Manufacturing and Growth in the Longer Term: An Economic Perspective

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Abstract

This IMS Vision 2020 Forum is intended to focus on the key issues shaping manufacturing in the early decades of the new century, having regard to emerging technological and socio-economic trends. My task in this paper is to provide some economic perspective to this agenda, with special reference to recent economic theorising about growth and to the continuing impact of technological change on the global economic and social structure. In doing so I am conscious of the diversity of possible approaches to this agenda, and in particular to the discussion of similar issues in this place three years ago, which gave rise to the important National Research Council publication *Visionary Manufacturing Challenges for 2020* (National Research Council 1998). Thus this paper can be seen only as one limited and personal perspective.

Manufacturing and Growth in the Longer Term: An Economic Perspective

1. Overview

Growth and Manufacturing

Economists have worried about the nature and causes of economic growth for a long time, even before Adam Smith's classic 1776 treatise *The Wealth of Nations*. However, recent work, whether in the neoclassical or in the evolutionary tradition, has focused on one dominant theme: the central role of knowledge and ideas, and of the application of new ideas (i.e. innovation), as the key to growth. This emphasis is especially relevant with the world in the midst of an economic revolution, of a scale comparable to that of the original Industrial Revolution, driven above all else by the pervasive impact of successive waves of new computing and communications technologies. In the emerging global knowledge economy, the ability to access and to apply economically relevant knowledge is central to the growth and prosperity of firms, regions and nations.

The new information and communications technologies, and the processes of globalisation which have been associated with them, have already changed the face of manufacturing. As is well known, much of manufacturing is now *globalised*, in the sense that a wide range of functions from R&D and marketing to production and distribution are now undertaken on an integrated global basis; *networked*, in that the coordination of these functions makes intensive use of electronic networks and of virtual and geographical clusters of expertise; *customised*, in that methods of production must allow for detailed customisation of products to meet the needs of individual markets and indeed individual consumers; and *digitised*, in the sense that many of these processes, and particularly final production, are controlled by advanced computer systems which limit the need for human intervention.

So pervasive are these changes that we need to ask whether the concept of manufacturing remains relevant. As the manufacturing process has been transformed the role of the actual production process, whether in terms of value added or employment, has declined sharply. That is, the share of value added or employment in final production is falling relative to that in areas such as R&D, design, marketing, legal and financial services, and transport and distribution. The manufacturing industry is normally defined as consisting of those firms whose predominant activity is the production of goods, whether as an input to further productive activities or to meet final demand. But as production becomes a much smaller share of value added the number of firms for which this is the predominant activity declines, and this accentuates the decline of manufacturing as a share of GDP shown in the national statistics for many countries. Yet a decline in the economic returns to pure production activities does not mean an equivalent decline

in the importance of goods in economic activity. Indeed, the creation, production and distribution of goods remain fundamental to the modern economy. Thus, looking ahead, it is likely to be of more value to think of *integrated systems for the production, creation and distribution of goods* rather than to concentrate on manufacturing as traditionally defined. This broader concept, which incorporates many firms which themselves undertake no final production activities, is sometimes referred to as 'new manufacturing' below.

It is equally relevant to question the concept of growth. Earlier theorists stressed the fact that the ultimate measure of growth is the increase in human welfare generated by economic activity. Yet most work on growth over the past half century has skirted around the question of human needs and human welfare. This has occurred at the theoretical level by concentration on maximisation of a simple measure of utility and at the practical level by emphasis on GDP (that is, value added in the production of goods and services). But we are being forced back to question of human needs and welfare as the measure of growth (e.g. Nussbaum and Sen 1993). As the new century unfolds there is likely to be increased emphasis on *growth as increased satisfaction of human needs* rather than just as an increase in GDP.

Knowledge and Growth in 'New Manufacturing'

It is clear that the era of the global knowledge economy has just begun, and that the forces driving this new economy will generate further fundamental change in the decades ahead. Growth for firms, regions and nations will depend heavily on the extent to which they can access and apply new knowledge and new ideas. What are these continuing changes likely to mean for the processes of the creation, production and distribution of goods, and for the growth and welfare of nations to which they are so central? While being conscious of the personal and subjective nature of the selection, I highlight in the body of the paper five main issues. The first two concern areas of new knowledge likely to be particularly important to the growth in 'new manufacturing' in the future.

Technologies at the Atomic Level. The information and communications technologies have been revolutionary in large part because they are so pervasive, reflecting the pervasiveness of information throughout the economic system. It is arguable that technologies which can create and structure materials and products at the atomic level – nanotechnologies, broadly defined – may be almost equally pervasive and equally revolutionary. These technologies enable us, as it were, to introduce knowledge into the structure of matter itself, and hence to design and create products to meet the needs of firms and consumers in ways not yet conceived. In areas as diverse as genetically customised drugs, energy storage, new materials (ceramics, polymers or structural materials), production processes, electronics and bioelectronics, technologies at or near the atomic level will provide a fundamental element of the context of advanced manufacturing in 2020.

