using the maximum likelihood estimation method as employed by Musolesi and Huiban (2010), White (1996) and Wooldridge (2010). The idea of this approach is also quite similar to the generalised structural equation model of Baum et al. (2017) who estimated a system of equations in the CDM model as one system using maximum likelihood and accounting for cross-equation correlation of the errors. The maximum likelihood estimation utilises mean–variance adaptive Gauss–Hermite quadrature as an integration method for random effects. Musolesi and Huiban (2010, p. 69) advocate that the simultaneous estimation of the innovation and productivity equations should 'take into account the correlation between the error terms and should be more efficient than a single equation approach'. Hashi and Stojcic (2013) and Sauer (2017) support this notion, asserting that the simultaneous equations framework applied to the innovation output and productivity equations of the CDM model is capable of addressing the endogeneity issue and deriving consistent estimators.[33]

Another common problem in innovation research is selectivity bias due to the omission of firms without R&D activities or non-innovative firms from the estimation (Griffith et al. 2006; Hashi & Stojcic 2013). Elimination of firms with no innovation activities will

[33] Simultaneous estimation of random effects probit regressions with endogenous innovation covariates was conducted using the recently released Stata *xteprobit* command. *xteprobit* is referred to as extended regression models that fit random effects models (two-level models) for panel data, accommodating endogenous covariates and accounting for within-panel correlation (Stata Press 2019).

bias the sample, especially one dominated by service firms (Aboal & Garda 2016). In addition, the vast majority of Australian firms, particularly SMEs, did not undertake or report R&D activities (ABS 2018e; ISA, 2020). Unlike the CIS for European countries, where only innovative firms respond to the bulk of questions in the questionnaire (Baum et al. 2017), all questions in the BCS questionnaire were asked of all firms with no filter questions for innovators. Thus, the whole sample is used for our analysis, similarly to studies by Crépon et al. (1998), Crespi and Zuniga (2012), Frick et al. (2019) and Hall et al. (2009). As asserted by Griffith et al. (2006, p. 485), "… all firms exert some innovative effort, but not all firms report this effort". By including all firms, rather than just innovators, the present study covers the entire efforts SMEs put into their innovation processes, enabling the identification of the characteristics of innovators.

5.4.3. Modelling strategy

At the aggregate level, the full sample, including all SMEs in three Australian economic sectors, are fitted to the econometric model developed in the previous section. This exercise is to provide an overall understanding of the innovation process in an economy-wide context to serve as a benchmark for analysis at the sectoral level. The next step is disaggregation of the sample into three sectors: primary, secondary and service. The model is then fitted into the sector-specific dataset to estimate the innovation process in each sector. This process is depicted in Figure 5.1.

In terms of the econometric procedure, goodness-of-fit tests are first conducted to evaluate the significance of the model. The endogeneity of innovation covariates is assessed via the estimates of (i) the correlation of observation-level error variances and (ii) the correlation of the variances of the random effects. The unobserved firm heterogeneity is evaluated via the likelihood ratio test. The statistical significance of explanatory variables is then assessed by Wald tests. This procedure is applied to the aggregate economy analysis, and then, sector-specific analyses. The estimated results are used to identify the determinants of innovation outputs and the impacts of innovation outputs on SME productivity across the three Australian economic sectors.

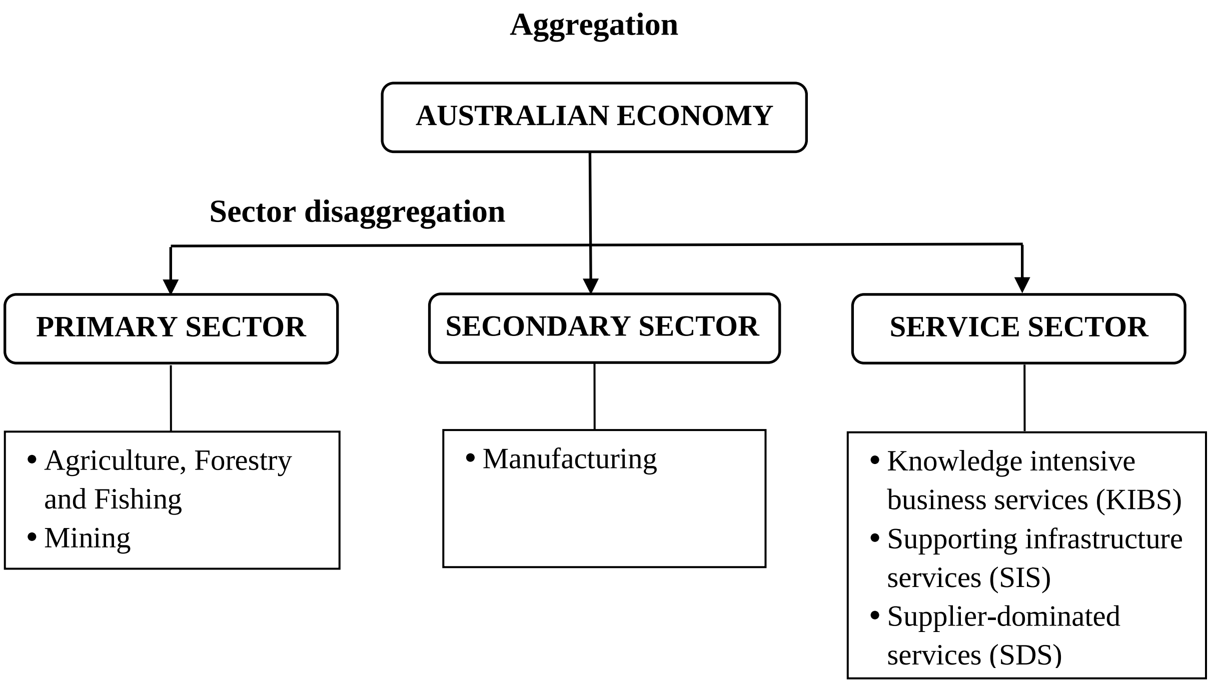

Figure 5.1: Modelling process

5.5. SUMMARY

The aim of this chapter is to present the sources of data and develop the empirical model used for econometric analyses in the next chapter. The study uses the confidential data drawn from the BLD, i.e. Microdata: Business Characteristics 2011–12 to 2015–16, collected by the ABS (2019f). Input to the BLD is from the annual Business Characteristics Survey, including substantial firm level information on innovation activities as well as characteristics of SMEs across the three Australian economic sectors. The aggregate dataset consists of 1,967 SMEs in three sectors, representing the Australian economy. It is then disaggregated into sector-specific datasets, i.e. primary, secondary and service, allowing sectoral analyses to be conducted.

Considering the nature of the dependent variables and the panel structure of the dataset, the random effects probit model was developed to examine the innovation and productivity relationship. After reviewing commonly used estimation techniques, this study opts to employ a simultaneous estimation approach in which the two innovation output equations and the productivity equation are estimated simultaneously using the maximum likelihood estimation method. This method accounts for the potential endogeneity of innovation covariates in the productivity equation. This chapter builds the base for the empirical analysis to be conducted in Chapter Six.

CHAPTER SIX:
EMPIRICAL RESULTS AND DISCUSSION: AGGREGATE AND SECTORAL ANALYSIS

6.1. INTRODUCTION

This chapter presents the empirical results of the econometric models developed in Chapter Three and answers the following three research questions:

RQ2: How do SME innovation determinants vary in the aggregate economy and in each economic sector?

RQ3: To what extent does innovation impact SME productivity in the aggregate economy and each economic sector?

RQ4: How does innovation and productivity performance of SMEs vary across economic sectors?

The chapter is organised as follows. First, the aggregate analysis is carried out to provide a broad understanding of the innovation process in the Australian economy. The aggregate analysis acts as a benchmark for the sectoral analysis. This is followed by empirical analysis for each economic sector (i.e. primary, secondary and service). In the process, each section begins with the summary statistics and model evaluation, followed by empirical results for the determinants of SME innovation and the impact of innovation on SME productivity. The summary of findings and conclusion on the proposed hypotheses is at the end of each section. Based on the findings of the aggregate and sectoral analyses, similarities and differences in the innovation processes among the three sectors are discussed. Finally, the findings of the present study are compared with findings of relevant studies on innovation in Australian SMEs.

6.2. AGGREGATE RESULTS

6.2.1. Summary statistics and model evaluation

The random effects probit regression model developed in Chapter Three is fitted into the aggregate dataset, obtained from Microdata: Business Characteristics, Australia, 2011–12 to 2015–16. This dataset includes 1,976 SMEs in all three economic sectors. The model estimates the triad link between the determinants, innovation outputs and firm productivity simultaneously using maximum likelihood estimation. For analytical convenience, the econometric results are divided into three sub-sections. The first provides summary statistics of the data used and evaluation of the model, the second presents the estimated results of the determinants of innovation outputs, technological innovation and non-technological innovation and the third examines the impact of innovation outputs on firm productivity. This procedure is also applied for the three sectoral analyses presented later in this chapter.

Tables 6.1 and 6.2 provide the summary statistics, namely, mean and standard deviation (SD), of all the variables used for estimation (i) explanatory variables and technological and non-technological innovation and (ii) innovation outputs and productivity.

As Table 6.1 shows, overall, for SMEs that reported innovations, either technological or non-technological, the means of their innovation input variables—training, collaboration, ICT investment, financial support, innovation focus—are higher than those that did not report innovation. For example, for SMEs that introduced technological innovation, their mean of training is 0.197, whereas for those that did not report technological innovation, their mean of training is 0.067. The corresponding mean of training variable for non-technological innovators is 0.207 compared with 0.057 of those without non-technological innovation. Similarly, the mean of collaboration is 0.238 for SMEs introducing technological innovation, while it is just 0.042 for those that did not report technological innovation. These preliminary statistics imply a greater use of these innovation inputs by innovators rather than non-innovators. In relation to firm characteristics, higher means of firm size, foreign ownership and exports are also observed in SMEs that implemented innovation (both technological and non-technological) compared with those that did not. The age of innovators is slightly younger than non-innovators. With respect to the external environment, the means of both market competition and sector are higher for those that reported innovations.

Regarding the relationship between innovation and productivity, SMEs experiencing increased productivity exhibit larger means of technological as well as non-technological innovation. For SMEs whose productivity improved, their mean capital investment is AUD309,000 compared with AUD96,000 of those whose productivity did not improve. SMEs with increased productivity spent on average AUD3,993,000 in non-capital investments, relative to AUD2,275,000 spent by those that did not gain productivity increases. The mean differences for the sector variable are relatively small.

Table 6.1: Summary statistics[34]—Aggregation

	Technological innovator				Non-technological innovator			
	Yes		No		Yes		No	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Training	0.197	0.398	0.067	0.250	0.207	0.405	0.057	0.232
Collaboration	0.238	0.426	0.042	0.201	0.232	0.422	0.038	0.192
ICT investment	0.343	0.475	0.118	0.323	0.345	0.476	0.110	0.312
Financial support	0.338	0.487	0.229	0.420	0.388	0.487	0.223	0.417
Innovation focus	0.666	0.472	0.311	0.465	0.627	0.484	0.318	0.466
Firm size	1.969	0.947	1.632	0.984	2.010	0.931	1.598	0.983
Firm age	11.529	6.705	12.300	6.713	11.155	6.662	12.530	6.704
Foreign ownership	0.076	0.265	0.045	0.206	0.065	0.247	0.049	0.216
Exports	0.193	0.395	0.093	0.291	0.155	0.362	0.111	0.314
Competition	2.404	0.920	2.145	1.154	2.442	0.894	2.115	1.166
Sector	2.740	0.605	2.606	0.759	2.739	0.616	2.602	0.759

[34] The summary statistics are the averages for the same firm over the five years.

Table 6.2: Summary statistics—Productivity

	Productivity			
	Increased		Not increased	
	Mean	**SD**	**Mean**	**SD**
Technological innovation	0.508	0.500	0.275	0.447
Non-technological innovation	0.541	0.499	0.296	0.456
Capital investment (AUD million)	0.309	1.813	0.096	0.725
Non-capital investment (AUD million)	3.993	10.497	2.275	7.115
Sector	2.623	0.721	2.657	0.713

Table 6.3 presents the statistics for the goodness-of-fit and endogeneity tests for the aggregate model. First, the goodness-of-fit of the model is assessed based on the Wald statistics. The corresponding p-value is 0.000, confirming that the model is statistically significant at the 1% level. The likelihood ratio test shows that the estimated proportion of the total variance contributed by the panel-level variance component is also statistically significant. Thus, the use of the panel data model is necessary to account for unobserved heterogeneity in the innovation process.

Table 6.3: Model statistics—Aggregate

Key statistics	
Observations	6,399
Goodness-of-fit	
Log likelihood	–9,158.347
Likelihood ratio test (Prob > chi-squared)	0.000***
Wald statistics	481.47
Wald test (Prob > chi-squared)	0.000***
Endogeneity	
Observation-level errors	
Corr (e.technological, e.productivity)	–0.446***
Corr (e.non-technological, e.productivity)	–0.607***
Random effects	
Corr (technological [firm], productivity [firm])	–0.194***
Corr (non-technological [firm], productivity [firm])	–0.154***

*Note: ***: statistically significant at 1%; Corr: Correlation*

The possibility of endogeneity of innovation covariates is assessed via the estimates of (i) the correlation of observation-level error variances and (ii) the correlation of the variances of the random effects. The results show that the correlations between the observation-level errors and between the random effects are statistically significant for both technological innovation and productivity and non-technological innovation and productivity. This indicates that technological and non-technological innovations are endogenous in the productivity equation. Therefore, the estimation treats technological and non-technological innovations as endogenous covariates in the productivity equation. Further, simultaneous estimation of the technological innovation, non-technological innovation and productivity equations is useful since it accommodates the issues of endogeneity in the estimates. . To make the estimated results easy to follow, section 6.2.2 presents the results of the innovation output equations, while section 6.2.3 reports the results of the productivity equation.

6.2.2. Determinants of innovation outputs

Table 6.4 presents the estimates of the first equation—the determinants of innovation outputs—separately for technological innovation and non-technological innovation, along with the associated average marginal effects. The average marginal effects are calculated to illustrate the average change in the probability of achieving a given type of innovation output when a given explanatory variable changes their value. Marginal effects are useful since the sign and significance of the coefficients in the random effects probit model provide only the direction of the impact but not the magnitude of the economic significance of the factors (Bland & Cook 2019). The results reveal various factors that determine innovation outputs of Australian SMEs; the impact of each factor varies among innovation types.

The innovation inputs—financial support, collaboration, ICT investment, training for employees and innovation focus—appear to be the major determinants of SME innovations in Australia. Of those, collaboration shows the largest effect with a positive sign. As the marginal effects indicate, firms involved in collaboration are more likely to report technological and non-technological innovation by 23 percentage points and 27 percentage points, respectively, compared with those without collaboration. This finding endorses the view that collaboration is a significant contributor to innovation and lends further support to the importance of networks, access to knowledge and resources for the development and implementation of innovation among SMEs (Vahter et al. 2014).

Table 6.4: Results of random effects probit estimation—innovation outputs

	Technological innovation			Non-technological innovation		
	Coefficient	SE	Marginal effects	Coefficient	SE	Marginal effects
Training	0.314***	0.069	0.062	0.452***	0.069	0.094
Collaboration	0.837***	0.068	0.230	0.967***	0.072	0.270
ICT investment	0.484***	0.055	0.116	0.535***	0.055	0.118
Financial support	0.339***	0.049	0.089	0.325***	0.049	0.087
Innovation focus	0.691***	0.045	0.172	0.533***	0.045	0.134
Firm size (ref: non-employer)						
Less than 5 employees	0.089	0.101	0.024	0.165	0.103	0.038
5 to 19 employees	0.210***	0.101	0.047	0.459***	0.103	0.106
20 to 199 employees	0.333***	0.103	0.078	0.632***	0.106	0.154
Firm age	-0.015***	0.004	-0.003	-0.031***	0.004	-0.007
Foreign ownership	0.220*	0.116	0.065	-0.055	0.117	-0.009
Exports	0.257***	0.072	0.059	-0.067	0.074	-0.019
Competition (ref: No competition)						
1 or 2 competitors	0.402***	0.101	0.084	0.588***	0.103	0.131
3 or 4 competitors	0.530***	0.098	0.115	0.593***	0.099	0.136
5 or more competitors	0.420***	0.085	0.097	0.610***	0.087	0.139
Sector (ref: Primary sector)						
Secondary sector	0.540***	0.131	0.138	0.246*	0.134	0.064
Service sector	0.423***	0.087	0.105	0.280***	0.088	0.069

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

ICT investment is another major determinant of SME innovation outputs. The associated estimates demonstrate that increases in ICT investment result in approximately 11.6 percentage point and 11.8 percentage point increases in the probability of implementing technological and non-technological innovation. These results support Higón's (2011) finding that ICT is an important avenue for SMEs to innovate in both technological and non-technological aspects.

Employee training positively affects both types of innovation outputs. SMEs that increased structured or formal training for employees show significantly higher probabilities of implementing technological and non-technological innovation by 6.2 percentage points and 9.4 percentage points, respectively. This result confirms the vital role of a skilled workforce in innovation in SMEs, which often encounter human resources and skill constraints. It further supports Sheehan (2013), who also found formal training an effective way to enhance SMEs' human capital, leading to better innovation performance.