The Impact of Sustainability. The pattern of economic activity built up in the advanced economies since the Industrial Revolution is clearly not sustainable for the world as a whole in the 21st century. In many advanced countries environmental

systems are severely damaged, and global warming appears to be well advanced already. But as countries such as China, India, Indonesia and Brazil move up the development ladder, a new global pattern of economic activity, environmentally sustainable over the long term, becomes an undeniable imperative. This will mean not only substantive changes to present processes for the creation, production and distribution of goods, but fundamentally new approaches to many aspects of human life. One example of this is transport. In this sector, the next few decades are likely to see the development of electric and hybrid vehicles, intelligent vehicle-highway systems, new types of transit vehicles and alternative urban freight distribution systems. Quite new solutions are likely to emerge to meet the need for freight and passenger movement, particularly within large cities.

Thus knowledge of many different types will drive growth in the new century. While the almost costless storage, manipulation and exchange of codified knowledge through information technologies will be a dominant factor, technologies operating at or near the atomic level may well become equally important enabling technologies for 'new manufacturing'. New knowledge about how human needs can be met through goods and services, the production and use of which is sustainable in the long term, will also be vital.

Challenges to Growth through 'New Manufacturing'

The Decline of Manufacturing Firms. Over the past century the development of major economies – such as USA, Japan and Germany, or more recently, Korea – has been driven by the emergence and growth of large manufacturing firms. That is, by the growth of firms at the heart of whose activities is the large-scale production of goods. But such firms are in relative decline around the world, as production activities become less important in the overall value chain. Major footwear, textiles and clothing firms such as Nike have become information management companies, matching information about markets, design, production and distribution on a global basis and contracting out production to the lowest cost producers. Major pharmaceutical companies, such as Glaxo and Smith Kline Beecham, are merging and becoming global health care businesses, again contracting out production to the lowest cost producers on an increasingly global basis.

Thus the corporate structures through which the creation, production and distribution of goods takes place are changing rapidly. This has many ramifications that we do not begin to understand. Companies everywhere are scrambling to stake out their position in the broader canvas of the 'new manufacturing'. Government support programs, such as for R&D and industry development, are being reconsidered in the new corporate landscape. Some nations, and many regions within nations, are watching their manufacturing base shrink with little idea about how to reshape their economy for the new world. Adjusting to this continuing change in corporate structure is a major challenge for all concerned.

Development and the Control of Knowledge. There are growing signs that the emerging knowledge economy may be one of increasing rather than declining inequality, both within and between nations. The creation and application of knowledge tends to concentrate in particular social groups, regions and nations, for

many reasons. For example, the process of knowledge creation is a cumulative one, which builds on past successes; it involves a substantial transfer of tacit knowledge, through personal interaction, and it is very expensive. The Industrial Revolution, based on the application of the new scientific knowledge, led to massive inequality between countries. In 1800 per capita incomes were roughly equal in what were to become the developed countries and the Third World; by 1970 average incomes were about seven times higher in the developed countries, which had been able to access and apply the new sciences. There is a danger of a new surge in inequality in coming decades, with further increases in relative incomes in those advanced countries that control the next generation of knowledge.

The global community could not survive a further massive increase in inequality, especially in a globalised world where differences are readily apparent. The issue of how this is to be avoided will be a fundamental one over the period to 2020. In particular, it may require some radical rethinking about how knowledge is controlled and shared. For example, current policy settings encourage the development of technologies by private firms and provide protection for the intellectual property of those firms. While this encourages investment in R&D, it also means that private firms in the advanced countries control most important technologies. This in turn limits their application by firms in developing countries, except under terms beneficial to the owners. It is arguable that the greatest successes in postwar development – in health and in agriculture – were due to the public control of advanced technologies, and their consequent ready availability to poor countries.

Output, Growth and Welfare. A central theme underlying this paper is the meeting of human needs as the rationale for the economy. In advanced economies today these needs are mainly met through the production and distribution of goods and services through the market. Overall national welfare is measured by the total level of value added in the production of goods and services (GDP). Two centuries of experience with a market based, capitalist system has shown that while it is a superb generator of output in response to market demand, that demand is often a poor signal of underlying human need. This is for many reasons: the manipulation of demand through advertising, the dominance of the well-off in terms of purchasing power, the lack of provision in areas where returns cannot be privately appropriated, the lack of market signals for communal goods, and so on. One example is the fact that vaccines are available to eliminate many diseases that ravage the Third World, but they are neither produced nor used for lack of financial incentive or resources. Another is the much higher ranking in human development indicators, relative to GDP level, of countries such as China, which have addressed many human needs directly rather than through the market.

2. The Theory of Growth – A Brief Historical Perspective

Ideas about the nature of economic growth have proliferated over the past two hundred years, and have been central both to economic thought and to political action. In this proliferation some key themes have recurred: specialisation and the division of labour, the accumulation of physical capital, the application of

technology and knowledge, the role of demand and the distribution of income, and the need for a 'big push' (coordinated programs of expansion across industries). These themes have in turn been given expression, at various times and places, in the development programs of nations and of international agencies.