Financial support significantly and positively influences both types of innovation outputs. As the marginal effects show, firms that received funding are 8.9 percentage points more likely to implement technological innovation than those without this support. The corresponding probability for non-technological innovation is 8.7 percentage points. SMEs are well known for their financial resource scarcity, which prevents them from investing in innovation (Lukovszki et al. 2020). The findings confirm the widely held view that financial support is an important facilitator of innovation among SMEs.

With respect to innovation focus, the results show that SMEs with an innovation focus had a higher likelihood of achieving technological and non-technological innovation by 17.2 percentage points and 13.4 percentage points, respectively. The results highlight the significance of having an innovation focus for SMEs. Bounded by limited resources, a business focus on innovation leads SMEs to utilise their resources strategically and efficiently to achieve innovation outputs. This finding also supports Halim et al.'s (2015) viewpoint that SMEs with an innovation focus are more likely to devote their resources and effort to develop and implement innovations as well as Aksoy's (2017) finding that a strong innovation culture is important in fostering innovation creation and performance in SMEs, not only in technological but also in non-technological aspects.

Of the firm characteristics, firm size, is positive and statistically significant for SMEs. The estimates show that, compared with non-employer firms, the probabilities of implementing technological innovation are 4.7 percentage points higher for small firms with 5 to 19 employees and 7.8 percentage points higher for medium firms with 20 to 199 employees. The predicted probability of innovating increases as firm size increases, indicating that larger firms are more likely to implement innovation. This finding reflects the resource advantages enjoyed by larger firms (e.g. Hall et al. 2009; Hashi & Stojcic 2013). No significant differences are found between non-employer firms and micro firms with less than 5 employees.

Firm age also has a significant but negative impact on innovation outputs, both technological and non-technological innovation. The finding supports the view that older SMEs are less likely to innovate than young firms (Rosenbusch et al. 2011). The negative effect of firm age could be due to organisational inertia and large capability adjustment costs faced by mature SMEs. In contrast, younger SMEs are more flexible in creating new processes and pursuing innovation opportunities (Rosenbusch et al. 2011). This finding is also consistent with those of Huergo and Jaumandreu (2004) and Smith and Hendrickson (2016) in the SME context.

Foreign ownership has a positive influence on technological innovation. Firms with foreign ownership are 6.5 percentage points more likely to implement technological innovation, relative to wholly Australian-owned firms. This reflects the advantages enjoyed by foreign-owned firms in relation to access to advanced technologies, resources, worldwide pools of information, market opportunities and international experience (Divisekera & Nguyen 2018a; Nordman & Tolstoy 2016). As Corsi and Prencipe (2018) report, foreign-owned SMEs tend to be more innovative than domestic SMEs. The effect of foreign ownership is negative and insignificant on non-technological innovation, as found by Aboal and Garda (2016) in the case of small Uruguayan firms.

SMEs that export are more likely than non-exporting SMEs to implement technological innovation by 5.9 percentage points. Due to higher quality standards and intense competition in international markets, exporters need to be innovative in introducing new products and implementing more cost-effective processes (Hashi & Stojcic 2013). Such technological innovations enable SMEs to gain competitive advantages in foreign markets (Paul et al. 2017). Therefore, exports trigger technological innovation. No significant relationships are found between non-technological innovation and exports. These findings are similar to prior studies such as those of Peters et al. (2018) in the case of German firms and Siedschlag and Zhang (2015) in Irish firms.

The results for competition reveal a significant and positive impact on both types of innovation outputs. In general, firms operating in a competitive market are more likely to innovate compared with those in a captive market with no effective competition. The finding for competition effect, in the Australian case, varies across the two types of innovation. For technological innovation, the magnitude of the effect increases as the degree of competition increases from 'no competition' to '1 or 2 competitors' and to '3 or 4 competitors', then slightly decreases when the firm faces '5 or more competitors' in the market. This is indicative of an inverted U-shaped relationship between competition and technological innovation, as found by Aghion et al. (2005) and Scherer (1965). In relation to non-technological innovation, the result is in line with Arrow's (1962) viewpoint that the probability of innovating increases as the degree of competition increases.

Finally, there exist sectoral effects that influence innovation outputs. As the marginal effects show, SMEs in the secondary sector and the service sector are 13.8 percentage points and 10.5 percentage points more likely to implement technological innovation than those in the primary sector. In relation to non-technological innovation, SMEs in service and manufacturing are 6.9 percentage points and 6.4 percentage points more likely to obtain innovation outputs than those in the primary sector. Based on the marginal effects, it can also be inferred that among the three sectors, manufacturing SMEs are most likely to implement technological innovation, whereas service SMEs are most likely to implement non-technological innovation. The primary sector is least likely to implement both technological and non-technological innovation. The significant differences in terms of innovation performances, both technological and non-technological, among sectors support the proposition of sectoral differences proposed by Nelson and Winter (1982). Given this result, analysis of innovation at the firm level should be conducted in a sector-specific context instead of an economy-wide aggregation.

6.2.3. Innovation and productivity

The estimates for the relationship between innovation outputs and productivity are presented in Table 6.5. Capital investment, non-capital investment and sectoral effects are included in the model as control variables.

Table 6.5: Results of random effects probit estimation—productivity

	Productivity		
	Coefficient	**SE**	**Marginal effects**
Technological innovation	0.734***	0.203	0.200
Non-technological innovation	1.035***	0.182	0.281
Capital investment	0.048***	0.018	0.012
Non-capital investment	0.004*	0.003	0.001
Sector (ref: Primary)			
Manufacturing	–0.031	0.119	0.022
Service	–0.257***	0.076	–0.039

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

The results show that innovation has a significant and positive effect on SME productivity, as commonly found in the generic innovation literature. Further, this positive impact is evident not only for technological innovation, but also for non-technological innovation. As the marginal effects indicate, SMEs with technological innovation are 20 percentage points more likely to experience increased productivity compared with the previous year. Likewise, implementing non-technological innovation is associated with 28 percentage points higher probability of achieving productivity increases. The findings therefore confirm that the positive impact of innovation on firm productivity is also relevant for SMEs and is consistent with Schumpeter's theory of innovation. Further, the results also reveal a greater effect of non-technological innovation over technological innovation on productivity among Australian SMEs (by 8 percentage points).

The greater impact of non-technological innovation could be linked to the distinct nature of SMEs. It is suggested that the inherent flexibility of SMEs, along with organisational agility, adaptability and proximity to markets and customers allows SMEs to gain more benefits from non-technological innovations (Radicic & Djalilov 2019; Salavou et al. 2004). This finding adds to the SME literature by providing empirical evidence that, at the aggregate economy level, non-technological innovations are the main contributor of productivity improvement for SMEs. In addition, this finding partly reflects the structure of the Australian economy, which is service-based and dominated by small businesses. Non-technological innovation is often cited as the most common type of innovation in services; it has also been found to generate the largest productivity returns for service firms (Aboal & Garda 2016; Gallego et al. 2015; Peters et al. 2018).

In addition to innovation outputs, investments in capital assets, such as plants, equipment and machinery, are the other drivers of productivity improvement for SMEs. The result demonstrates that a million dollar increase in capital expenditure translates into a 1.2% increase in the probability that SME productivity will increase compared with the previous year. Economic theories of growth have indicated the role of capital as one of the important inputs in the production processes (Nelson & Winter 1974). Recent empirical research adds that it is not just increases in capital but also the knowledge and technology embodied in such machinery and equipment that are the main causes of SME performance (Hervas-Oliver et al. 2021). The result supports Blake et al.'s (2006) finding, according to which physical capital was found to raise productivity among UK small service firms. Non-capital investment also has a positive impact on productivity, but at a moderate level.

Finally, sectoral effects also matter for firm productivity. As revealed from the estimates, there are significant differences in productivity performance between SMEs in the service sector and those in the primary sector. Australian service SMEs are on average 3.9% less productive than SMEs in the primary sector. This result is supported by Sorbe et al. (2018) who show that in OECD nations, services, in general, tend to have weaker productivity levels compared with other economic sectors.

6.2.4. Summary of aggregate findings

The results from the aggregate analysis revealed several factors affecting innovation outputs. The five input variables—training, collaboration, ICT investment, financial support and innovation focus—have significant and positive impacts on both technological and non-technological innovation. Accordingly, formal or structured training for employees, involvement in collaboration for innovation, investment in ICT, receiving financial support and having a business focus on innovation, lead to a higher likelihood of innovation outputs among SMEs. Given these results, the following hypotheses are supported in the economy-wide context.

H1: Training has a positive effect on technological and non-technological innovation in SMEs.

H2: Collaboration for innovation has a positive effect on technological and non-technological innovation in SMEs.

H3: ICT investment has a positive effect on technological and non-technological innovation in SMEs.

H4: Financial support has a positive effect on technological and non-technological innovation in SMEs.

H5: Innovation focus has a positive effect on technological and non-technological innovation in SMEs.

In addition to innovation inputs, certain firm characteristics also influence innovation outputs. Larger firm size shows a higher likelihood of SMEs implementing both technological and non-technological innovation. In contrast, firm age and the likelihood of implementing technological and non-technological innovation are negatively related. Younger SMEs are more likely to implement innovation than older SMEs. The effects of foreign ownership and exports are only significant for technological innovation. SMEs with foreign ownership have a higher likelihood of implementing technological innovation, while SME exporters are more likely to implement technological innovation. Hence, the following hypotheses are supported in the economy-wide context.

H6: Firm size has a positive influence on technological and non-technological innovation in SMEs.

H7: Firm age has a negative influence on technological and non-technological innovation in SMEs.

H8: Foreign ownership has a positive influence on technological innovation in SMEs.

H9: Exports have a positive influence on technological innovation in SMEs.

With regards to the external environment, a higher degree of market competition is significantly linked to higher likelihood of SMEs implementing technological and non-technological innovation. The estimates also revealed a significant impact of sector on both technological and non-technological innovation. SMEs in the secondary and service sectors are more likely to implement technological and non-technological innovation than those in the primary sector. The results support the below hypotheses.

H10: Market competition has a positive impact on technological and non-technological innovation in SMEs.

H11: Sector has a significant impact on technological and non-technological innovation in SMEs.

Finally, the findings from the productivity equation confirmed the significant and positive impact of technological and non-technological innovation on SME productivity in the Australian economy context.

H12a: Technological innovation has a positive impact on SME productivity.

H12b: Non-technological innovation has a positive impact on SME productivity.

6.3. RESULTS FOR THE PRIMARY SECTOR

6.3.1. Summary statistics and model evaluation

The random effects probit model is conducted using the primary dataset. This panel dataset includes 268 SMEs in the Australian primary sector over the period 2011–12 to 2015–16, with 174 in the Agriculture, Forestry and Fishing industries and 94 in the Mining industry. Using the same procedure as in the previous sections, the model is first assessed for its goodness-of-fit and endogeneity, followed by estimates for the determinants of technological and non-technological innovation and the impact of innovation outputs on the productivity of SMEs. The results are then discussed, taking into account the nature of the primary sector and the Australian context. Summary statistics for the primary model are presented in Tables 6.6 and 6.7.

As shown in Table 6.6, the means of innovation input variables are higher for firms that implemented technological innovation, implying the greater use of such inputs by innovators compared with non-innovators. The largest mean difference is found in the innovation focus variable with respect to technological innovation (0.690 versus 0.288). The smallest mean difference between those who implemented technological innovation and those who did not is found in the case of the training variable (0.177 versus 0.052). A similar pattern is observed for non-technological innovation. With regards to firm characteristics and external factors, the associated means for these variables are also higher for innovators than non-innovators, except for firm age, where innovators in the primary sector tend to be younger than non-innovators.

Table 6.6: Summary statistics for innovation outputs—Primary sector

	Technological innovator				Non-technological innovator			
	Yes		No		Yes		No	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Training	0.177	0.383	0.052	0.221	0.169	0.176	0.049	0.215
Collaboration	0.223	0.417	0.044	0.205	0.247	0.432	0.029	0.169
ICT investment	0.338	0.474	0.081	0.273	0.308	0.462	0.080	0.271
Financial support	0.550	0.499	0.329	0.470	0.504	0.501	0.335	0.472
Innovation focus	0.690	0.464	0.288	0.454	0.589	0.493	0.303	0.460
Firm size	1.948	0.856	1.458	0.950	1.860	0.846	1.466	0.963
Firm age	12.452	6.365	13.906	6.875	11.796	6.595	14.158	6.766
Foreign ownership	0.143	0.351	0.114	0.318	0.153	0.361	0.110	0.313
Exports	0.255	0.437	0.076	0.265	0.214	0.411	0.082	0.274
Competition	2.184	1.176	1.764	1.350	2.202	1.156	1.742	1.358
Industry	1.387	0.488	1.315	0.465	1.432	0.496	1.299	0.458

Table 6.7: Summary statistics for productivity—Primary sector

	Productivity			
	Increased		Not increased	
	Mean	SD	Mean	SD
Technological innovation	0.405	0.492	0.145	0.352
Non-technological innovation	0.422	0.495	0.178	0.383
Capital investment (AUD million)	0.594	2.346	0.126	0.445
Non-capital investment (AUD million)	4.622	12.361	1.920	6.844
Industry	1.293	0.456	1.348	0.477

In terms of productivity performance (Table 6.7), the means of technological innovation and non-technological innovation are higher for SMEs whose productivity improved. This could be an indication that SMEs that innovate are more likely to improve productivity than those that do not innovate. Innovators (technological and non-technological) also reported greater investment in capital assets and non-capital assets compared with non-innovators.

Table 6.8 presents the statistics for model evaluation for the primary model. First, the goodness-of-fit of the (extended) random effects probit regression model—which simultaneously estimates all the innovation outputs and productivity equations—is assessed based on the Wald test. As the statistics show, the model for the primary sector is statistically significant at the 1% level (p-value = 0.000). The likelihood ratio test is also significant, confirming the importance of applying a panel data model to account for unobserved firm heterogeneity. In terms of the potential endogeneity of innovation covariates, the results show that the correlations between the observation-level errors are significantly different from zero. This is evidence that in the Australian primary sector, both technological innovation and non-technological innovation are endogenous in the productivity equation. Thus, it is necessary for the innovation covariates to be treated as endogenous variables in the estimation.

Table 6.8: Model statistics—Primary sector

Key statistics	
Observations	890
Goodness-of-fit	
Log likelihood	–1,093.491
Likelihood ratio test (Prob > chi-squared)	0.000***
Wald statistics	87.41
Wald test (Prob > chi-squared)	0.000***
Endogeneity	
Observation-level errors	
Corr (e.technological, e.productivity)	–0.603***
Corr (e.non-technological, e.productivity)	–0.565**
Random effects	
Corr (technological [firm], productivity [firm])	–0.263
Corr (non-technological [firm], productivity [firm])	–0.103

*Note: ** and ***: statistically significant at 5% and 1%, respectively; Corr: Correlation*

6.3.2. Determinants of innovation outputs in primary SMEs

The two innovation output equations and the productivity equation are estimated simultaneously as one system using the maximum likelihood estimation method. The estimates of the determinants of innovation are presented in Table 6.9. The average marginal effects are also calculated to demonstrate the average change in the probability of implementing a given type of innovation output when a given explanatory variable changes its value.

Of the innovation inputs, collaboration is significantly and positively associated with innovation outputs and has the largest marginal effects, making it the most important determinant of innovation in the primary sector. SMEs that collaborated for innovation are 15.1 percentage points and 26 percentage points more likely to implement technological innovation and non-technological innovation, respectively, compared with those without collaboration. The results support the findings of Soriano et al. (2019), who highlight the importance of collaboration for innovation in SMEs whose resources and innovation capabilities are limited. Collaboration facilitates knowledge sharing and technology transfer, which enables SMEs to obtain the necessary resources for their innovation process. It also allows SMEs to share the risks and costs of technology development and to build a successful agriculture innovation system (Caiazza & Stanton

2016; Wixe et al. 2017). As Vanclay et al. (2013, p. 406) emphasise, innovation in agriculture is ‘not only about what happens at the farm level, there needs to be innovation all along the value chain’. In mining, developing innovation or new technologies is complex. Thus, collaboration is important for mining SMEs to access scientific knowledge and equipment for developing innovation (Matysek & Fisher 2016). Despite the significance of collaboration, poor cross-industry, cross-sectoral and international scientific collaboration exists in Australian agriculture (ABARES 2019), which has been undermining the performance of innovation in the industry.