The attempt to embody ideas about growth in more formal models, often with some mathematical character, is more recent. A beginning may be located in John von Neumann's famous paper 'A Model of General Economic Equilibrium', given in Princeton in 1938, and in Roy Harrod's 'An Essay in Dynamic Theory', published in the *Economic Journal* in 1939. The seminal paper in the theory of optimal growth was even earlier, being Frank Ramsey's 1928 article in the *Economic Journal* entitled 'A Mathematical Theory of Saving'. Building on these contributions was a substantial body of work between 1945 and 1965, culminating in the basic neoclassical theory of growth. Much prominence has been given over the past decade to two new streams of work about growth. One is the vast new neoclassical literature known as new growth theory, in which models expressing a wide range of ideas about growth have been created. The other is an alternative literature that is often referred to as evolutionary theory. The new growth theories remain children of this neoclassical modelling tradition, while the recent evolutionary growth models must be seen as reactions to the perceived limitations of that approach.

The Basic Neoclassical Model of Growth

Through their independent but contemporaneous contributions in 1956, Robert Solow and Trevor Swan instigated a major new phase in growth theory, creating the foundations of what is often referred to as the neoclassical theory of growth (Solow 1956; Swan 1956). The motivation was to show how, in contrast to the findings of Harrod and Domar (Harrod 1939, 1948; Domar 1946, 1947), steady state economic growth was possible in a pure competitive economy. This issue was more consistent with the optimistic tenor of the postwar period than the Harrod/Domar image of the economy on the knife-edge between unsustainable growth and depression, natural though that image was in the wake of the volatility of the 1920s and the 1930s.

The key economic assumptions of the Solow/Swan model are those of the competitive equilibrium model of a free market economy. For producers this means that constant or decreasing returns prevail and that all future technologies are known and available to firms in due course. In terms of markets it means that prices adjust to equate supply and demand in capital and labour markets, with the wage rate equal to the marginal product of labour, with the interest rate equal to the marginal product of capital and with savings equal to investment. It is also assumed that both population growth and the rate of technological change are exogenous and constant, each taking place at a rate which is either zero or positive, and that a constant proportion of income is saved at all times. This last assumption – of a constant and given rate of saving – sits oddly with the general equilibrium context of the model, in which outcomes are generated by processes within the model. It was the subject of considerable work in the 1960s, aiming to explain the savings choice within the growth model as an optimising one the part of consumers. The

complex work required to achieve this (Cass 1965; Koopmans 1965) became a feature of most subsequent neoclassical growth models, but did not change the basic properties of the Solow/Swan model.

The main feature of the Solow/Swan model is that exogenous technological change is what drives long-term, steady state per capita growth. The driver of economic growth *per capita* is improvements in technology, which are determined outside the economic system. Thus the broad economic message of the Solow/Swan model is that steady growth is possible in a purely competitive world, but in per capita terms its source is the independent growth in technology. Given that in the 1950s and 1960s the populations of industrial countries were growing strongly and firms were drawing on a wide range of inventions from the publicly funded science system, this seemed a plausible explanation for long-term growth. Solow (1957) further developed this model in a way that provided the foundations for the subsequent growth accounting industry.

New Growth Theory

The Solow/Swan model thus clarified the possibility of long-term growth in the market economy, and highlighted technological change as the source of that growth in per capita terms. But it did so at the cost of some very dubious assumptions. Indeed, the key assumptions – that technological change is exogenous to the economic system, that its consequences are fully foreseen by firms, that there are no unforeseen new goods or processes and hence that how firms learn about or implement new technologies can be ignored – seem to be inconsistent with the basic character of the knowledge economy. By contrast, it is clear that modern firms invest heavily in creating new product and process technologies, that the outcomes of this investment are quite uncertain and not fully foreseen by firms, and that the effectiveness of search and innovation processes is often crucial to the competitiveness of contemporary firms. Hence a central starting point for the two new strands of thought about growth in the 1980s was variations in these assumptions of the neoclassical system.

Unrealistic as they are, however, the assumptions of the neoclassical model about technology and innovation were not made lightly, but are intimately linked to the mechanics of the model. More realistic assumptions inevitably introduce two features – investment in R&D and in innovation and imperfect information – which are destructive of the standard neoclassical methodology. For these features lead to sunk costs, increasing returns, market power and oligopoly, asymmetric information and so on, matters which are inimical to the standard methods of competitive general equilibrium theory. Thus deviations from the assumptions about technology and innovation are not bought cheaply in terms of the integrity of the original enterprise.

The new growth literature is vast and diverse, with hundreds of papers now published exploring growth models within this genre. Seminal contributions include those of Romer (1986, 1990), Lucas (1988) and Grossman and Helpman (1991). Typical new growth models explore the implications for growth of endogenous technological change and innovation (that is, resulting from the deliberate actions

of firms) in the context of oligopoly and overall increasing returns, although perfect information assumptions are generally retained. Such issues can be modelled in many different ways, with very diverse results. Nevertheless, the results of this work are in many respects strikingly different from that of the neoclassical growth model.

One simple example is in terms of trade and industrial policy. In many of these models the benefits of trade in terms of global income or growth are enhanced in aggregate relative to the standard competitive model. This is so if the increase in knowledge, technology or innovation that drives growth is greater when national economies are open to international influences in these areas through trade. But these benefits do not necessarily flow through to individual countries, so that some countries may be harmed by a move to greater openness.