The second significant factor in innovation outputs is ICT. The estimates reveal that investing in ICTs statistically and positively leads to both types of innovation outputs. Increases in ICT investment are associated with 11.8 percentage points and 11.2 percentage points increases in the probability of implementing technological and non-technological innovation, respectively. The finding supports the work of Domenech et al. (2014), who suggest that investment in ICT is vital for innovation in agriculture. Moreover, Soriano et al. (2019) indicate that ICT intensity positively affects the innovation of small agri-food businesses. The adoption of ICT has transformed today’s economic activities and created numerous opportunities for innovation in the primary sector (Salim et al. 2016; World Bank 2017). The relevance of ICT to the agriculture and mining industries is through cost reduction and efficiency improvement (Domenech et al. 2014). ICT facilitates electronic capture, processing, storage and decentralised information collection, connectivity and monitoring systems (Dufty & Jackson 2018; Munthali et al. 2018). For example, it enables timely monitoring and detection of issues on farms or in mines and the transmission of information and data to extension organisations or value chain actors for prompt responses (McCole et al. 2014). An ICT application (i.e. GPS-enabled technologies) is heavily invested in agriculture given its usefulness in harvest monitoring, electronic identification and herd management (Dufty & Jackson 2018). In mining, autonomous trucks equipped with GPS courses help move materials efficiently and safely without human involvement in underground work (DIIS 2018c). However, this encouraging result needs to be contextualised against the backdrop of the lack of ICT-related skills in the sector. As Dufty and Jackson (2018) point out, 40% of small Australian farms reported insufficient ICT skills for innovation.

Table 6.9: Results of random effects probit regression, innovation outputs—Primary

	Technological innovation			Non-technological innovation		
	Coefficient	SE	Marginal effects	Coefficient	SE	Marginal effects
Training	0.237	0.215	0.017	0.347	0.240	0.050
Collaboration	0.591***	0.188	0.151	1.225***	0.227	0.260
ICT investment	0.572***	0.171	0.118	0.596***	0.190	0.112
Finance	0.462**	0.134	0.077	0.127	0.144	0.013
Innovation focus	0.812***	0.131	0.151	0.499***	0.144	0.099
Firm size (ref: non-employer)						
Less than 5 employees	0.796**	0.318	0.091	0.317	0.353	0.028
5 to 19 employees	0.834***	0.316	0.113	0.845**	0.348	0.140
20 to 199 employees	0.989***	0.321	0.159	0.408	0.358	0.077
Firm age	–0.019*	0.011	–0.003	–0.039***	0.014	–0.007
Foreign ownership	–0.287	0.243	–0.005	–0.493*	0.293	–0.075
Exports	0.515***	0.185	0.088	0.419*	0.220	0.081
Competition (ref: No competition)						
1 or 2 competitors	0.233	0.267	0.027	0.135	0.304	0.035
3 or 4 competitors	0.117	0.244	0.032	0.538**	0.265	0.126
5 or more competitors	0.352**	0.173	0.067	0.415**	0.193	0.080
Industry (ref: Agriculture, Forestry and Fishing)	0.018	0.198	0.001	0.214	0.240	0.042

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

The next important input into the innovation process is financial support. The results show that SMEs that obtained financial funding are 7.7 percentage points more likely to implement technological innovation. The role of funding in the agricultural industry has been identified as a determinant of innovative capacity among agri-food SMEs in Italy (De Martino & Magnotti 2018) and Spain (Acosta et al. 2015). It has also been identified as a significant input into technological innovation in Dutch agri-food firms (Batterink et al. 2006) and an enhancer of overall innovation performance in small food firms in Australia (Soriano et al. 2019). Finance is also significant for innovation in Chilean mining firms (Fernandez 2020). Nonetheless, the coefficient of financial support is not statistically significant for non-technological innovation. This may be an indication that funding in the primary sector is mainly dedicated to developing and implementing technological innovation—which involves new products or production processes—rather than improving organisational processes or marketing associated with non-technological innovation.

The variable—innovation focus—is highly significant and positively associated with innovation outputs. A firm's strategy that focuses on innovation performance is 15.1 percentage points and 9.9 percentage points more likely to generate technological and non-technological innovation, respectively. As the literature suggests, this is a prerequisite of innovation success because innovation-oriented firms will encourage and support innovative ideas and devote efforts and resources to innovation (Halim et al. 2015; Wikhamn et al. 2018). Therefore, they are more likely to obtain innovation outputs. In the primary sector, the farmers' incentives—willingness and capacity to pursue innovative ideas—is decisive in the development and implementation of innovation. This finding is in line with that of Baregheh et al. (2012), who report that food SMEs with innovation-oriented strategies are more likely to innovate. However, as ABARES (2019) notes, the innovation culture in the Australian agriculture industry is lagging behind other OECD countries, which slows down the diffusion of technologies and acts as a barrier to disruptive innovation and entrepreneurship in the sector.

Employee training is not significant for either technological innovation or non-technological innovation in the primary sector. This result seemingly contradicts an aspect of human capital theory that focuses on training and education. This could partly reflect the fact that the role of the labour force in this sector has increasingly been replaced by new technologies. Over the last decade, the emergence and application of new technologies have significantly transformed the agriculture industry, along with the mining industry. In agriculture, robots have been widely used across fields to complete human tasks such as dairy milking, harvesting, spraying and surveying (Kimura & Sauer 2015). Intelligent robots have been working alongside farmers to assist them in a range of farming activities. The use of robotics and automation technologies creates substantial benefits for farmers, businesses and the industry by reducing production costs, enhancing efficiency and higher quality of fresh products, while minimising the impact of human activities on the environment (ABARES 2019). The Australian mining industry is heavily capitalised (Australian Government 2019). Mining firms are increasingly using technologies in various areas of operations, for example, in exploration, extraction and processing. Technologies enable firms to explore the location of natural resources, enhance the efficiency of mining operations, minimise environmental impact and, most importantly, improve worker safety. The adoption of robotics and autonomous systems helps remove humans from dangerous environments, such as autonomous trucks used in underground mining work (DIIS 2018b). The use of robotics and new technologies, therefore, have significantly substituted the need of human labour in the primary sector.

In terms of firm characteristics, firm size has a positive effect on innovation outputs. The predicted probability of implementing technological innovation increases progressively (by 9%, 11.3% and 15.9%, respectively) with increasing levels of firm size, indicating that larger firms in the primary sector are more likely to implement technological innovation. This result reflects the resource and technology advantages possessed by larger agriculture firms (De Martino & Magnotti 2018). Regarding non-technological innovation, the impact of firm size is only significant for small firms with 5 to 19 employees, that is, they are 14 percentage points more likely to implement non-technological innovation than non-employer firms. Firm age also has a significant, but negative effect on both technological and non-technological innovation. This result indicates that mature agriculture and mining SMEs are less likely to implement innovations than their younger counterparts. However, the effect of firm age is only minor, as found by Fernandez (2020).

In relation to ownership, SMEs with foreign ownership are less likely to implement non-technological innovation than those that are wholly owned by Australians. The negative effect of foreign ownership has also been evident in the literature beyond the primary sector, for instance, in Italian SMEs (Minetti et al. 2015) and in small Uruguayan firms (Aboal & Garda 2016). One argument could be that multinational firms tend to conduct innovation activities in their home country rather than in foreign affiliates (Falk

2008). However, it should be noted that the effect of foreign ownership is only moderately significant at the 10% level. Exports show a positive and significant impact on both types of innovation outputs. SME exporters are 8.8 percentage points and 8.1 percentage points more likely to implement technological and non-technological innovation than non-exporters, respectively. As mentioned earlier, firms in the primary sector largely rely on the global markets; and their earning is greatly determined by the volume of exports. In this regard, the econometric results underscore the important role of export in stimulating innovation of SMEs in this sector.

With regards to the external environment, competition is an important driver of innovation outputs. SMEs that compete with three or four competitors are 12.6 percentage points more likely to implement non-technological innovation, while SMEs that have five or more competitors are 8 percentage points more likely to implement non-technological innovation than those in the captive market. The results for non-technological innovation tend to support Scherer (1965) and Aghion et al. (2005) regarding the inverted U-shaped relationship between competition and innovation because the probability of innovating increases then decreases. For technological innovation, SMEs that operate in the highest competitive environment (five or more competitors) are 6.7 percentage points more likely to implement innovation than those in the captive market. This result supports Arrow (1962), who states that strong competition stimulates firms to conduct more innovation. In relation to the industry effect, no significant differences are found between the Australian agriculture industry and mining industry in terms of innovation outputs for both technological and non-technological innovation.

6.3.3. Innovation and productivity in primary SMEs

The impact of innovation outputs on productivity of SMEs in the primary sector is presented in Table 6.10. The results show that both technological and non-technological innovation positively affect SME productivity. Technological innovation is highly significant at the 1% level, whereas the effect of non-technological on productivity is moderately significant at the 10% level. As the marginal effects indicate, the implementation of technological innovation is associated with 38 percentage points higher probability of productivity increases. Likewise, non-technological innovation leads to a 22.5 percentage point increase in the probability of SMEs improving productivity. These findings highlight the significant impact of not only technological innovation, but also non-technological innovation on SMEs in this sector. This is an important contribution given that the focus of previous research in the primary sector was narrowed to technology adoption or technological innovation.[35] In addition, the results provide further empirical evidence indicating that, of the two innovation types, technological innovation still plays a major role. This is proven by its greater significant impact on SME productivity relative to non-technological innovation.

Table 6.10: Results of random effects probit regression, productivity—Primary

	Productivity		
	Coefficient	**SE**	**Marginal effects**
Technological innovation	1.365***	0.465	0.380
Non-technological innovation	0.853*	0.483	0.225
Capital investment	0.208**	0.091	0.051
Non-capital investment	–0.001	0.007	–0.000
Industry (ref: Agriculture, Forestry and Fishing)	–0.457***	0.169	0.096

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

Technological innovations are universally transforming the Agriculture, Fishing, Forestry and Mining industries. With increasing awareness of quality and healthy foods and sustainable farming systems, new agri-food products that meet such customers' demand are likely to boost production, output and drive firm performance. New agricultural products that are able to combat diseases and cope with severe weather conditions, for example, drought and water shortages, are most needed in Australia (ABARES 2019). In addition to new products, the implementation of new and more efficient production and delivery processes is also driving productivity by increasing production, while reducing input costs and resource uses (Kimura & Sauer 2015). As the OECD (2019c) asserts, new technologies in agriculture help manage inputs at highly accurate levels across fields, increase sustainability of farms through improvement in land use and minimisation of environmental impact. Therefore, technological solutions that respond to climate change have significant effects on economic activities and productivity (ABARES 2019; OECD 2019c). In the mining industry, technological innovations enhance the safety of workers in mines, enable better utilisation of resources, increase the efficiency of operations and boost production and productivity (DIIS 2018c; Matysek & Fisher 2016). As the future of innovation develops over the coming decades,

[35] Sauer (2017) also identifies a positive impact of non-technological innovation on productivity in Dutch firms; however, Sauer's study did not focus on SMEs.

technological innovation will be vital in driving transformation and future productivity for the primary sector.

Further, the role of non-technological innovation, namely, improvement in organisational/managerial processes or new marketing strategies, in this sector should not be overlooked given its impact on SME productivity. SMEs with less formal organisational structures can reorganise quickly and more efficiently to adapt to changes in the environment or seize innovation opportunities (Radicic & Djalilov 2019). Further, the resource scarcity typically associated with SMEs means they primarily rely on the market; thus, implementation of innovative marketing practices is also important to boost demand and market performance (Hervas-Oliver et al. 2016). The findings relating the significant role of both technological and non-technological innovation in improving firm productivity of SMEs in the primary sector is crucial given the ongoing marked slowdown in productivity growth of the sector and particularly, the significant fall (10.1% in labour productivity and 9.8% in multifactor productivity) recorded in the Agriculture, Forestry and Fishing industry in 2018–19. Nevertheless, it should be noted that apart from low innovative effort, the decline in agricultural productivity could also be affected by harsh weather conditions (Boult & Chancellor 2020). Thus, where is data available future research on innovation and productivity could examine the impact of weather events on productivity performance of firms in this industry.

In addition to innovation, investment in capital assets, such as machinery, equipment, hardware and software, significantly contributed to increased productivity of SMEs in the primary sector. The results reveal that an increase in capital expenditure of one million AUD leads to a 5.1% increase in the probability that SMEs will gain productivity increases in the following year. This finding supports prior research where capital is required to sustain, grow and develop innovative approaches to drive productivity in the primary sector (Bureau of Resource and Energy Economics, 2013). Finally, the results reveal significant differences in productivity performance between the two sub-sectors. Australian Mining SMEs are 9.6 percentage points less productive than Agriculture, Forestry and Fishing SMEs.

6.3.4. Summary of primary sector findings

The results for the primary sector showed that innovation outputs in this sector are also determined by various factors, including innovation inputs, firm characteristics and market competition. Of the inputs, collaboration, ICT investment and innovation focus positively affect both types of innovation, whereas financial support only affects technological innovation. The effect of training on SME innovation outputs is not significant. Thus, H1, which proposes that training has a positive effect on SME innovation outputs, is rejected in the context of Australian primary sector. The following hypotheses are supported.

H2: Collaboration for innovation has a positive effect on technological and non-technological innovation in primary sector SMEs.

H3: ICT investment has a positive effect on technological and non-technological innovation in primary sector SMEs.

H4: Financial support has a positive effect on technological innovation in primary sector SMEs.

H5: Innovation focus has a positive effect on technological and non-technological innovation in primary sector SMEs.

Regarding firm characteristics, larger firms are associated with a higher likelihood of implementing technological innovation. In the case of non-technological innovation, the positive effect of firm size is only significant for small firms with 5 to 19 employees relative to non-employing firms. The negative effect of firm age is significant for both types of innovation outputs. In this sector, SME exporters are more likely to implement technological and non-technological innovation than non-exporters. Given these results, the following hypotheses are supported:

H6: Firm size has a positive influence on technological and non-technological innovation in primary sector SMEs.

H7: Firm age has a negative influence on technological and non-technological innovation in primary sector SMEs.

H9: Exports have a positive influence on technological and non-technological innovation in primary sector SMEs.

In relation to ownership, the results revealed a negative influence of foreign ownership on non-technological innovation in SMEs in this sector, rather than the proposed positive influence. Thus, H8 is revised as below.

H8: Foreign ownership has a negative influence on non-technological innovation in primary sector SMEs.

In terms of the external environment, SMEs facing at least five competitors are more likely to implement technological innovation compared with those in a captive market with no competition. For non-technological innovation, SMEs facing three or four competitors and those facing five or more competitors also are more likely to innovate than those in the captive market. These findings suggest a positive impact of market competition on SME innovation outputs. No significant differences are found between the two sub-sectors, thus H11 is not supported. The results relating to the external environment only support H10, which is:

H10: Market competition has a positive impact on technological and non-technological innovation in SMEs.

The results from the productivity equation showed that SMEs implementing innovation are more likely to improve productivity. This is true for both technological and non-technological innovation in the primary sector. Therefore, the following hypotheses are confirmed:

H12a: Technological innovation has a positive impact on SME productivity in the primary sector.

H12b: Non-technological innovation has a positive impact on SME productivity in the primary sector.

6.4. RESULTS FOR THE SECONDARY SECTOR

6.4.1. Summary statistics and model evaluation

The following section provides empirical results for the secondary sector. The panel dataset for the secondary sector includes firm-level data of 126 Australian manufacturing SMEs over the period 2011–12 to 2015–16. Tables 6.11 and 6.12 summarise the statistics for SMEs in the secondary sector, which correspond to the two equations: (i) determinants and innovation outputs and (ii) innovation outputs and firm productivity. Similarly to the aggregate and primary cases, there is also a pattern in that the means of input variables are higher for innovators than for non-innovators. This holds for both technological and non-technological innovation. As mentioned before, this pattern implies that innovators tend to invest more on these innovation inputs relative to non-innovators. The mean value of variables related to firm size, foreign ownership, exports and competition are also higher for innovators compared with non-innovators, whereas smaller mean age is observed for innovators.

Table 6.11: Summary statistics for innovation outputs—Manufacturing

	Technological innovator				Non-technological innovator			
	Yes		No		Yes		No	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Training	0.189	0.393	0.068	0.253	0.215	0.412	0.055	0.228
Collaboration	0.239	0.428	0.030	0.170	0.200	0.401	0.065	0.246
ICT investment	0.312	0.464	0.163	0.370	0.363	0.482	0.132	0.339
Finance	0.473	0.501	0.266	0.443	0.492	0.501	0.260	0.439
Innovation focus	0.718	0.451	0.340	0.475	0.679	0.468	0.380	0.486
Firm size	2.150	0.810	1.956	0.797	2.163	0.806	1.954	0.798
Firm age	12.625	7.188	13.372	6.239	12.721	7.017	13.280	6.414
Foreign ownership	0.097	0.297	0.049	0.215	0.103	0.304	0.047	0.211
Export status	0.366	0.483	0.225	0.418	0.308	0.463	0.271	0.445
Competition	2.451	0.716	2.469	0.754	2.464	0.747	2.459	0.731

Table 6.12: Summary statistics for productivity—Manufacturing

	Productivity			
	Increased		Not increased	
	Mean	SD	Mean	SD
Technological innovation	0.636	0.483	0.334	0.473
Non-technological innovation	0.587	0.494	0.331	0.471
Capital investment (AUD million)	0.643	2.258	0.085	0.274
Non-capital investment (AUD million)	4.753	8.955	2.618	5.701

For the productivity equation, higher means of technological and non-technological innovation are observed for SMEs reporting productivity increases. The means of the explanatory variables presented only provide an overall view of their potential impacts on the dependent variables. Conclusions on the impact of each factor can only be drawn based on the estimates of the econometric model, which is presented in the next section.

Table 6.13 presents the tests for goodness-of-fit of the model for the secondary sector and for the endogeneity of the innovation covariates. The Wald test shows that the secondary sector model is also statistically significant at the 1% level. In addition, the significance of the likelihood ratio test confirms the importance of using panel data model that accounts for unobserved effects.