When growth is driven by innovation, learning by doing or other externalities and these effects are geographically concentrated, initial conditions can generate major long-term differences between countries in comparative advantage and in growth potential. Suppose the industries in which a small country is specialised are deficient in relevant respects (e.g. have a lower capacity for learning by doing, have lower returns to or lower capacity for R&D or have lower levels of other externalities) relative to other industries. Then free trade will inhibit the growth of the small country, because it will tend to concentrate activity in that country in areas with lower capacity to generate growth. In such a case, a national policy, e.g. to promote R&D, could have a major positive impact on the economic history of the country in question, generating new forms of comparative advantage. In appropriate circumstances, then, a given national policy can generate a dynamic comparative advantage.

Evolutionary Theories of Growth

The evolutionary tradition is also very much focused on these issues of technology, innovation and growth in a knowledge based economy, but dispenses with much of the neoclassical apparatus to develop a fresh, empirically based approach. The view taken is that the neoclassical apparatus is so deeply inimical to the realistic treatment of knowledge and innovation that a new start is required. Thus this literature stresses the empirical study of technological change and innovation in firms, of the processes by which firms innovate and of the characteristics of, and relationships between, innovating firms. Much of this literature has been self-consciously evolutionary, following the lead of Veblen (1898), Marshall (1919), Schumpeter (1934) and Boulding (1981) in drawing an explicit analogy with biology. Evolutionary models of growth have also been developed, in which firms search for improved routines and evolve over time in response to their environment, to the results of their innovative activities and to random factors. The seminal evolutionary growth model is that of Nelson and Winter (1982).

One key feature of evolutionary models in biology is the process of selection of the ‘fittest’ in an environment of diversity and randomness. In evolutionary models of economic growth, growth typically occurs because those

firms which are successful in their search and learning processes (the fittest) grow relative to other firms. Innovation and technological change are inherently uncertain and involve random elements in these models. Firms follow a diverse range of search strategies, and those which are successful become more profitable and better able to participate in the next stage of search activity, and so on. But innovation always involves an element of randomness, so that past success never absolutely guarantees future performance. Thus these models seek to include Schumpeter's themes of innovation, uncertainty and creative destruction as being at the heart of growth in the capitalist economy.

Knowledge, Innovation and Growth

The new growth models and the evolutionary growth models are fundamentally different in technique, structure and intent. But in the end they focus attention on many common issues. The overriding one is the pivotal role in modern economic growth of the intentional actions of firms in creating, accessing and applying new ideas. Others factors whose importance is highlighted in one way of another in both traditions include:

- the processes by which an individual firm makes use of ideas new to it, and of policies to encourage effective innovation;
- the inevitable intrusion of oligopoly and market power in knowledge intensive growth;
- the uncertainty of the innovation process, and the role of networks and alliances in helping firms to cope with knowledge based growth;
- the importance of initial conditions to final outcomes, and hence the path dependence of knowledge based growth, and
- the possibility of diverging outcomes for regions or nations even in a free market context.

Thus in spite of their differences they both have an important role to play in our attempt to understand the current economic revolution, the emergence of the global knowledge economy.

3. Growth in the Global Knowledge Economy

In this section I review briefly some aspects of the new economic situation, and its historical context, before addressing some specific issues related to manufacturing in Sections 4 and 5.

The Global Knowledge Economy

In this paper I follow OECD (1996) and other authors in describing the newly emerging set of activities, structures and arrangements as a knowledge-based economy, and use the term *the global knowledge economy* (see also World Bank

1998 and Sheehan and Tegart 1998). The central technological facts leading to the global knowledge economy derive from the revolution in information technology. They include the ability to deliver codified knowledge, assembled on a global basis if necessary, very quickly and very cheaply to the area where it is needed, to transform such knowledge extensively as required and to make it effective in machines and other production and service delivery processes. The central policy fact is the global trend to the deregulation of the flow of goods, capital, technology and services, and of national processes of production and distribution.

These two factors have had mutually reinforcing effects, and many other forces are also contributing to shaping the new global economy. The term *global knowledge economy* makes explicit reference to what we take to be the defining characteristics of the world economy emerging as a result of these causal factors – the rise in the knowledge intensity of economic activities and the increasing globalisation of economic affairs. But this term is intended to refer to the overall economic system that is emerging, rather than to these characteristics alone.

The remarkable development of information and communications technologies over the past two decades needs no documentation here, but the rapid process of international deregulation over the same time has been an equally important driver of the global knowledge economy. The period since the early 1970s has seen a widespread movement to economic deregulation, manifested principally in three areas:

- liberalisation of trade, that is reduction of tariff and non-tariff barriers to trade in both goods and services;
- liberalisation of capital markets, including floating of currencies, deregulation of financial markets more generally and reduction of barriers to foreign direct investment and to other international capital flows, and also of barriers to technology transfer, and
- deregulation of internal markets for goods, services and financial flows.

These two driving forces have not been entirely independent factors, but have had mutually reinforcing effects over the period since the early 1970s. Exploration of these links is beyond the scope of this paper, but they should not be neglected. Dramatic new global capabilities in computing and communications provided both the pre-conditions for, and some impetus to, deregulation of global markets, while global competition and technology flows have contributed to the rapid declines in both goods and services prices. These links are particularly evident, for example, in financial markets, where the new technological capabilities have facilitated the development of new financial products and of global capital flows on an unprecedented basis, and perhaps beyond the capacities of many countries to supervise effectively.