In terms of the endogeneity issue, the correlations between the observation-level errors and between the random effects of technological innovation and productivity are not significant. This suggests that in the case of manufacturing SMEs, technological innovation is not endogenous in the productivity equation; thus, is not treated as an endogenous variable in the productivity equation. The correlation between the observation-level errors of non-technological innovation and productivity is statistically significant at the 1% level. This result indicates that non-technological innovation is endogenous in the productivity equation. This means that the unobserved factors that influence non-technological innovation in manufacturing SMEs are correlated with the unobserved factors that influence productivity. Therefore, non-technological innovation is treated as an endogenous variable in the model.

Table 6.13: Model statistics—Manufacturing

Key statistics	
Observations	424
Goodness-of-fit	
Log likelihood	–658.855
Likelihood ratio test (Prob > chi-squared)	0.000***
Wald statistics	60.27
Wald test (Prob > chi-squared)	0.000***
Endogeneity	
Observation-level errors	
Corr (e.technological, e.productivity)	–0.092
Corr (e.non-technological, e.productivity)	–0.854***
Random effects	
Corr (technological [firm], productivity [firm])	0.289
Corr (non-technological [firm], productivity [firm])	0.323

*Note: ***: statistically significant at 1%; Corr: Correlation*

6.4.2. Determinants of innovation outputs in manufacturing SMEs

The two innovation outputs and productivity equations are estimated simultaneously, with non-technological innovation treated as an endogenous variable. Table 6.14 presents the econometric results of the innovation output equations for the secondary sector.

Of the inputs, collaboration, finance and innovation focus are positively and significantly linked to both types of innovation outputs, whereas training and ICT investments positively affect non-technological innovation. Collaboration shows a positive and significant effect on both innovation outputs; this effect is largest on technological innovation. Manufacturing SMEs that engaged in collaboration for innovation purposes are 35.9 percentage points and 16.3 percentage points more likely to implement technological innovation and non-technological innovation compared with those without collaboration. Innovation in the manufacturing industry is characterised as costly, sophisticated and mainly science-based. However, for manufacturing SMEs, lack of skilled labour (especially STEM workers) and financial resources are the most reported challenges (Australian Industry 2019). Collaboration is therefore an effective means for manufacturing SMEs to obtain expert knowledge, information and necessary human and financial resources for developing and implementing innovation. Collaboration, for example, between manufacturing SMEs and research institutions (e.g. CSIRO with advanced manufacturing facilities and expertise), facilitates the transfer of multidisciplinary knowledge and experience. This would allow SMEs to take advantage of the strengths and insights of their collaborative partners and gain access to Industry 4.0 technologies (AMGC 2018). Hence, the substantial benefits that collaborations bring about significantly lead to innovation success for manufacturing SMEs. This finding is consistent with that of Gronum et al. (2012), who also report a significant impact of collaboration networks on overall innovation performance in manufacturing SMEs.

Receiving financing for innovation is associated with 11.3 percentage points higher probability of implementing technological innovation. Likewise, the probability of implementing non-technological innovation is 13.3 percentage points greater for SMEs that received financial support. Prior research shows that the lack of finance significantly hampers innovation in French manufacturing firms (Savignac 2008), German manufacturing firms (Hottenrott & Peters 2012) and European manufacturing firms in general (Efthyvoulou & Vahter 2016). Financial constraints are even more serious for SMEs, which typically face shortages of internal finance and difficulty in accessing external finance (e.g. Efthyvoulou & Vahter 2016; Freel 2007). Such financial issues impede SMEs' propensity to invest in innovation (Hottenrott & Peters 2012; Savignac 2008). Therefore, the finding of this study highlights the crucial role of financing in the innovation performance of manufacturing SMEs. Receiving financial funding significantly contributes to innovation outputs, both technological and non-technological, in Australian manufacturing SMEs.

Similarly to firms in the primary sector, manufacturing SMEs with a major focus on innovation are more likely to implement both technological and non-technological innovation. This is reflected in the marginal effects of the innovation focus variable, which are 25.6 percentage points for technological innovation and 19 percentage points for non-technological innovation. This finding is consistent with Terziovski (2010), who finds a positive impact of innovation culture on innovation performance in manufacturing SMEs. These findings support Rosenbusch et al.'s (2011) viewpoint that an innovation focus provides an effective response for SMEs to overcome liabilities associated with their smallness. It is also in line with Aksoy (2017) in the generic SME literature insofar as an innovation focus not only affects technological innovation, but also non-technological innovation. The results reinforce the necessity of having an innovation-focused strategy in the organisation.

Table 6.14: Results of random effects probit estimation, innovation outputs—Manufacturing

	Technological innovation			Non-technological innovation		
	Coefficient	SE	Marginal effects	Coefficient	SE	Marginal effects
Training	0.093	0.278	0.025	0.452*	0.235	0.142
Collaboration	1.344***	0.280	0.359	0.585***	0.218	0.163
ICT investment	–0.044	0.207	–0.012	0.404**	0.172	0.095
Financial support	0.423***	0.183	0.113	0.390**	0.156	0.133
Innovation focus	0.960***	0.171	0.256	0.611***	0.147	0.190
Firm size (ref: less than 5 employees)						
5 to 19 employees	0.298	0.257	0.079	0.207	0.226	0.045
20 to 199 employees	0.359	0.266	0.096	0.206	0.218	0.082
Firm age	–0.022	0.015	–0.006	–0.010	0.012	–0.004
Foreign ownership	0.692	0.436	0.185	0.666*	0.378	0.253
Exports	–0.027	0.226	–0.007	–0.349*	0.193	–0.108
Competition (ref: 1 or 2 competitors)						
3 or 4 competitors	0.499*	0.274	0.134	–0.184	0.226	–0.043
5 or more competitors	0.158	0.255	0.042	–0.144	0.209	–0.025

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

The impact of training is moderately significant for non-technological innovation. The probability of implementing non-technological innovation is 14.2 percentage points higher for SMEs that undertook employee training. The impact of training is not statistically significant in the case of technological innovation. A possible explanation for this could be the transformation of manufacturing into a less labour-intensive and more capital-intensive industry, in which technologies are increasingly affecting the way business operations take place. The implementation of technologies such as automation has progressively replaced labour involvement in many parts of the manufacturing production process (DIIS 2018c). Nevertheless, innovations in non-technological aspects are more closely linked to humans, for example, the reorganisation of business routines, work responsibilities, implementation of new management methods, or external relations. SMEs often face human resource shortages and lack of skills for innovation (Woschke et al. 2017). Training is required to prepare employees in SMEs with appropriate skills and knowledge to achieve higher performance. The findings for Australian manufacturing SMEs are consistent with the study of Antonioli and Torre (2016) on Italian manufacturing SMEs, which also reports a positive impact of training on non-technological innovation, but not on technological innovation.

Increases in ICT investment are associated with approximately 9.5 percentage points higher probability of implementing non-technological innovation in manufacturing SMEs. The benefits of ICT in SMEs can be seen through 'cost savings, organisational effectiveness, access to new business opportunities and market information' (Giotopoulos et al. 2017, p. 60). As the OECD (2017b) indicates, the adoption of new ICT facilitates innovation in organisational and managerial arrangements, work processes and business models. ICT, by enhancing information processing and transferring, allows more decentralisation and task delegation (Sapprasert & Clausen 2012). ICT further assists coordination and communication, both internally and externally, enabling a more efficient use of information between employees and management, improved administrative activities and better interaction among employees (Bayo-Moriones et al. 2013; Tung & Rieck 2005). The evolution of ICT has also significantly resulted in numerous innovations in marketing (Buhalis & Law 2008; Buhalis et al. 2019). It acts as an enabler of online sales and e-marketing. With the support of website and social media platforms, a substantial amount of marketing initiatives has been implemented, thereby helping manufacturing firms to effectively introduce and promote their products to both national and global markets (Ganzer et al. 2017; OECD 2011). Therefore, these substantial benefits of ICT significantly affect non-technological innovation in manufacturing SMEs. However, the effect of ICT investment is not statistically significant in technological innovation. This result could imply that ICT investment by Australian manufacturing SMEs is not effective or sufficient to result in a significantly new technological output, for example, the introduction of a new technological product or implementation of a new production process. This seems to reflect a concerning trend identified by the Advanced Manufacturing Growth Centre (2020, p. 34), that 'Australia's manufacturing industry lags behind other industries in its use of digital technology and its perceived future importance'. Further investigation is needed to explain this insignificant effect. Nevertheless, the above results suggest that ICT investment by Australian manufacturing SMEs is more likely to lead to non-technological innovations, such as new organisational processes or new marketing practices.

With regards to firm characteristics, no significant differences in innovation performance are found among manufacturing SMEs across size[36] and age. Foreign ownership and exports matter for innovation output in manufacturing SMEs, but their effects are only moderately significant. As the marginal effects show, SMEs with foreign ownership exhibit a higher likelihood of implementing non-technological innovation by 25.3 percentage points compared with wholly Australian-owned SMEs. This result suggests an important influence of foreign ownership on innovation in non-technological aspects among manufacturing SMEs. In relation to exports, SME exporters in this sector are 10.8 percentage points less likely to implement non-technological innovation than non-exporters. This result is similar to that of Gallego et al. (2015) and Aboal and Garda (2016), who also report a negative and significant impact of export on small manufacturing firms in Colombia and Uruguay, respectively.

In terms of market competition, the results reveal that competition has a positive and moderate significant impact on technological innovation of SMEs that face three or four competitors. The marginal effect indicates that manufacturing SMEs facing three or four competitors are 13.4 percentage points more likely to implement technological innovation than those facing one or two competitors. It should be noted that the 'no competition'

[36] Unlike the aggregate and primary case, the base level for firm size in the manufacturing model is '1–4 employees', rather than 'non-employer'. This is because all manufacturing SMEs in the sample employ a certain number of employees.

category was omitted from the model because of null cell.[37] Thus, no interpretation is made for this category and '1 or 2 competitors' was used as the reference group. This also means that none of the manufacturing SMEs in the sample operates in a captive market; instead, they all face some degree of competition.

6.4.3. Innovation and productivity in manufacturing SMEs

Table 6.15 presents the estimation results of the productivity equation for manufacturing SMEs. Results show that both technological and non-technological innovation positively and significantly leads to higher firm productivity in manufacturing SMEs. A significant number of prior studies also demonstrate a positive impact of innovation on productivity in the manufacturing industry (e.g. Crespi & Zuniga 2012; Gallego et al. 2015). However, an overwhelming number of studies were conducted on large manufacturing firms with substantial resources and forefront technologies ready for innovation investment, which does not reflect the SME context.

Table 6.15: Results of random effects probit estimation, productivity—Manufacturing

	Productivity		
	Coefficient	**SE**	**Marginal effects**
Technological innovation	0.460***	0.176	0.134
Non-technological innovation	1.275***	0.346	0.372
Capital investment	0.373**	0.191	0.117
Non-capital investment	–0.001	0.013	–0.000

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

The results for Australian manufacturing SMEs show that non-technological innovation has a greater impact on firm productivity than technological innovation. As evident from the marginal effects, non-technological innovation is associated with 37.2 percentage points higher probability of increasing productivity for manufacturing SMEs, whereas technological innovation leads to a 13.4 percentage point increase in the probability of improved SME productivity. This is an interesting result since in manufacturing, technological innovation is often anticipated to be the most important driver of productivity as opposed to non-technological innovation. The greater significant

[37] Null cell (base level): No innovation was reported by manufacturing SMEs in the captive market (no competition).

impact of non-technological over technological innovation in manufacturing has also been found in the generic literature, for example, De Fuentes et al. (2019) in the case of Mexican manufacturing and Gallego et al. (2015) in Colombian manufacturing industries. The findings highlight the significance of innovation in non-technological aspects (i.e. reorganisation, knowledge management, marketing and branding) in boosting productivity for manufacturing SMEs in Australia. Nevertheless, the findings of this study partly contradict those of Aboal and Garda (2016), which indicate a positive impact of technological innovation, but a negative impact of non-technological innovation in small manufacturing firms (with less than 50 employees) in Uruguay.

In addition to technological and non-technological innovation, capital investments are another important driver of SME productivity in the manufacturing sector. In particular, a million dollar increase in capital expenditure results in an 11.7% increase in the probability that firm productivity of manufacturing SMEs will increase compared with the previous year. A recent empirical study by Kijek and Kijek (2019) also find a positive and significant effect of investments in capital assets (i.e. machinery and equipment) on productivity among Polish innovative manufacturing firms.

6.4.4. Summary of secondary sector findings

The results for the secondary sector reveal that collaboration, financial support and innovation focus have a significant and positive impact on both types of innovation outputs. ICT investment and training positively affect only non-technological innovation in manufacturing SMEs at the 5% and 10% level, respectively. Based on these results, the following hypotheses are supported in the secondary sector context.

H1: Training has a positive effect on non-technological innovation in manufacturing SMEs.

H2: Collaboration for innovation has a positive effect on technological and non-technological innovation in manufacturing SMEs.

H3: ICT investment has a positive effect on non-technological innovation in manufacturing SMEs.

H4: Financial support has a positive effect on technological and non-technological innovation in manufacturing SMEs.

H5: Innovation focus has a positive effect on technological and non-technological innovation in manufacturing SMEs.

In relation to firm characteristics, the effects of firm size and age are not statistically significant. Thus, H6 and H7 are rejected in the secondary sector. Manufacturing SMEs with foreign ownership are more likely to implement non-technological innovation than wholly Australian-owned SMEs. Thus, H8 is supported.

H8: Foreign ownership has a positive influence on non-technological innovation in manufacturing SMEs.

SMEs involved in exports are found to be less likely to implement non-technological innovation compared with those that only focus on the domestic market. This result contradicts H9, which proposed a positive influence of exports on innovation outputs. The revised hypothesis is as follows:

H9: Exports have a negative influence on non-technological innovation in manufacturing SMEs.

In terms of the external environment, the finding showed that SMEs facing three or four competitors are more likely to implement technological innovation than those facing one or two competitors in the market. This suggests a positive impact of market competition, yet only on technological innovation and at the 10% level. Since the secondary sector in this present study includes only manufacturing SMEs, H11 is not applicable. The result relating the external environment only supports H10, which is:

H10: Market competition has a positive impact on technological innovation in manufacturing SMEs.

In term of the innovation–productivity link, the implementation of technological and non-technological innovation also led to a higher likelihood of increased productivity of SMEs in the secondary sector. Thus, the following hypotheses are confirmed:

H12a: Technological innovation has a positive impact on SME productivity in the secondary sector.

H12b: Non-technological innovation has a positive impact on SME productivity in the secondary sector.

6.5. RESULTS FOR THE SERVICE SECTOR

6.5.1. Summary statistics and model evaluation

The following sections present the results of the empirical model investigating the factors influencing technological and non-technological innovation and productivity among Australian service SMEs. Following the same procedure as in the previous sections, summary statistics for variables used in the service model are presented in Tables 6.16 and 6.17.

The service sector dataset includes 1,573 service SMEs, making up around 80% of the total SMEs in the aggregate sample. As the service sector accounts for approximately 88% of total businesses in Australia and forms the vast majority of the sample for the present study (aggregate dataset), the patterns observed in the service dataset are relatively quite similar to those of the aggregate dataset. Accordingly, the means of innovation input variables are higher for technological innovators and non-technological innovators compared with non-innovators. For example, SMEs that implemented technological innovation showed a higher mean of ICT investment (0.356) compared with those that did not implement technological innovation (0.125) or SMEs that implemented non-technological innovation demonstrated a higher mean of innovation focus (0.630) relative to those that did not implement non-technological innovation (0.321). Further, SMEs that gained productivity increases also show higher mean values of technological innovation (0.534) and non-technological innovation (0.569) compared with those that did not experience productivity improvement (0.291 and 0.317, respectively).

Table 6.16: Summary statistics for innovation outputs—Service

	Technological innovator				Non-technological innovator			
	Yes		No		Yes		No	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Training	0.205	0.404	0.071	0.256	0.213	0.409	0.060	0.238
Collaboration	0.249	0.432	0.045	0.208	0.242	0.429	0.040	0.195
ICT investment	0.356	0.479	0.125	0.331	0.354	0.478	0.116	0.321
Financial support	0.363	0.481	0.204	0.403	0.367	0.482	0.195	0.396
Innovation focus	0.666	0.472	0.317	0.465	0.630	0.483	0.321	0.467
Firm size	1.996	0.936	1.702	0.972	2.058	0.920	1.652	0.968
Firm age	11.395	6.654	11.857	6.636	11.049	6.597	12.083	6.645
Foreign ownership	0.074	0.261	0.032	0.175	0.056	0.229	0.040	0.197
Exports	0.181	0.385	0.090	0.287	0.140	0.347	0.110	0.313
Competition	2.412	0.909	2.192	1.121	2.442	0.883	2.164	1.137
Industry	1.867	0.757	1.880	0.775	1.870	0.775	1.879	0.766

Table 6.17: Descriptive statistics for productivity—Service

	Productivity			
	Increased		Not increased	
	Mean	SD	Mean	SD
Technological innovation	0.534	0.499	0.291	0.454
Non-technological innovation	0.569	0.495	0.317	0.465
Capital investment (AUD million)	0.241	1.741	0.100	0.835
Non-capital investment (AUD million)	4.161	10.934	2.481	7.622
Industry	1.914	0.767	1.866	0.769

The random effects probit regression model is carried out to estimate the factors affecting technological and non-technological innovation and the impact of these two innovation outputs on productivity of service SMEs. Table 6.18 provides estimates for goodness-of-fit of the model and endogeneity tests for innovation covariates.