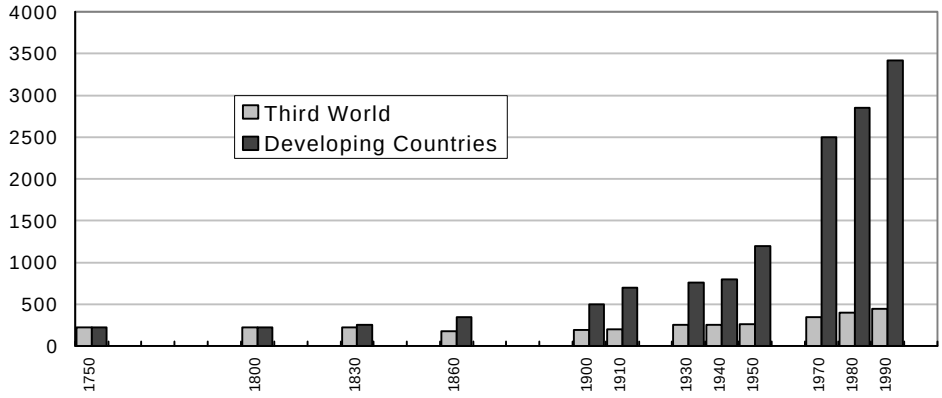
Growth and Equity in the Global Knowledge Economy

The fundamental change in the world economy referred to as the Industrial Revolution was itself a knowledge revolution, as new scientific and engineering principles were applied to industrial activity. It thus seems reasonable to look to

that historical episode for some guidance concerning the growth implications of the current knowledge revolution. In terms of the level and distribution of new economic activity, the lessons of the Industrial Revolution are quite clear. The fruits of development based on the new knowledge were immense, but they went to those (initially in UK) who generated the economic applications of knowledge and then to those (in Europe and later in USA) who could readily access and expand on this knowledge. As a result, for two centuries from about 1770 to 1990 the pattern of economic development heavily favoured (with the striking exception of Japan) the countries of the West.

For example, on Bairoch's estimates (1993), the level of real GDP per capita was about the same in 1750 and 1800 in what are now the developed countries and the developing countries (see Chart 1). Over the nineteenth century average real per capita incomes in the developed countries increased by 150%, while those in the Third World fell by about 15%. While the twentieth century saw some growth in Third World incomes, by 1970 per capita GDP levels in the developed countries were about seven times those in the Third World. But over the two centuries nearly all of growth in per capita GDP took place in the developed countries, with a massive change in their standard of living and deeply ingrained inequalities between rich and poor on the world scene.

Chart 1: GDP Per Capita (constant US$)



Source: Bairoch (1993).

It is possible that the new technological revolution will also usher in a period of rapid growth in the world economy, as new ways of meeting persistent human needs are developed through the new technologies. A number of facts, notably the persisting boom in the USA, suggest that this may indeed be so, although concerns remain about the stability of a globalised economy. If this is so, a central issue will be that of inequality, and of whether growth is again concentrated

on those countries which already possess the knowledge, the existing developed countries. This is an issue to which we will return below.

4. Manufacturing and the Creation, Production and Distribution of Goods

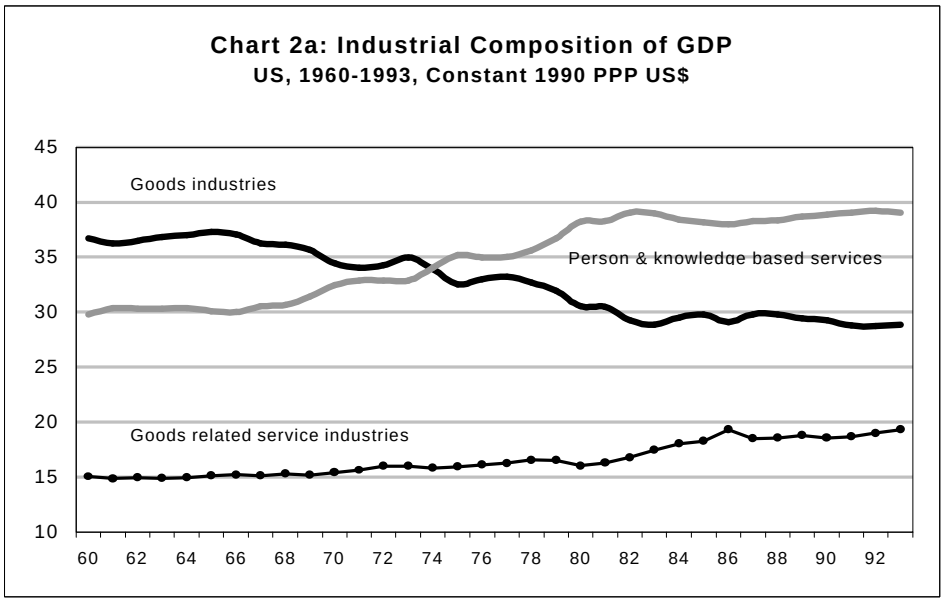
It is widely understood that the advent of the knowledge economy has been associated with sharp changes in the structure of economic activity in the developed countries, and that these changes have substantial implications for firms and industries and for individuals, communities and nations. One dimension of these changes – the changing industry composition of economic activity – is briefly reviewed here, while the changing nature of the activities undertaken within particular industries, and specifically the increasing integration of manufacturing and service industries, is also addressed.

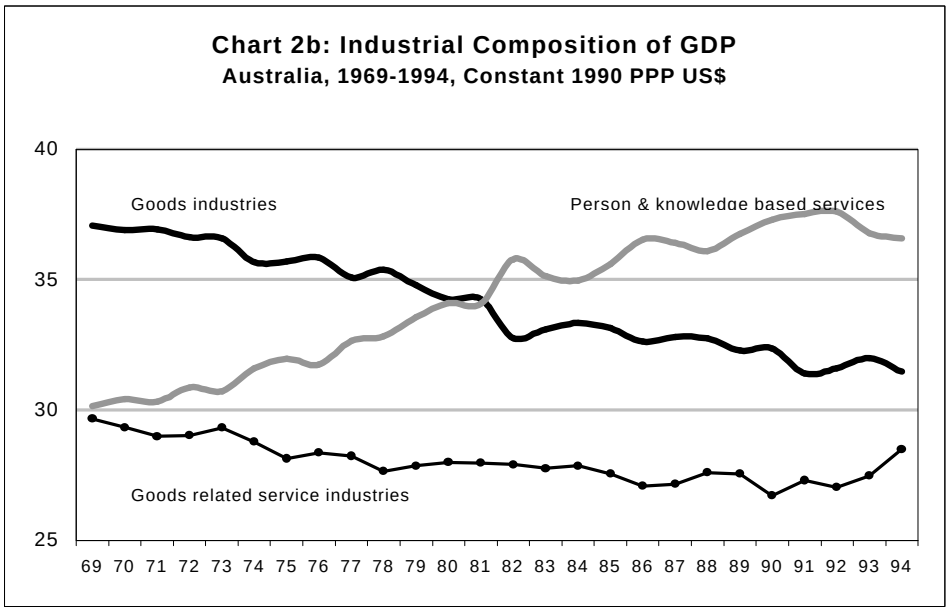
In terms of the industry composition of GDP, this ongoing trend can best be summarised in terms of three clusters of industries (Sheehan and Tikhomirova 1998). These are the primary and secondary industries or the goods producing industries (*the goods industries*); the traditional service industries, notably wholesale and retail trade and transport and storage, largely related to the movement, storage or marketing of goods (*the goods related service industries*), and the emerging services industries, primarily the knowledge based service industries such as education, health and business and consulting services, and the person based service industries such as recreation, entertainment and community services (*the person and knowledge based service industries*).

A diverse combination of factors – from greater productivity arising from technological change in the goods industries, a shift of demand in high income countries from goods to services in spite of declining relative prices for goods and intense global competition, including from newly industrialising economies – is leading to a decline in the share of GDP arising from goods production in all developed countries. (For the cases of USA and Australia see Charts 2a and 2b.) This decline is being largely offset by the share of GDP arising from the person and knowledge based service industries, which is rising rapidly in virtually all developed countries, while the share of traditional services in GDP is flat or declining in most countries. In the USA, for example, person based service industries accounted for just on 40% of GDP by 1994, whereas the goods industries accounted for only 29% of GDP. Similar trends are apparent in other developed countries, but are less advanced in Japan.

This shift from the goods industries to the knowledge and person based industries in terms of the composition of GDP or employment is a fundamental feature of the knowledge economy, but it should not be misinterpreted. It is not as if one group of industries is replacing another, much as the motor vehicle replaced the horse-drawn carriage. While there is some increased demand for services as final products, activities related to the creation, production and distribution of goods still lie at the heart of advanced economies. But those activities are becoming

increasingly knowledge and service intensive, so that there is growing convergence between what are traditionally regarded as goods industries (such as agriculture, manufacturing and mining) and service industries.





Source: Sheehan and Tikhomirova (1998), based on OECD data.

For example, firms engaged in manufacturing rely heavily on services, both from within the firm and outside it, and sell both goods and services. Many service sector firms are totally focused on providing services to manufacturing firms, or to firms producing other types of goods. *Indeed, an integrated manufacturing-services sector – integrating the vast range of services now required to develop, produce, market and distribute industrial goods and services on a global basis – is the most dynamic sector of many economies.*

Thus economic activity is certainly becoming more service intensive – drawing more heavily on service rather than production activities – but this is occurring across virtually all industries. Focusing on industries, defined in terms of their typical activities (e.g. a firm is in manufacturing if its main activity is production of certain types of goods), can lead us to overlook the changing nature of activities within industries, the growing links between industries and the continued role of processes for the creation, production and distribution of goods in driving many service activities. *The key focus for policy should be on clusters of production and service activities, which are jointly competitive on a world scale.*

It is possible to provide here only some limited evidence for these assertions. Extensive case study evidence is available from a number of recent studies and reports, such as Quinn (1992), US Department of Commerce (1998), UK Department of Trade and Industry (1998) and Deloitte Consulting (1998). At the aggregate level, however, economic analysis suffers from an inability to test hypotheses by experiment in real economies. But a most remarkable natural experiment has taken place in Hong Kong over the past decade, which provides a dramatic illustration of these manufacturing-services linkages. Since the mid 1980s Hong Kong manufacturing firms have shifted production activities to mainland China on a massive scale. It is estimated that in 1995 Hong Kong firms employed about five million persons in China, some five times total manufacturing employment in Hong Kong in 1984. According to standard figures, the share of manufacturing in GDP fell from 24% in the early 1980s to 9% in the mid 1990s and over the same period manufacturing employment fell by nearly 60% (Berger and Lester 1997; Enright, Scott and Dodwell 1997). But in a broader sense the operation and control of manufacturing activities remains at the heart of the Hong Kong economy.