Table 6.18: Model statistics—Service

Key statistics	
Observations	4,470
Goodness-of-fit	
Log likelihood	–6409.757
Likelihood ratio test (Prob > chi-squared)	0.000***
Wald statistics	314.95
Wald test (Prob > chi-squared)	0.000***
Endogeneity	
Observation-level errors	
Corr (e.technological, e.productivity)	–0.486***
Corr (e.non-technological, e.productivity)	–0.527***
Random effects	
Corr (technological [firm], productivity [firm])	–0.250***
Corr (non-technological [firm], productivity [firm])	–0.167**

*Note: ** and ***: statistically significant at 5% and 1%, respectively; Corr: Correlation*

The overall goodness-of-fit test confirms that the service sector model is statistically significant at the 1% level. The use of the panel data model also accounts for unobserved effects in the estimation. Further, the correlations between the observation-level errors and between the random effects are statistically significant, both for (i) technological innovation and productivity and (ii) non-technological innovation and productivity. This indicates the endogeneity of technological and non-technological innovations in the productivity equation in the service sector. Thus, both innovation output covariates are treated as endogenous variables in the estimation.

6.5.2. Determinants of innovation outputs in service SMEs

Table 6.19 presents the estimated results for determinants of technological and non-technological innovation while Table 6.20 presents the results for innovation outputs and productivity. The results for service SMEs show that collaboration for innovation purposes is also the most significant determinant of both technological and non-technological innovation. Service SMEs that are involved in collaboration for innovation purposes are more likely to implement technological and non-technological innovation by 23.3 percentage points and 28.2 percentage points, respectively, compared with those without collaboration. The findings are consistent with prior work in the literature on innovation in services, where collaboration was found to be a determinant of innovation success for service firms (Love et al. 2011; Miozzo et al. 2016). As Mina et al. (2014) assert, successful innovation requires the recombination of knowledge across firm boundaries such as customers, suppliers and research institutions. For SMEs with resource constraints, collaboration is an effective means of gaining external knowledge and ideas; it also spreads the costs and risks of the innovation process among collaborative partners. This result confirms the crucial role of collaboration in both technological and non-technological innovation in the service SME context.

The results show that training for employees positively impacts both technological and non-technological innovation. Service SMEs that increased training are 7.6 percentage points and 9.6 percentage points more likely to implement technological and non-technological innovation, respectively. The results emphasise that upskilling staff is highly relevant to innovation performance in services. Services are labour-intensive industries, with employees being the providers of services to customers, the key influencers of service quality as well as sources of innovative ideas. Therefore, service industries rely heavily on investments in human capital for their performance (CEDA 2017). Formal training enhances the stock of human capital by upskilling and broadening the knowledge of employees. Inevitably, a skilled workforce is the key contributor to the creation of new ideas, development and implementation of innovation in services. This study supports the findings of prior research, which demonstrates that investments in a firm’s human resources (e.g. training and education) have a positive impact on the innovativeness of service firms in general (Love et al. 2010; Martínez-Ros & Orfila-Sintes 2012) and service SMEs in particular (Divisekera & Nguyen 2018a).

There is also a significant and positive influence of ICT investment on both types of innovation outputs. For service SMEs that increased investments in ICT, their probability of implementing technological and non-technological innovation is 13 percentage points higher. This result underscores the importance of ICT in innovation implementation in services. Australian services industries have significantly transformed their business operations using new ICT (Australian Government 2017b). The adoption of ICT helps improve the quality and efficiency of service delivered and reduce costs of service processes. It also opens up opportunities for more services to be traded and delivered over online platforms (OECD 2017b). In addition to facilitating technological innovation, ICT facilitates organisational and marketing innovation by providing an effective means of internal and external communication and coordination for service firms (Broersma & Ark 2007). It also enables new work processes (e.g. to organise work schedules and tasks via the Internet and mobile apps), new management practices and techniques, new ways of communicating between service providers and customers worldwide. The application of ICT is even more important in marketing aspects, for example, service firms are increasingly using social networks and digital media to advertise and promote their services nationally and globally (particularly popular in accommodation and transport services) (Hall & Williams 2019). Although ICT is a significant enhancer of innovation, recent research points out that SMEs, particularly in services, are lagging behind in ICT adoption. This is mainly due to the financial cost of implementing ICT, lack of skilled ICT personnel and inadequate awareness of ICT opportunities (OECD 2019d; Okundaye et al. 2019).

Table 6.19: Results of random effects probit estimation, innovation outputs—Service

	Technological innovation			Non-technological innovation		
	Coefficient	SE	Marginal effects	Coefficient	SE	Marginal effects
Training	0.376***	0.080	0.076	0.447***	0.082	0.096
Collaboration	0.811***	0.080	0.233	0.998***	0.087	0.282
ICT investment	0.547***	0.064	0.130	0.575***	0.066	0.130
Financial support	0.319***	0.060	0.090	0.366***	0.061	0.102
Innovation focus	0.655***	0.053	0.172	0.506***	0.054	0.131
Firm size (ref: non-employer)						
Less than 5 employees	–0.010	0.135	–0.001	0.225	0.145	0.048
5 to 19 employees	0.050	0.135	0.008	0.473***	0.145	0.104
20 to 199 employees	0.185	0.137	0.038	0.763***	0.147	0.177
Firm age	–0.013***	0.005	–0.003	–0.030***	0.005	–0.007
Foreign ownership	0.383***	0.146	0.087	–0.071	0.152	–0.028
Exports	0.280***	0.088	0.070	–0.090	0.092	–0.019
Competition (ref: No competition)						
1 or 2 competitors	0.487***	0.121	0.105	0.704***	0.126	0.154
3 or 4 competitors	0.567***	0.119	0.124	0.643***	0.126	0.134
5 or more competitors	0.473***	0.105	0.110	0.664***	0.109	0.146
Industry (ref: Supplier-Dominated Services)						
Supporting Infrastructure Services	0.026	0.077	0.006	–0.015	0.080	–0.012
Knowledge-Intensive Business Services	–0.105	0.093	–0.023	0.054	0.097	0.013

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

The need for finance to support innovation in service SMEs is also evident. The results reveal that receiving funding increases the probability of achieving both technological and non-technological innovation by 9 and 10.2 percentage points, respectively. The development and implementation of innovation is characterised by high fixed costs and high levels of uncertainty and economic risk (Crespi & Zuniga 2012). As Un and Montoro-Sanchez (2010) emphasise, SMEs in service industries tend to lack financial resources for innovation, thus hampering their capacity to invest in innovation (Antonioli & Torre 2016; Savignac 2008). Receiving financial support is therefore decisive in innovation performance of service SMEs. This finding supports Romero-Martínez et al. (2010), who also find that service SMEs that received funding are more likely to implement both technological and non-technological innovation. The positive effect of financial support has also been found in previous studies in the broader service context, for example, Love et al. (2011) in UK service firms and Gallego et al. (2015) in Colombian service firms.

Similarly to the results for the primary and secondary sectors, an innovation focus also has a positive and significant effect on innovation outputs: service SMEs that have a major focus on innovation are more likely to implement innovation, both technological and non-technological. The results reinforce the importance of having an innovation culture in an organisation regardless of the industry it belongs to. A favourable attitude towards innovative ideas and new developments is the key driver of a firm's innovation performance.

Regarding firm characteristics, firm size has a positive and significant impact on non-technological innovation in service SMEs. Treating non-employer firms as a reference group, firms with one to four employees and firms with 20 to 199 employees are 10.4 percentage points and 17.7 percentage points more likely to implement non-technological innovation. The effect of firm size on technological innovation is not statistically significant. Similarly to the primary and manufacturing cases, firm age also has a negative and significant impact on innovation outputs in services. The results indicate that the longer the years of operation, the less likely the service SMEs will implement innovation, both technological and non-technological.

Further, foreign ownership and exports significantly influence technological innovation in service SMEs, but not non-technological innovation. SMEs with foreign ownership are 8.7 percentage points, while SME exporters are 7 percentage points, more likely to implement technological innovation. These results highlight the importance of exports and foreign ownership in facilitating technological innovation. The absent effect of foreign ownership and exports on non-technological innovation is in line with the findings of Aboal and Garda (2016) in Uruguayan service firms and Peters et al. (2018) in German service firms.

For factors related to the external environment, market competition has a significant and positive influence on both types of innovation outputs. As the results show, service SMEs that face some degree of competition exhibit a higher probability of implementing technological as well as non-technological innovation compared with those in a captive market with no effective competition. Yet, the magnitude of competition effects is heterogeneous across the competition categories. Finally, no significant differences are found in relation to innovation performance, both technological and non-technological, among the three Australian service sub-sectors.

6.5.3. Innovation and productivity in service SMEs

The estimates of the productivity equation for service SMEs are presented in Table 6.20. As the results reveal, innovative service SMEs are more likely to increase productivity. This positive impact is evident for both types of innovation outputs. The marginal effects show that the implementation of technological and non-technological innovation is associated with approximately 23 percentage points higher probability that service SMEs will gain productivity increases compared with the previous year.

Regarding the control variables, investment in non-capital assets also contributes to productivity increases. However, this effect is relatively small and moderately significant. A million dollar increase in non-capital expenditure translates to a 0.1% increase in the probability that SME productivity will increase compared with the previous year. In terms of sectoral differences, SMEs in the KIBS are more productive than those in the SDS. A possible reason could be the characteristics of firms in these two service sub-sectors. KIBS firms are often referred to as dynamic firms with high technological capability, knowledge and business performance, whereas those in SDS are commonly characterised by lower capabilities, more limited resources (Castellacci 2008; Martin-Rios & Ciobanu 2019) and lower productivity levels (Hall & Williams 2019).

Table 6.20: Results of random effects probit estimation, productivity—Service

	Productivity		
	Coefficient	**SE**	**Marginal effects**
Technological innovation	0.866***	0.220	0.232
Non-technological innovation	0.867***	0.211	0.229
Capital investment	0.026	0.019	0.006
Non-capital investment	0.006*	0.003	0.001
Industry (ref: Supplier-Dominated Services)			
Supporting Infrastructure Services	0.101	0.071	0.017
Knowledge-Intensive Business Services	0.194**	0.080	0.040

*Note: ***, ** and *: statistically significant at 1%, 5% and 10%, respectively*

The significant impact of innovation on productivity in the service sector has been evident in previous research. In the broader innovation literature, a positive effect of technological innovation on productivity was found in the case of French KIBS firms (Musolesi & Huiban, 2010) and Estonian service firms (Masso & Vahter 2012). Using a large dataset of 43 countries, a recent study by Morris (2018) also reveals that technological innovation is positively associated with increased labour and total factor productivity in service firms. Several studies found the positive impact of both technological and non-technological innovation on labour productivity of service firms in Mexico (De Fuentes et al. 2015, 2019), Columbia (Gallego et al. 2015), Chile (Álvarez et al. 2015), Uruguay (Aboal & Garda 2016), Spain (García-Pozo et al. 2018) and Germany and the UK (Peters et al. 2018)[38]. Although an increasing number of studies has found a positive relationship between innovation and productivity in the broader service sector, studies focusing on service SMEs remain limited. Of the existing studies found, findings from the present study support Aboal and Garda's findings (2016), which reveal that both technological and non-technological innovation had a positive impact on small service firms in Uruguay. Moreover, Audretsch et al. (2020) report a positive impact of technological innovation on productivity of micro service firms in Germany. Nonetheless, the results of the present study contradict those of Díaz-Chao et al. (2016), who record a negative impact of non-technological innovation on Spanish tourism SMEs. In this regard, the findings of this study contribute to the literature by providing empirical

[38] Some studies found no effect of innovation on productivity for service firms, for example, in the UK and Northern Ireland (Love et al. 2010) and in the UK (Mansury & Love 2008).

evidence of the positive impact of both innovation types in the context of Australian service SMEs.

6.5.4. Summary of service sector findings

Estimates from the service sector model reveal that innovation outputs of service SMEs are also determined by several factors relating to innovation inputs, firm characteristics and the external environment. The five input variables—training, collaboration, ICT investment, financial support and innovation focus—have significant and positive impacts on both technological and non-technological innovation. Therefore, the following five hypotheses are supported in the service sector context:

H1: Training has a positive effect on technological and non-technological innovation in service SMEs.

H2: Collaboration for innovation has a positive effect on technological and non-technological innovation in service SMEs.

H3: ICT investment has a positive effect on technological and non-technological innovation in service SMEs.

H4: Financial support has a positive effect on technological and non-technological innovation in service SMEs.

H5: Innovation focus has a positive effect on technological and non-technological innovation in service SMEs.

Characteristics of the firm also influence innovation outputs. Larger firm size is associated with a higher likelihood of SMEs implementing non-technological innovation. Older SMEs are less likely to implement technological as well as non-technological innovation than younger SMEs. The positive effects of foreign ownership and exports are significant for technological innovation. Hence, the following hypotheses are supported:

H6: Firm size has a positive influence on non-technological innovation in service SMEs.

H7: Firm age has a negative influence on technological and non-technological innovation in service SMEs.

H8: Foreign ownership has a positive influence on technological innovation in service SMEs.

H9: Exports have a positive influence on technological innovation in service SMEs.

Compared with service SMEs in the captive market, those in the competitive market are more likely to implement technological and non-technological innovation. This holds for all degrees of market competition. No significant differences are found in terms of innovation performance among service sub-sectors, which rejects H11. The results support H10 only.

H10: Market competition has a positive impact on technological and non-technological innovation in service SMEs.

Finally, the findings from the estimation confirmed the significant and positive impact of technological and non-technological innovation on SME productivity in the Australian service sector, supporting the following hypotheses:

H12a: Technological innovation has a positive impact on SME productivity in the service sector.

H12b: Non-technological innovation has a positive impact on SME productivity in the service sector.

6.6. CONTEXTUALISING THE FINDINGS

6.6.1. Benchmarking the sectoral results

In response to the lack of empirical research on sectoral innovation in the SME context, this study empirically investigated the innovation processes of SMEs at the aggregate economy and sectoral levels. The random effects probit model was employed to estimate innovation determinants, innovation outputs and firm productivity in the context of Australian SMEs. Analyses for aggregate, primary, secondary and service sectors were run separately. Table 6.21 summarises the determinants of innovation outputs and Table 6.22 summarises the impact of innovation on productivity of SMEs across sectors, benchmarking against the aggregate economy results. Since the results have been discussed and explained in the sector-specific contexts in previous sections, the following only presents the similarities and major differences between the sectoral and aggregate results.

Table 6.21: Determinants of SME innovation across sectors

Variables	Aggregate economy		Primary		Secondary		Service	
	Technological innovation	Non-technological innovation	Technological innovation	Non-technological innovation	Technological innovation	Non-technological innovation	Technological innovation	Non-technological innovation
Training	0.062	0.094	n.s.	n.s.	n.s.	0.142	0.076	0.096
Collaboration	0.230	0.270	0.151	0.260	0.359	0.163	0.233	0.282
ICT investment	0.116	0.118	0.118	0.112	n.s.	0.095	0.130	0.130
Financial support	0.089	0.087	0.077	n.s.	0.113	0.133	0.090	0.102
Innovation focus	0.172	0.134	0.151	0.099	0.256	0.190	0.172	0.131
Firm size	+	+	+	+	n.s.	n.s.	+	+
Firm age	–	–	–	–	n.s.	n.s.	–	–
Foreign ownership	+	n.s.	n.s.	–	+	+	+	n.s.
Exports	+	n.s.	+	+	n.s.	–	+	n.s.
Competition	+	+	+	+	+	n.s.	+	+
Sector/Industry	+	+	n.s.	n.s.	n/a	n/a	n.s.	n.s.

Note: + positively significant, – negatively significant, n.s.: not statistically significant and n/a: not applicable, numbers refer to average marginal effects

In terms of innovation inputs, the aggregate results show that all innovation inputs considered in this study have significant and positive impacts on both technological and non-technological innovations of Australian SMEs (as a whole). However, the sectoral results reveal that, while the signs of the effects of these innovation inputs remain positive across all three sectors, not all effects are significant. Particularly, the effect of training is not significant in the primary sector, and technological innovation in the secondary sector. ICT investment by Australian manufacturing SMEs also does not show a significant impact on technological innovation, whereas the effect of financial support is not statistically significant for non-technological innovation of SMEs in the primary sector. Only collaboration and innovation focus significantly affect both technological and non-technological innovation across all sectors, with their marginal effects being most pronounced on technological innovation in manufacturing SMEs.

As revealed by the aggregate analysis, firm size has a significant and positive influence, while firm age has a significant, but negative, influence on both types of innovation outputs of Australian SMEs. Estimates from the primary and service sector show similar results. Nonetheless, neither firm size nor firm age have a significant effect in the secondary sector. At the economy-wide level, foreign ownership and exports exhibit a significant and positive influence only on technological innovation. Analysis of the service sector yields similar results, which is understandable given the service-dominated nature of the Australian economy and that service SMEs constitute around 80% of the aggregate dataset. However, corresponding results for the primary and secondary sectors are mixed. The impact of foreign ownership is significant, but negative, on non-technological innovation in the primary sector, while it is significant and positive on both technological and non-technological innovation in the secondary sector.

Regarding the external environment, the aggregate result demonstrates a significant and positive impact of market competition on both types of innovation outputs. This result also holds for SMEs in the primary and service sectors. However, in the secondary sector, the positive impact of competition is only significant for technological innovation. As found from the aggregate analysis, there are significant differences among sectors in terms of their innovation performance, both technological and non-technological. In each sector, the differences among their sub-sectors are not significant.

Table 6.22: Impact of innovation on productivity across sectors

Productivity	Aggregate Economy	Primary	Secondary	Service
Technological innovation	0.200	0.380	0.134	0.232
Non-technological innovation	0.281	0.225	0.372	0.229
Capital investment	+	+	+	n.s.
Non-capital investment	+	n.s.	n.s.	+
Sector/Industry	–	–	n/a	+

Note: + positively significant, – negatively significant, n.s.: not statistically significant, n/a: not applicable, numbers refer to average marginal effects

In terms of the link between innovation and productivity, the aggregate and sectoral results share similar findings regarding the significant and positive impact of both innovation outputs on SME productivity. At the aggregate economy level, non-technological innovation shows a larger marginal effect on SME productivity than technological innovation. Most would think that the larger effect of non-technological innovation at the economy level would be attributed to the service sector. However, it is the secondary sector that experiences a much larger effect of non-technological innovation on SME productivity. In the service sector, the effects of technological and non-technological innovation on productivity are relatively similar. For the primary sector, technological innovation shows a greater impact than non-technological innovation. These results indicate that the impact of each innovation type, in terms of magnitude, varies across sectors.

In addition to innovation outputs, capital and non-capital investments are the other two drivers of improved productivity among SMEs at the aggregate level. Analysis of the primary and manufacturing sectors shows similar results to the aggregate analysis regarding the significant and positive impact of capital investment on SME productivity. However, this impact is not significant in the case of service SMEs. In contrast, the significant and positive impact of non-capital investment is similar between the aggregate and the service results, but this impact is not significant for the other two sectors. Finally, there are significant differences in terms of productivity performance among sub-sectors. In the primary sector, Mining SMEs are less productive than Agriculture, Forestry and Fishing SMEs, while in the service sector KIBS are more productive than SDS.

To conclude, the above findings show that differences exist in the innovation processes of SMEs among sectors in relation to innovation determinants, innovation outputs (technological and non-technological) and productivity performance. Such differences suggest that the analysis of firms' innovation processes based on economy-wide aggregation is insufficient to truly understand how SMEs in each sector innovate and what drives their innovation and productivity performance. Thus, the analysis of innovation and productivity in SMEs should be conducted from a sector-specific perspective.

6.6.2. Comparison with other Australian studies

Table 6.23 compares the findings of the present study with other relevant empirical studies on innovation and productivity, particularly on Australian SMEs. It can be seen that most studies in this area take advantage of the BLD, which provides information on innovative activities and firm performance of Australian SMEs. Yet there are differences between the present study and prior Australian research in terms of choice of variables in the innovation output and productivity equations. Some studies, such as Gronum et al. (2012), Reeson and Rudd (2016) or Jones and Zubielqui (2017), examine the effect of a few factors on SME innovation performance in the economy-wide context. Others, such Soriano et al. (2019) and Divisekera and Nguyen (2018a) cover a wide range of variables, but focus only on a specific industry and on the innovation output equation.

In comparison with prior Australian studies on SME innovation, this thesis provides empirical results not only for the aggregate economy, but also for each economic sector and on both innovation output and productivity equations. As shown in Table 5.23, the thesis shares some common results with prior Australian studies on the sign and significance of the determinants of innovation at the economy level. For example, the positive impact of collaboration is also found in Gronum et al. (2012), Palangkaraya et al. (2015) and Tuhin (2016). The effect of training and ICT on innovation performance supports Tuhin (2016). The positive influence of firm size is also revealed in studies such as Palangkaraya et al. (2010), Gronum et al. (2012) and Reeson and Rudd (2016), while the negative impact of firm age on SME innovation output is found in Gronum et al. (2012). The finding that SME exporters are more likely to implement technological innovation compared with non-exporters is in line with Tuhin (2016). The role of market competition as a driver of SME innovation is identified in Palangkaraya et al.'s (2015) study. Further, the findings of this thesis add to the Australian academic literature on SMEs by confirming that financial support and innovation focus have a significant and positive influence on both technological and non-technological innovation, and that foreign ownership positively affects technological innovation at the aggregate economy level. Most importantly, there are significant differences in technological as well as non-technological innovation performance across sectors, which stresses the importance of examining innovation in sectoral contexts rather than at an aggregate level.

Regarding industry-specific studies on Australian SMEs, Palangkaraya et al. (2010) in the case of the resources and manufacturing industries, report a positive effect of firm size on technological innovation. This is partly consistent with the results of this thesis, which affirms that size has a positive impact on technological innovation among SMEs in the primary sector although this effect is not significant in manufacturing SMEs. This slightly different finding could be due to different approaches used (i.e. this thesis examines the primary and manufacturing sectors separately, whereas Palangkaraya et al. (2010) use an aggregate dataset of the two sectors). Divisekera and Nguyen (2018a, b) examine the determinants of SME innovation in the tourism industry, which belongs to the service sector. Their study shares common findings with the service results in this thesis with respect to the positive impact of collaboration, training and foreign ownership on technological innovation, and size, funding, collaboration, ICT and competition on non-technological innovation. Soriano et al.'s (2019) study on small firms in the Australian agriculture industry demonstrates that collaboration, ICT, finance, exports and competition are among the drivers of overall innovation output, which is consistent with the results for the primary sector examined in this thesis.

Table 6.23: Comparison of findings with relevant Australian empirical studies on SMEs

Study	Industries/sectors covered	Data/Estimation	Determinants of innovation outputs		Innovation impact on productivity
			Technological	Non-technological	
Palangkaraya et al. (2010)	Resources, Manufacturing	BLD 2004–2007 Cross-sectional estimation	Size (+), joint R&D (+), investment intensity (+)	Not examined	Technological innovation (+)
Gronum et al. (2012)	All sectors aggregation	BLD 2004–2007 Cross-sectional estimation	* Size (+), age (–), collaborative network (+), industry (+)		Innovation breadth (+)
Palangkaraya et al. (2015)	All sectors aggregation	BLD 2005–2012 Panel data estimation	* Collaboration (+), competition (+)		Technological innovation (+)
Reeson & Rudd (2016)	All sectors aggregation	BLD 2006–2011 Panel data estimation	Size (+), industry (–)	Size (+), industry (–)	Technological innovation (+) Non-technological innovation (+)
Tuhin (2016)	All sectors aggregation	BLD 2004–2009 Panel data estimation	Collaboration (+), export (+), training (+), ICT (+)	Foreign ownership (+)	Not examined
Jones & Zubielqui (2017)	All sectors aggregation	Authors' survey data 2014 Cross-sectional estimation	* Human resource transfer (+)		Innovativeness (+)
Divisekera & Nguyen (2018a)	Tourism	BLD 2006–2011 Cross-sectional estimation	Collaboration (+), human capital (+), environment (–) foreign ownership (+)	Size (+), funding (+), collaboration (+), ICT (+), industry (+), competition (+)	Not examined
Soriano et al. (2019)	Agriculture	BLD 2006–2011 Panel data estimation	Collaboration (+), ICT intensity (+), STEM skills (+), flexible working arrangements (+), finance (+), export (+), competition (+)		Not examined
The present thesis	Aggregate economy, primary, secondary, service	BLD 2011–2016 Panel data estimation	# Collaboration (+), training (+), ICT (+), finance (+), innovation focus (+), size (+), age (–), foreign ownership (+), export (+), competition (+), sector (+)	# Collaboration (+), training (+), collaboration (+), ICT (+), finance (+), innovation focus (+), size (+), age (–), competition (+), sector (+)	Technological innovation (+) Non-technological innovation (+)

*Note: + positively significant, – negatively significant, * the study used overall innovation, no separation between innovation types, # findings for the aggregate economy, see Tables 5.21 and 5.22 for each economic sector*

In relation to the productivity equation, prior Australian studies found a positive link between innovation and firm productivity, with most studies using technological innovation or firm innovativeness as the innovation output, and relied on cross-sectional estimation. Contributing to the Australian literature, not only did the present study show a significant and positive impact of technological as well as non-technological innovation on SME productivity, but it further provided empirical evidence, indicating that the effect of each innovation type on productivity varied across the three economic sectors. For example, technological innovation showed a greater impact on SME productivity than non-technological innovation in the primary sector, while non-technological innovation exhibited a more significant impact in manufacturing SMEs. To conclude, the empirical results produced in this chapter confirm the existence of sectoral differences—not only in innovation outputs, but also in innovation determinants and drivers of productivity across the three economic sectors in Australia.

6.7. SUMMARY

To date, limited empirical research has analysed the similarities and differences in the innovation process across the primary, secondary and service sectors in the SME context. This chapter presented and discussed the empirical findings on innovation and productivity in the context of Australian SMEs at the aggregate economy and sector levels. The estimations revealed several factors that determine innovation in SMEs across sectors. Engaging in collaboration and having an innovation focus significantly resulted in both technological and non-technological innovation in the three sectors. ICT investment, financial support and training also affected innovation outputs; yet, the significance and magnitude of the effect varied among sectors and innovation types. Factors related to firm characteristics and the external environment also influenced innovation outputs in SMEs; but the coefficient sign and the significance of their effect also varied among sectors.

The empirical results confirmed the significant and positive impact of technological innovation on firm productivity of SMEs across the three sectors. Further, non-technological innovation also positively affected SME productivity across sectors. These findings not only contribute to the limited sectoral research on innovation and productivity in the SME context, but also offer further insights into the extent to which each type of innovation output drives SME productivity in the three-sector context. In the primary sector, technological innovation showed a greater impact on SME productivity than non-technological innovation. The reverse was found for manufacturing SMEs in the secondary sector. In the service sector, the effect of technological innovation on service SMEs' productivity was relatively similar to that of non-technological innovation.

The differences in innovation determinants, innovation outputs and productivity performance found among the three economic sectors in Australia support the proposition of Nelson and Winter (1982) in evolutionary theory and Malerba (2006) and Castellacci (2008) that innovation behaviours and processes significantly differ from sector to sector. These empirical findings confirm the need to analyse innovation and SME productivity in sector-specific contexts. The results of this chapter also provide useful insights into the factors driving and hampering SME innovation and productivity in each economic sector. This lays an empirical foundation for policy recommendations, which are presented in the next chapter.

CHAPTER SEVEN:
CONCLUSION AND POLICY IMPLICATIONS

7.1. INTRODUCTION

The preceding chapter reported the results of the data analysis and discussion in the economy and sectoral contexts. This chapter first presents the research summary and key findings of the thesis. It then discusses the theoretical and policy implications of the research as well as the limitations of the study, suggesting future research directions. The chapter is arranged as follows: section 7.2 summarises the thesis in terms of addressing the research problem outlined in Chapter One. Section 7.3 summarises the key findings drawn from Chapter Three and the empirical results in Chapter Six. Section 7.4 summarises the contributions of the study and section 7.5 discusses the policy implications of the research findings. Section 7.6 acknowledges the limitations of this study and proposes future directions for research, while section 7.7 provides the concluding remarks of the thesis.

7.2. RESEARCH SUMMARY

Innovation is imperative to long-term economic growth and competitiveness. The literature has extensively examined innovation and productivity relationships in large firms and the aggregate economy. However, little is known about the innovation process of SMEs in various economic sectors outside the manufacturing sector. There is also a lack of sectoral studies examining the innovation and productivity relationship in SMEs using longitudinal data. This relative lack of empirical knowledge of the determinants of innovation and the innovation–productivity link acts as a major obstacle to the development of appropriate policies that promote innovation activities by SMEs, which are widely acknowledged to be resource-constrained organisations. Given the existing gaps in the innovation literature, this thesis empirically investigated the innovation and productivity of SMEs in three Australian economic sectors. Based on Chapter One, the research problem was presented as follows:

To empirically investigate the determinants of innovation and the impacts of innovation on firm productivity in Australian SMEs from a sectoral perspective (i.e. primary, secondary and service).

Four research questions arose from the research problem as follows:

1. *What is the state of innovation in Australia's three economic sectors (i.e. primary, secondary and service)?*
2. *How do SME innovation determinants vary in the aggregate economy and in each economic sector?*
3. *To what extent does innovation impact SME productivity in the aggregate economy and each economic sector?*
4. *How does innovation and productivity performance of SMEs vary across economic sectors?*

The objective of this thesis was to empirically examine the determinants of SME innovation and the impacts of innovation on SME productivity across the three economic sectors in Australia. The specific research objectives were to:

1. explore the innovativeness of SMEs and the state of innovation in the three Australian economic sectors (i.e. primary, secondary and service)
2. identify and quantify the key determinants of SME innovation in the aggregate economy and in each economic sector
3. estimate the impacts of innovation on SME productivity in the aggregate economy and in each economic sector
4. examine the differences in innovation and productivity performance of SMEs across the three economic sectors.

To address the research problem, an econometric model, based on the conceptual framework, was developed, linking innovation determinants, innovation outputs and firm productivity. The analysis was conducted using data accessed from the ABS. A longitudinal panel dataset was used, containing 1,976 Australian SMEs over the period 2011–12 to 2015–16. Random effects probit models and a simultaneous estimation approach were employed to estimate innovation output and productivity equations as one system using Stata software. The SMEs' innovation process at the aggregate economy level was first analysed to provide an overall understanding of the innovation process in an economy-wide context and to serve as a benchmark for analysis at the sectoral level. This was then followed by empirical analysis of each of the three economic sectors (i.e.

primary, secondary and service). The key findings of the thesis, in accordance with the four research questions, are summarised in the following section.

7.3. SUMMARY OF THE MAJOR FINDINGS

The following summarises the major findings corresponding to each research question. Research question (1) was addressed in Chapter Three; research questions (2), (3) and (4) were addressed in Chapter Six.

RQ1: What is the state of innovation in Australia's three economic sectors (i.e. primary, secondary and service)?

On the national average, approximately nearly half of Australian firms engaged in innovative activities, i.e. 46.2% on average over the period 2011–16 and at 49.8% in 2017–18. The state of innovation varied across Australian economic sectors. Of the three sectors under study, the primary sector was the least innovative because it had the lowest proportion of innovation-active firms as well as innovation outputs, which were appreciably lower than the national average. The secondary sector was relatively innovative in all types of innovation. This sector introduced more technological innovation than non-technological innovation in the period under study. In the service sector, there were variations among service industries regarding the proportion of innovative-active firms and the types of innovation they introduced. The observed heterogeneity was expected given the diversity of industries constituting this sector. The majority of service industries (seven out of ten industries under study) had higher rates of innovation-active firms and innovation outputs, relative to the national average. Of the industries, Manufacturing, Information Media and Telecommunications and Wholesale Trade are among the most innovative one with high proportions of innovation-active firms as well the rate of innovations implemented in 2017–18. This finding suggests that the service sector should no longer be considered a laggard in the innovation race.

RQ2: How do SME innovation determinants vary in the aggregate economy and in each economic sector?

To highlight differences among sectors, Table 7.1 presents the summary of the significant variables across the three economic sectors.

Table 7.1: Summary of determinants of SME innovation across sectors

Variables	Aggregate economy		Primary		Secondary		Service	
	Technological innovation	Non-technological innovation	Technological innovation	Non-technological innovation	Technological innovation	Non-technological innovation	Technological innovation	Non-technological innovation
Training	0.062	0.094	n.s.	n.s.	n.s.	0.142	0.076	0.096
Collaboration	0.230	0.270	0.151	0.260	0.359	0.163	0.233	0.282
ICT investment	0.116	0.118	0.118	0.112	n.s.	0.095	0.130	0.130
Financial support	0.089	0.087	0.077	n.s.	0.113	0.133	0.090	0.102
Innovation focus	0.172	0.134	0.151	0.099	0.256	0.190	0.172	0.131
Firm size	+	+	+	+	n.s.	n.s.	+	+
Firm age	–	–	–	–	n.s.	n.s.	–	–
Foreign ownership	+	n.s.	n.s.	–	+	+	+	n.s.
Exports	+	n.s.	+	+	n.s.	–	+	n.s.
Competition	+	+	+	+	+	n.s.	+	+
Sector/Industry	+	+	n.s.	n.s.	n/a	n/a	n.s.	n.s.

Note: + positively significant, – negatively significant, n.s.: not statistically significant, numbers: average marginal effects and n/a: not applicable

The aggregate result showed that all five innovation input variables under study—training, collaboration, ICT investment, financial support and innovation focus—positively and significantly affected both technological and non-technological innovation in Australian SMEs. Of the firm characteristics, firm size had a positive effect on both types of innovation outputs, while firm age showed a negative effect. Foreign ownership and exports positively influenced technological innovation, but their effects were not significant for non-technological innovation. In terms of external environment, market competition positively influenced technological as well as non-technological innovation. Sector also demonstrated a significant impact on SMEs' innovation performance, both technological and non-technological. SMEs in the secondary and service sector were more likely to implement innovation than those in the primary sector.