Whereas the traditional framework leads to a view of industries in isolation, what we now see is product systems in which manufacturing and services are combined in the creation, production and distribution of goods and services. There are many ways to approach these integrated systems. They can be seen as clusters, sectoral innovation systems, complex product systems, service-enhanced or new manufacturing systems. But in whatever guise, the key feature is the integration of a range of industries into increasingly tightly coupled systems which focussed on the creation, production and distribution of goods. The advantage of using terms such as ‘new manufacturing’ to describe these trends is that they highlight the critical role of services and the product system linkages between industries, while also bringing out the centrality of manufacturing.

5. ‘New Manufacturing’ in the Global Knowledge Economy – Some Issues

Given our themes to date – the crucial role of knowledge and innovation in growth, the emergence of the new era of the global knowledge economy and the continuing importance of integrated systems for the creation, production and distribution of goods in that economy – what can be said about the crucial issues

facing 'new manufacturing' over the next few decades? While again conscious of their personal nature, I make below five specific points.

Technologies at the Atomic Level

The ICT technologies have been revolutionary in large part because they are so pervasive, reflecting the pervasiveness of information throughout the economic system. The development of these technologies has also been facilitated by rapid progress in miniaturisation, for example in relation to chips and chip design. But miniaturisaion is in some respects just in its early stages. Indeed, it is arguable that technologies which can create and structure materials and products at the atomic level – nanotechnologies, broadly defined – may be almost as pervasive and as important as the ICT technologies. In a way, these technologies will be an ultimate expression of the knowledge economy. For they will enable us, as it were, to introduce knowledge into the structure of matter itself, and hence to use that embodied knowledge to design and create products to meet the needs of firms and consumers in ways not yet conceived.

In a narrow sense, nanotechnology refers to the study of nanoparticles, nanostructures and nanodevices, where a nanometre is one billionth of a metre. Hence they are particles, structures and devices engineered at the scale of individual atoms and molecules. An important recent study for the US National Science and Technology Council (Seigel, Hu and Roco1998), undertaken by a panel of experts, concluded as follows:

> Nanostructuring represents the beginning of a revolutionary new age in our ability to manipulate materials for the good of humanity. The synthesis and control of materials in nanometer dimensions can access new material properties and device characteristics in unprecedented ways. Panelists had seen the tip of the iceberg or the pinnacle of the pyramid before starting this study, but only since undertaking the study do we fully appreciate just how broad the field really is and begin to understand what its exciting potential and impact may really be. It is clear that work is rapidly expanding worldwide in exploiting the opportunities offered through nanostructuring. (1998, p. 4)

This report also highlights some of the more specific applications of nanotechnology, and assesses their state of development. In areas as diverse as genetically customised drugs, energy storage, new materials (ceramics, polymers or structural materials), production processes, electronics and bioelectronics, technologies at the atomic level will provide the fundamental context of advanced manufacturing in 2020.

In a somewhat broader sense, major changes are occurring as a result of technologies that operate at close to the atomic or molecular level. The pharmaceutical industry is one in which the changes are likely to be profound. Vast efforts are currently being made to work out the sequence and structure of the human genome, which contains of the order of 100,000 genes, and this is expected to be largely completed by 2005. These efforts, and more generally work in genomics, offer an increasing capability to establish the link between specific genes and specific diseases. This is turn will enable the creation of drugs to target

particular disease related genes, the preparation of preventative programs for individuals susceptible to a particular disease, and the customisation of health programs for individuals, having regard to their individual pattern of disease susceptibility.

This case illustrates one important economic feature of nanotechnologies, namely their ability to enable firms to meet real individual or producer needs in quite new ways. Thus their impact is not just on the production of existing products or on the development of new variants on those products, but on the creation of quite new ways of meeting human needs.

The Impact of Sustainability

The pattern of economic activity built up in the advanced economies since the Industrial Revolution is clearly not sustainable for the world as a whole in the 21st century. In many advanced countries environmental systems are severely damaged, and global warming appears to be well advanced. But as countries such as China, India, Indonesia and Brazil move up the development ladder a new global pattern of economic activity which is environmentally sustainable becomes an undeniable imperative. This will mean not only substantive changes to present processes for the creation, production and distribution of goods, but fundamentally new approaches to many aspects of human life.

Thus knowledge will drive growth in the new century, but of necessity a good part of it will be knowledge about how human needs can be met through goods and services the production and use of which is sustainable in the long term. For example, Ainsley Jolley has recently reviewed some of the critical issues arising in relation to transport in and between megacities (1999). He concludes that major technological transformations are both necessary and likely. For example, the next few decades are likely to see the development of electric and hybrid vehicles, intelligent vehicle-highway systems, new types of transit vehicles and alternative urban freight distribution systems.