With regards to the sectoral results, in the primary sector, collaboration, ICT investment, innovation focus, firm size, exports and market competition positively affected both types of innovation outputs, whereas firm age showed a negative influence. Financial support had a positive impact only on technological innovation of SMEs in this sector. SMEs with foreign ownership were less likely to implement non-technological innovation than wholly Australian-owned SMEs. The effect of training for employees was not significant, both for technological and non-technological innovation of SMEs in this sector.

In the secondary sector, collaboration, financial support and innovation focus positively affected both technological and non-technological innovation among manufacturing SMEs. In addition, training and ICT investment positively affected non-technological innovation. Unlike the primary sector, manufacturing SMEs with foreign ownership were more likely to implement both types of innovation outputs, while SME exporters in this sector were less likely to implement non-technological innovation. Market competition was also found to be a driving force of technological innovation in this sector.

The results for the service sector were relatively similar to the aggregate economy results due to the service-dominated nature of the Australian economy. All innovation input variables—training, collaboration, ICT investment, financial support and innovation focus—significantly contributed to both innovation outputs in service SMEs. In relation to firm characteristics, firm size had a positive effect on both technological and non-technological innovation, while firm age showed a negative impact. Further, foreign-owned SMEs and exporters were more likely to implement technological innovation. Similarly to the other two sectors, the degree of competition in the market also drove innovation in service SMEs.

Comparing the results across the three sectors, collaboration was the most important driver of innovation outputs in all sectors, followed by innovation focus. The effects of ICT, training and financial support varied depending on the sector and innovation type. Firm characteristics and market competition also had significant influences on innovation outputs of SMEs; yet their effects also varied.

RQ3: To what extent does innovation impact SME productivity in the aggregate economy and each economic sector?

The results confirmed a positive and significant relationship between technological as well as non-technological innovation and productivity among SMEs in the aggregate economy and all three economic sectors. The results of the impact of innovation on SME productivity at the aggregate and sectoral levels are summarised in Table 7.2.

Table 7.2: Summary of impact of innovation on SME productivity across sectors

Productivity	**Aggregate Economy**	**Primary**	**Secondary**	**Service**
Technological innovation	0.200	0.380	0.134	0.232
Non-technological innovation	0.281	0.225	0.372	0.229
Capital investment	+	+	+	n.s.
Non-capital investment	+	n.s.	n.s.	+
Sector/Industry	–	–	n/a	+

Note: + positively significant, – negatively significant, numbers: average marginal effects; n.s.: not statistically significant, n/a: not applicable

As indicated by the average marginal effect, at the aggregate level, non-technological innovation exerted a greater effect on productivity improvement of Australian SMEs as a whole compared with technological innovation. The role of the two innovation outputs in improving productivity was different across sectors. In the primary sector, technological innovation showed a more significant impact on SME productivity improvement compared with non-technological innovation. The opposite was evident in the secondary sector. While most prior research found technological innovation to be the major driver of large manufacturing firms or manufacturing firms as a whole, the results of the present study revealed that in the SME context, non-technological innovation led to greater productivity gains for Australian manufacturing SMEs than technological innovation. In the service sector, the impacts of technological and non-technological innovation on service SMEs' productivity were comparatively similar.

RQ4: How does innovation and productivity performance of SMEs vary across economic sectors?

The results proved the existence of sectoral differences—not only in innovation determinants, but also in the innovation and productivity performance of SMEs across the three economic sectors in Australia. It was found that SMEs in the manufacturing and service sectors were more likely to implement both technological and non-technological innovation compared with those in the primary sector. Among the three sectors, manufacturing SMEs were most likely to implement technological innovation, while service SMEs were most likely to implement non-technological innovation. There were also significant differences in productivity performance across the sectors, with SMEs in services on average being less productive than those in the primary sector. Further, the positive impact of technological innovation and non-technological innovation on SME productivity also varied across sectors. The findings of this thesis support the proposition of Nelson and Winter (1974, 1982), Malerba (2005, 2006) and Castellacci (2008) that innovation processes greatly differ from sector to sector, reflecting the heterogeneity of the knowledge base, technological paradigms and institutional conditions between economic sectors. Such differences also hold true in the SME context.

7.4. CONTRIBUTION TO THE INNOVATION LITERATURE

While the broader innovation literature has amassed a large volume of knowledge on innovation and productivity, the empirical research on the SME context is still scarce. There are also inconclusive findings on the factors affecting innovation in SMEs and contradictions relating to the innovation and productivity link in different country contexts and between studies using cross-sectional and longitudinal data. Despite the substantial number of studies on innovation and productivity in manufacturing, relative empirical evidence in service SMEs is still lagging behind, while in the SME primary sector it is absent. This thesis bridged these gaps, contributing to the empirical innovation literature in five ways.

First, given the relative lack of empirical studies on innovation and productivity in SMEs, this study enhanced existing literature on this stream of research by providing empirical evidence on the Australian SME case. The empirical results for the aggregate economy revealed several factors that determine SME innovation in Australia. The result further confirmed a significant and positive relationship between innovation and firm productivity in the context of Australian SMEs.

Second, existing studies on SME innovation and productivity overwhelmingly focus on manufacturing SMEs or on the economy as a whole, with little research conducted on service sector SMEs, and no empirical studies on the innovation–productivity link in primary sector SMEs. Given this gap in the SME innovation literature, this thesis conducted both aggregate and sectoral analysis of the determinants and impacts of SME innovation in the three economic sectors: primary, secondary and service. This thesis made an original contribution to knowledge by providing benchmarking and comparable results on SMEs' innovation processes across the three sectors. The empirical results revealed significant differences in terms of innovation determinants, innovation outputs and productivity performance of SMEs across sectors. These findings confirmed the proposition of the evolutionary theory, which holds that there exist sectoral differences affecting innovation and productivity performance. This study provided evidence that this is true in the SME context. Therefore, economic analysis of innovation should be undertaken from a sectoral perspective rather than in an economy-wide context.

Third, while technological innovation has been widely examined in the broader innovation literature and in most SME studies, empirical research on non-technological innovation in the SME context remains limited (Audretsch et al. 2020; Radicic & Djalilov 2019). This thesis empirically analysed non-technological innovation along with technological innovation in Australian SMEs across sectors. The results showed that the determinants of non-technological innovation are not the same as those of technological innovation and are heterogeneous across sectors. Further, not only technological innovation, but also non-technological innovation leads to increased productivity for SMEs in all sectors. Most importantly, the positive impact of non-technological innovation on SME productivity is greater than that of technological innovation at the aggregate economy level. It is also found that in the SME context, Australian manufacturing firms achieve higher productivity gains from non-technological innovation than from technological innovation. This contradicts the common prediction since technological innovation is often perceived as the key driver of productivity in manufacturing firms. The finding on the significant impact of non-technological innovation on the primary sector is another original contribution given that, to the best of the researcher's knowledge, no empirical studies examining non-technological innovation and productivity in the primary sector are available in the SME context. The above findings highlight the important role of non-technological innovation in SMEs, which has largely been overlooked in prior research and policy spheres.

Fourth, most prior studies on innovation and productivity are based on cross-sectional estimation (Audretsch et al. 2020), which does not take into account the time lag of innovation and unobserved firm heterogeneity (Morris 2018). Prior findings on the link between innovation and productivity using cross-sectional data and longitudinal data are somewhat conflicting (Taveira et al. 2019). In the SME context, while there exist studies using panel longitudinal data, the scope of most of these (i.e. Calza et al. 2019; Mañez et al. 2013; Rochina-Barrachina et al. 2010) is narrowed to manufacturing SMEs. Only a recent study by Audretsch et al. (2020) covers micro firms in services.[39] Contributing to this strand of literature, the present study used a 5-year panel dataset to provide comparable analyses on the innovation–productivity relationship among SMEs across not only the manufacturing and service sectors, but also across the primary sector. Estimations using longitudinal panel data of three Australian sectors moved beyond the cross-sectional analysis of innovation and also provided comparable results on the effect of the two innovation types across sectors. Such estimations provided more robust results and therefore, better-informed recommendations for policy formulation.

Fifth, existing studies in the SME context merely analyse the innovation and productivity relationship based on econometric models, rather than constructing a specific framework for studying innovation and productivity in SMEs. The present study contributes to the innovation literature by developing a framework suitable for SME sectoral studies. Building upon the CDM framework, the framework developed in Chapter Three linked (i) innovation determinants, encompassing three groups of factors

[39] Audretsch et al. (2020), Calza et al. (2019), Mañez et al. (2013) and Rochina-Barrachina et al. (2010) examined only technological innovation and productivity.

relating to innovation inputs, firm characteristics and external environment, (ii) innovation outputs, including technological and non-technological innovation and (iii) SME productivity, to represent the innovation process in SMEs. This framework depicts a more comprehensive picture of how various factors simultaneously influence the innovation and productivity performance of SMEs across economic sectors. The framework was tested by empirical data of Australian SMEs across three sectors, thereby proving its significance and usefulness. Thus, it can be used as a foundation for further analysis of innovation processes in various sectors and country contexts.

Sixth, this study also contributes to the Australian literature on innovation and productivity, particularly in the SME context. Taking advantage of the unique panel structure of the BLD, the analysis conducted in this thesis is able to explicitly account for unobserved firm heterogeneity in the innovation process and draw a more robust conclusion on a causal relationship between innovation and productivity in Australian SMEs. Moreover, it extends the panel data analysis to cover both stages of the innovation process, i.e. determinants of innovation outputs, and innovation impacts productivity, as well as both types of innovation outputs, i.e. technological and non-technological innovation. Most importantly, this thesis provides compatible aggregate and sectoral analysis for the Australian economy, Primary, Secondary, and Service Sectors, rather than estimating the pooled data, which enhances our understanding of the innovation process from a sectoral perspective.

7.5. POLICY IMPLICATIONS

The findings of this thesis make an important contribution to practice by providing recommendations for policy makers and practitioners about the drivers of SME productivity and the determinants of SME innovation outputs across three economic sectors. It is critical to have a thorough understanding of the factors that drive or hinder innovation performance in SMEs so that appropriate measures can be developed to support innovation in this class of firms.

The estimation results of this study provided empirical evidence on the effect of both technological and non-technological innovation on improving SME productivity across all three economic sectors. The results further revealed several factors that significantly affect SMEs' innovation outputs, notably, collaboration, innovation focus, ICT investment, financial support, training, firm characteristics and market competition.

Given these findings, policies should be refined to better reflect the impact of such factors on innovation outputs for SMEs across sectors. With regards to the Australian case, although innovation policies in Australia exist, the ongoing weak performance in both labour and multifactor productivity since 2005, the negative productivity growth in 2018–19 and the current poor innovation performance relative to global peers suggest there is room for improvement (Productivity Commission 2020). The following sections discuss policy implications for SMEs in general and recommendations for Australia in particular.

7.5.1. Implications for non-technological innovation

The estimated results demonstrated that, at the aggregate economy level, non-technological innovation generated a more significant impact on SME productivity than technological innovation. The effect of non-technological was significant in all three sectors, with the largest marginal effect being found in manufacturing SMEs. This is an important finding given that a large volume of academic work and policy directives have overwhelmingly focused on technological innovation, especially in the manufacturing sector. This could explain why innovation policies tend to be heavily focused on supporting technological innovation, while overlooking the role of non-technological innovation (Aboal & Garda 2016; Expósito & Sanchis-Llopis 2018; González-Blanco et al. 2019). Policies and support in Australia also excessively focus on technological innovation. As the OISA (2019, p. 31) indicates, Australian firms raise concerns that there is 'limited support available for businesses that could improve their productivity through changes to organisational structure and marketing [non-technological innovation]'.

SMEs are unable to improve productivity through economies of scale like large firms (Hervas-Oliver et al. 2016). However, with their behavioural advantages, SMEs can gain great benefit from non-technological innovations. Their smallness is typically associated with flexibility and less formal organisational structures and routines, allowing them to reorganise more efficiently with lower switching costs (Radicic & Djalilov 2019). SMEs' proximity to the market and customers provides them with significant innovation potential to conduct marketing initiatives that boost product/service demand, and thereby, their market performance (Sáez-Martínez et al. 2014). Further, most non-technological innovations do not require much investment (Expósito & Sanchis-Llopis 2018). Therefore, non-technological innovation is an important avenue for SMEs to improve their productivity. Thus, while technological innovation remains an important and conventional means to enhance productivity, SMEs are encouraged to also seize non-technological innovation opportunities. Hence, current policies that overwhelmingly target technological innovation, while neglecting the role of non-technological innovation, should be revisited to strike a better balance between support for non-technological and technological innovation, especially in small business economies. Such a shift in emphasis of policy direction should stimulate more non-technological innovations, which, in conjunction with technological innovation, would result in greater productivity improvement for SMEs and the economy as a whole.

7.5.2. Implications for innovation collaboration

The positive and significant role of collaboration in SMEs' innovation performance has been proven in all sectoral contexts. Practical advice stemming from this finding is that instead of choosing a closed innovation strategy that primarily relies on SMEs' limited internal resources and capabilities, SME owners should take advantage of collaboration and networks to access external knowledge, technologies, financial and skilled human resources. By collaborating with strategic partners, SMEs can overcome their resource limitations, lessen the cost of innovation development and make better-informed decisions thanks to the information and knowledge acquired through their network. Such benefits should also help SMEs minimise the risk of failure and maximise their innovation performance. Further, collaboration with other stakeholders is important not only in developing new products or processes, but also in non-technological innovation projects such as in joint marketing or joint product promotion. To foster collaboration among SMEs, governments and industry policy-making bodies should be proactive in developing strategies that facilitate networking, coordination and collaboration among SMEs and other stakeholders.

In Australia, only 17% of firms collaborated for innovation purposes in 2017–18 (ABS 2019e). In relation to the aggregate dataset used for the analysis, just over 10% of Australian SMEs collaborated. Due to weak collaboration, Australia ranked in the bottom half of the OECD's collaboration for innovation indicators (Australian Government 2017c), with particularly poor results for SME business and research collaboration (Scott-Kemmis 2018). Less than 5% of SMEs in Australia collaborated with universities and research institutions for their innovative projects (ABARES 2019). Collaboration is therefore a critical aspect that Australian SMEs must improve. This finding is supportive of recent policy initiatives implemented by the Australian government. Over the last few years, there has been a push to promote collaboration between SMEs and the Australian research sector. A government initiative, namely, SME Connect, assists Australian SMEs to access cutting-edge research expertise and facilities through collaboration with universities and research institutions such as CSIRO and Industry Growth Centres. Nevertheless, the focus of this initiative is mainly on SMEs in the primary and secondary sectors and on technological innovation. Therefore, the program should widen its scope to include service SMEs and non-technological innovation, given the crucial role of the service sector in the economy and the fact that service SMEs as a whole still have weaker productivity compared with the other two sectors.

7.5.3. Implications for innovation culture

Having an innovation focus that reflects an innovative culture in the organisation (Palangkaraya et al. 2015) should be encouraged among SMEs given its significant effect on innovation performance across all sectors. An organisational culture that is open to new ideas and supports new development is a prerequisite for innovation to flourish. As stated by Rosenbusch et al. (2011), a business strategy that focuses on innovation is even more important for SMEs than for larger firms. This is because it directly affects SMEs' capacity and strategy to utilise resources economically to generate innovation. Therefore, SMEs owners should embrace innovation practices and cultivate an innovation culture among employees. A creative and supportive workplace plays an important role in nurturing innovation in SMEs. Further, since innovation is diverse and can occur in various business aspects, such a focus on innovation should not be narrowed to only discovering innovative ideas for new products or operational processes. It should rather be extended to identifying solutions for improved organisational and managerial processes to better use and exchange information, knowledge and skills within the business. It could also be used to enhance the firm's market performance by implementing new sales methods, new ways to improve business–customer relationships or by expanding new marketing channels.

A lack of innovation culture has been repeatedly cited as a barrier to innovation in Australia across sectors. The country's innovation culture also lags behind many other economies (ABARES 2019; AMGC 2017; Scott-Kemmis 2018). This issue is particularly more profound in small firms (OISA 2019). Most Australian SMEs only focus on their day-to-day business with ‘no incentive to try something new’ (AMGC 2017, p. 5) The risk-averse culture and risk-avoiding actions of Australian SMEs also act as major obstacles that prevent them from undertaking innovative investments (OISA 2019). In addition, Australian SMEs exhibit an unambitious culture that focuses mainly on short-term objectives rather than long-term and ambitious goals (Australian Government 2017a; OISA 2019). Thus, it is imperative to build a compelling innovation narrative and cultivate a culture of innovation among SMEs. The Australian Government (2017a) introduced *Australia 2030: Prosperity Through Innovation*, with one of the missions focusing on the national innovation culture by launching ambitious large-scale initiatives. However, such large-scale initiatives may result in the policy overlooking the involvement of SMEs, which possess distinct characteristics. As the OISA (2019, p. 40) emphasises, ‘too many innovation strategies have failed to shift the culture of Australian businesses’. A more specific application is required to actively encourage an innovation focus among SMEs in sectoral contexts. Governments can assist by implementing policies and programs that, on one hand, help SMEs to understand emerging innovation opportunities and the nature of risks and, on the other hand, promote effective practices to manage risks. This should assist SMEs in making well-informed decisions when considering an innovation opportunity.

7.5.4. Implications for ICT investment

ICT significantly underpins SMEs’ innovation performance across the three sectors. Nevertheless, SMEs are often referred to as laggards in the digital evolution and ICT usage (OECD 2019d). This phenomenon is largely attributed to the costs of ICT adoption and partly due to lack of understanding of ICT-related opportunities by SME owners (Giotopoulos et al. 2017). Given the substantial benefits of ICT, SME owners are encouraged to pay more attention to emerging ICT opportunities and seize this future potential to improve their business performance. The broad avenue of ICT applications should also be noted. ICT-driven value comes not only through technological breakthroughs, but also through innovation in non-technological areas such as organisational processes, communication and sales channels. In the era of digital economies, government plays a particularly important role to coordinate and foster ICT investment and adoption among SMEs across the economy. It is crucial to enhance SMEs’ awareness by providing them with information and guidance about ICT opportunities.

Since SMEs have limited financial capability, ICT assistance programs should consider leveraging the cost barriers in adjusting to and adopting new ICTs.

ICT investment appears to be another area which Australia needs to improve to promote innovation in the economy. OECD (2019b) data show that Australia scores below the OECD average in terms of ICT investment. Further, Australia's ICT share of gross value added has significantly dropped since 2000, ranking the country second lowest among OECD nations (OECD 2019b). While ICT infrastructure is critical for the development and implementation of innovations (OECD 2018e), it is among the most commonly cited barriers by Australian SMEs. Widespread access to low-cost and high-quality ICT remains a key challenge for SMEs in Australia since its broadband access is ranked in the bottom half of OECD nations (OECD 2018e, 2019b). Given the above issues, policy interventions are needed to encourage more investment in ICT as well as to assist SMEs in adjusting to and adopting new ICT solutions. Such policies should also consider the level of development, business conditions, skills and technology needs of SMEs to provide them with appropriate support. In addition, improving ICT infrastructure is required for such technologies to be implemented and utilised at the optimal level and yield a significant effect on SME innovation. With the fast pace of the global digital economy, it is vital that SMEs are not only aware of ICT opportunities but also eagerly embrace new digital technologies to drive innovation in various business aspects and achieve significant productivity gains.

7.5.5. Implications for financial support

The results of this study demonstrated that financial support is a significant contributor to SMEs' innovation performance across the sectors. This finding suggests the need to provide sufficient financial assistance for innovative SMEs to unearth and maximise their potential to innovate, grow and succeed. Government grants and industry financing could be important channels for SMEs to obtain funding. In addition, favourable interest rates and credits could be considered for innovative SMEs applying for private finance to invest in their innovation projects. Given that SMEs are often at a disadvantage when borrowing finance compared with large firms (OECD 2019d), government or peak industry bodies, where appropriate, could act as a facilitator or guarantor for innovative SMEs to access financial resources in the early stages of innovation development via assistance programs.

Despite the critical importance of finance for SMEs, Australia ranked second lowest in terms of government funding for SMEs' innovation among OECD countries (Scott-Kemmis 2018). The ABS (2018e) data show that on the national average, only 4.1% of Australian firms received government financial assistance for innovation activities. The proportion is even lower for micro firms (3%) and small firms (3.7%) (see Chapter Four). In recent years, the Australian government has offered numerous financing programs to boost innovation among SMEs (OECD 2017c). The main purpose of most programs (e.g. government grants, R&D Tax Incentive and subsidised credit) is to lower the financial risk for businesses when investing in new products. However, a recent study by OISA (2019, p. 30) discovered that a large proportion of SMEs was not aware that the program existed, while others indicated that governments seems excessively focus on innovation in 'high-tech, cutting-edge industries', but less interested in incremental improvements. Many SMEs also faced substantial difficulties in accessing grants 'due to complex eligibility criteria, time-consuming paperwork and inflexibility in how money can be used' (AMGC 2020, p. 46; OISA 2019). The lack of venture capital has also been cited as an issue. The OECD data show that Australia's venture capital investments were around 0.03% of the national GDP in 2018. This is approximately only half of the OECD average, placing Australia in the bottom half of OECD in this category. This issue could cause start-up SMEs with innovations to fail or to move overseas (Bell et al. 2014; Productivity Commission 2015). The aforementioned issues suggest that current financing schemes should be reviewed and evaluated regularly to ensure their efficiency, accessibility and impact. Funding mechanisms should specifically target innovative SMEs with high growth potential and the scope should be widened to encourage non-technological innovations. It is important that information and application procedures for available funding programs should be clear and easily accessible so that SMEs are aware of such opportunities and capitalise on them to invest in their innovation projects.

7.5.6. Implications for training

Human resource scarcity, including inadequate knowledge and skill shortages for innovation, is a major constraint encountered by SMEs. As the OECD (2018c) underlines, productivity costs resulting from skill shortages impede SMEs' ability to grow. Training is a practical way to enhance the stock of human capital. The findings for the different sectoral contexts showed that formal and structured training for employees is only effective for SMEs' innovation outputs in services and for non-technological innovation in manufacturing. Given this finding, SME owners in these two sectors should provide more training opportunities for their employees. This is particularly important for SMEs in services, which are labour-intensive industries. To help SME practitioners in this area, targeted training and education programs are needed to enhance the quality of human capital of the SME workforce and to close the training gap between SMEs and large firms. The OECD (2018c) points out that SMEs find it difficult to communicate their skill needs to training providers. Thus, better attention on the skill needs for SMEs is required. Training programs need be tailored to meet the needs of the businesses and training providers. Such programs must also be widely accessible and affordable for SMEs.

Australian SMEs face severe skilled labour shortages for innovation (AMGC 2020; Australian Government, 2017c). Training is an effective way to upskill staff, which in turn boosts SMEs' innovation performance. As the OECD (2019d, p. 200) emphasises, skills development is critical 'in a context of a fast and irreversible digital transition and growing globalisation'. However, for small Australian firms, their solution to cope with skill shortages is to extend hours for their existing workforce, while large firms are more likely to offer on-the-job training (OECD 2018c). It is asserted that policy measures in Australia lack a trigger to prompt education and training of workers (Productivity Commission 2017). Although attempts have been made by the Australian government, further actions are required—not only to create more opportunities for training, but also to reduce the barriers to upskilling and retraining faced by SME owners, such as cost and time constraints in providing training. In part, joint policy promotion should also focus on closer alignment between the industries and education providers to develop targeted and affordable training programs that provide skills-based and on-the-job experience for the SME workforce. Promotion of such programs should focus more on services and manufacturing given the significant effect of training on innovation outputs found in these sectors. Effective training and education programs should enhance the skills base of the Australian SME workforce, thereby improving its innovation performance.

7.5.7. Implications for firm characteristics

A sound understanding of the key characteristics of innovative firms is useful to design specific and targeted policies that promote and support innovation investment. Apart from firm size, the age, ownership and export activities of SMEs have also demonstrated some influence on their innovation performance. It was found that younger SMEs in the primary and service sectors are more likely to implement both technological and non-technological innovation compared with mature SMEs. Although young SMEs are innovative, they typically have less financial resources, experience and organisational capabilities than established firms. Thus, there is a need to foster innovation in young SMEs. This finding is supportive of Australia's recent government initiatives, evidenced by the two recently launched programs—Incubator Support and Early Stage Venture Capital Limited Partnerships—which provide support for innovative start-ups. There are also tax incentives for early-stage investors.

In relation to ownership, SMEs with foreign ownership in services and manufacturing showed higher innovation outputs than wholly Australian-owned SMEs. Thus, there may be a need to provide more support for Australian-owned SMEs to bridge the gap with their foreign counterparts. Primary and service SMEs that engaged in export activities showed higher innovation performance than non-exporters. However, as the Export Council of Australia (2018, p. 8) stresses, 'too many Australian SMEs simply do not consider the opportunities that international markets present'. Thus, policy is required to promote export opportunities and assist SMEs in entering the global market. The findings of this thesis provide empirical evidence favouring the 2020 reforms of the Australian government, notably, the Export Market Development Grants scheme. This initiative aims to support SMEs that are new to export, seeking to grow, expand or make a strategic shift into international markets.

Finally, it is worth noting that due to sectoral differences, a single policy treatment would be inappropriate to apply for all sectors. The development of a government and industry policy framework must be tailored to suit the specific needs of each sector and take into account sectoral discrepancies in terms of their technology levels, institutional settings and innovative behaviour. The more active and better-targeted involvement of both government and businesses is crucial to maximise the impact of policy to boost SME innovation throughout the economy.

7.6. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The limitations of this thesis are mainly due to the data source. This is a common issue encountered by studies using large-scale surveys such as Community Innovation Surveys in European countries and, in the case of this thesis, the Business Characteristics Surveys in Australia. The first limitation is that most of the variables used in the study were measured by binary or categorical data. For example, with innovation outputs and firm productivity being measured by binary variables, the analysis was unable to entirely capture the depth of the incidents investigated. Therefore, the results should be interpreted with caution. There are opportunities for further research using additional innovation measures. For instance, the number of innovations implemented or sales of new products could be used to measure the extent of innovation output and innovation success. Innovation output can also be measured by radical innovation versus incremental innovation, or the four degrees of innovation novelty—new to the world, the country, the industry or just the business. In addition, where microdata on innovation novelty is available, future research could also examine if more novel innovations, e.g. new to the world, are likely to result in greater productivity outcomes, compared with innovations which are just new to the business or industry.

As discussed in section 3.4.5, there might exist a persistence in innovative activities where firms continuously innovate over the years, while others introduce innovations on an irregular basic. This suggests a direction for future work to explore the behaviour of continuous and intermittent innovators and assess whether the impact of innovation on productivity could be stronger when firms innovate more frequently or persistently. Another potential avenue for future research is to examine the extent to which the combined effect of both technological and non-technological innovation is likely to influence firm productivity across various economic sectors. In addition, another point of interest could be to explore if innovation could be a mediator in the production process.

The modelling strategy was subject to the availability of variables in the database offered to the researcher, which excluded R&D data. While this limitation was mitigated because the vast majority of Australian SMEs do not invest in R&D activities (ISA 2020); where data are available future research could estimate and compare the effect of R&D relative to non-R&D expenditure and innovation expenditure on different types of SME innovation outputs in different sectors. This would uncover the role of such expenditure on SME innovations across sectors. Further, as discussed previously, the productivity measure, i.e. self-reported productivity, used in this thesis has certain limitations. Where data is available, other measures of productivity such as labour, multifactor and total factor productivity, could be employed to better reflect the impact of various innovation types on different productivity measures and the extent of the impact in various sectoral contexts.

The choice of variables for the analysis was subject to microdata availability provided by the ABS. There may be additional sector-specific factors that affect SME innovation in each sectoral context. This opens up an avenue for future research to incorporate more factors specific to each sector to provide a more comprehensive picture of SMEs' innovation processes across economic sectors. Moreover, further insight and expert knowledge in the primary, secondary and service sectors is needed to better explain the results generated from this thesis.

Given the numerous initiatives and programs implemented by Australian governments in recent years with the aim of improving SME innovation performance, future research could empirically examine if the innovation initiatives and policy directions proposed in this thesis are effective in boosting innovation and productivity in Australian SMEs over time. If such policies are successful in driving innovation, they might be applicable for other economies with similar structures and economic conditions like Australia.

Finally, given this present study found young SMEs are more likely to innovate than established SMEs, another avenue for future research could be to isolate the new ventures (e.g. less than 5 years old) or to contrast the innovation strategy and performance of start-ups or new ventures against established SMEs.

7.7. CONCLUDING REMARKS

Innovation has been the underlying driver of long-run productivity growth and competitiveness of successful economies across the globe. Australia, with great advantages of a strong economy and established research strengths, has much potential to become a top-tier innovation country. To achieve this goal, Australia needs to improve its current innovation and productivity performance, which lags behind competitor countries. As the majority in the national economy, SMEs pose significant potential for improving Australia's innovation performance. This thesis generated new knowledge on innovation in SMEs in the Australian context. It uncovered the determinants of SME innovation and offered empirical insights into SMEs' innovation processes across the three economic sectors in Australia. The findings of this thesis also proved the crucial role of innovation in driving SMEs' productivity. The present thesis has contributed to the innovation literature in the strand of sectoral studies in the SME context. Informed by empirical results, the policy recommendations from this thesis can be used to address prevailing obstacles on the Australian innovation frontier. Finally, this study has laid a robust foundation for future in-depth analysis of this important area of academic research.

"Every new era offers new possibilities for action and development. Development never stands still. Innovations in one field inevitably lead to innovations in others. One must remain alert at all times, always ready to make the very best use of what emerges."

Daniel Swarovski (1862-1956)

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APPENDICES

Appendix A: Extracted BCS questionnaire

Note: The below questions are asked in each of the corresponding financial years: 2011-2012, 2012-2013, 2013-2014, 2014-2015, 2015-2016, where business identifications were held constant for this period.

Business characteristics

Industry division

☐ Agriculture, Forestry and Fishing ☐ Mining ☐ Manufacturing
☐ Construction ☐ Wholesale Trade ☐ Retail trade
☐ Accommodation and Food services ☐ Transport, Postal and Warehousing ☐ Information Media and Telecommunications
☐ Rental, Hiring and Real Estate Services ☐ Professional, Scientific and Technical Services
☐ Administrative and Support Services ☐ Arts and Recreation services

Number of persons working for this business

☐ Non-employer ☐ less than 5 employees ☐ 5 to 19 employees ☐ 20 to 199 employees

How many years had this business been in operation under current ownership?

Number of years ☐

	Yes	No
Did this business receive income from exporting any goods and/or services?	☐	☐
Did this business have any degree of foreign ownership?	☐	☐

Innovations

	Yes	No
(1) Did this business introduce any new or significantly improved goods or services in the last 12 months? ***Definition****: A new good or service means any good or service or combination of these which is new to the business. Its characteristics or intended uses differ significantly from those previously produced/offered by this business.*	☐	☐
(2) Did this business introduce any new or significantly improved operational processes in the last 12 months? ***Definition****: A new operational process is a significant change for the business in its methods of producing or delivering goods or services.*	☐	☐
(3) Did this business introduce any new or significantly improved organisational/managerial processes in the last 12 months? ***Definition****: A new organisational/managerial process is a significant change in this business's strategies, structures or routines which aim to improve the performance of this business.*	☐	☐
(4) Did this business introduce any new or significantly improved marketing methods in the last 12 months? ***Definition****: A new marketing method is a significant change in a design, packaging, placement, pricing, promotion or sales method aimed to increase the appeal of the business's goods or services or to enter new markets.*	☐	☐

	Not at all	A small extent	A moderate extent	A major extent
To what extent did this business focus on innovation measures when assessing overall business performance?	☐	☐	☐	☐

	Yes	No
Did this business collaborate with others to develop or introduce any new goods, services, processes or methods?	☐	☐

Business structure and operations

Compared to the previous year, did any of the following decrease, stay the same or increase?

	Not applicable	Decreased	Stayed the same	Increased
(a) Structured/formal training for employees	☐	☐	☐	☐
(b) Expenditure on Information Technology	☐	☐	☐	☐
(c) Productivity	☐	☐	☐	☐

	Yes	No
Did this business collaborate with others to develop or introduce any new goods, services, processes or methods?	☐	☐

Finance

	Yes	No
Did this business receive any financial assistance from Australian government organisations?	☐	☐
Did this business obtain any debt or equity finance?	☐	☐

What was the expenditure of this business during this financial period?

(a) Total capital expenditure $AUD [ ]

(b) Total non-capital expenditure $AUD [ ]

<u>Markets and competition</u>

Which one of the following best describes the number of competitors this business had?

- ☐ None/captive market/no effective competition
- ☐ One or two competitors
- ☐ Three or four competitors
- ☐ Five or more competitors

Appendix B: Frequencies of performance

Table B1: Productivity by year (% of firms)

Productivity compared to previous year	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Not applicable	13.68	10.07	9.86	7.02	5.90
Decreased	15.71	15.61	14.29	11.08	10.22
Stayed the same	34.32	36.25	34.32	33.55	31.06
Increased	21.81	16.68	16.07	14.39	13.83
Missing or invalid value	14.48	21.39	25.46	33.96	38.99

Table B2: Profitability by year (% of firms)

Profitability compared to previous year	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Not applicable	8.13	4.52	4.52	3.25	3.05
Decreased	33.20	32.89	29.94	24.20	21.61
Stayed the same	20.39	21.61	21.00	21.15	20.54
Increased	24.56	20.44	19.32	18.15	16.57
Missing or invalid value	13.72	20.54	25.22	33.25	38.23

Table B3: Income from sales by year (% of firms)

Income from sales compared to previous year	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016
Not applicable	9.35	5.39	4.52	4.52	3.81
Decreased	29.64	30.86	28.88	21.61	20.44
Stayed the same	17.08	18.66	17.49	18.40	17.44
Increased	31.06	25.52	24.81	23.08	20.64
Missing or invalid value	12.87	19.57	24.30	32.39	37.67