The Decline of Manufacturing Firms

In his major study of the historical emergence of industrial capitalism, entitled *Scale and Scope: The Dynamics of Industrial Capitalism*, Chandler (1990) ascribes the rapid growth of Germany and the United States between about 1860 and 1920 to the emergence in these countries of powerful firms able to take advantage of the economies of scale and scope offered by the new industrial technologies. These new enterprises were able to commit to the massive threefold investment – in production facilities, in distribution networks and in organisational structures – necessary to achieve the economies implicit in large-scale production and distribution of a wide range of products. By contrast, the development of these firms was held back in Great Britain by various factors, notably the continued personal involvement of the owners of large firms, and the economic growth of that country faltered.

Reviews of the experiences of four 'successful' economies – Japan, Germany, France and Korea – also highlight the crucial role in these countries of the development of competitive firms. From the time of the Meiji Restoration, policy makers in Japan have striven to develop firms with a scale and structure such that they can compete with those of the West. The pre-war zaibatsu and the post-war kieretsu have both been instrumental in Japanese economic growth. The emergence of major firms in Germany, on which Chandler placed such importance, was heavily driven by the major banks, as well as being facilitated by cartel and other legislation. The French planners have always placed great emphasis on the support and encouragement of strong French national firms. In Korea, the fundamental role of the chaebol as the prime vehicle of the rapid growth of the past three decades is well known. Recognition of this fact is entirely consistent with the current widespread argument that the chaebol have expanded and diversified well beyond the point at which diminishing returns sets in.

But such firms are in relative decline around the world, as production activities become less important in the overall value chain. Major footwear, textiles and clothing firms such as Nike have become information management companies, matching information about markets, design, production and distribution on a global basis and contracting out production to the lowest cost producers. Major pharmaceutical companies, such as Glaxo and Smith Kline Beecham, are merging and becoming global health care businesses, again contracting out production to the lowest cost producers on an increasingly global basis.

Thus the corporate structures through which the creation, production and distribution of goods takes place are changing rapidly. This has many ramifications that we do not begin to understand. Companies everywhere are scrambling to stake out their position in the broader canvas of the 'new manufacturing'. Government support programs, such as for R&D and industry development, are being reconsidered in the new corporate landscape. Some nations, and many regions within nations, are watching their manufacturing base shrink with little idea about how to reshape their economy for the new world. Adjusting to this continuing change in corporate structure is a major challenge for all concerned.

The Challenges of Development

Another important fact is that the world appears to be seeing growing inequality arising from economic trends, both within and between countries. Only a few examples of this apparent trend can be given here. In the US, for example, the real earnings of the bottom 10% of employed males fell by one quarter between 1973 and 1994, while those of the top 10% rose by about 15%. The effect for female wages is similar, but with a higher rate of growth of mean real wages. The other country for which there has been a major increase in wage inequality is the UK. The main difference between the UK and the US lies not in the extent of the increase in earnings inequality but in the fact that over the period since the 1070s overall real wages have risen significantly in the UK but have risen slowly or fallen (depending on the measure used) in the US.

In describing changes in the wage distribution in other developed countries, Gottschalk notes two other groups. One, including Canada, Australia, New Zealand and Israel, experienced substantial increases in wage inequality, but less so than USA and UK. Another, including the Nordic countries, the Netherlands, France, Italy and Japan, experienced small but positive increases in wage inequality. Only Germany seems to have avoided any increase in inequality at all, although this may be beginning to change (Gottschalk 1998).

Table 1: Developing Countries: Increased Polarisation in Cross Country Relative Incomes

	Position in 1965 income distribution (quintiles)					
	Lowest	*Second*	*Third*	*Fourth*	*Highest*	*Total*
	(Number of countries)					
Countries whose 1995 quintile position relative to their 1965 position was:	**52**	**34**	**15**	**2**	**5**	**108**
	Position in 1995 income distribution (quintiles)					
	(Number of countries)					
Lower	34	10	2	..	..	46
Unchanged	50	6	1	..	..	57
Higher	..	1	1	1	2	5
Total	**84**	**17**	**4**	**1**	**2**	**108**

Source: IMF, *World Economic Outlook*, May 1997.

Over the last decade or so, many poorer countries have fallen further behind the richer countries in real living standards rather than catching up. There is very real fear among developing countries that the knowledge economy will further strengthen the position of those who already possess the knowledge, namely the rich countries. Some understanding of these trends can be gained from Table 1, which summarises the results of an analysis of relative income movements of a group of 108 developing countries between 1965 and 1995 (IMF 1997, following Chari, Kehoe and McGratten 1996). The country coverage of the Table 1 includes the countries of East Asia but excludes the transition economies of Eastern Europe. In constructing this table five income bands, each covering 20% of developed country per capita GDP for that year, are defined for 1965 and 1995, and individual developing countries are allocated to them as appropriate.

This analysis shows quite clearly the polarising dynamics of recent decades. Of the 108 countries studied, 52 were in the lowest quintile and 34 were in the second lowest quintile in 1965. By 1995 84 were in the lowest quintile and 17 were in the second lowest quintile. That is, the proportion of developing countries which were in the lowest quintile of developed country income rose from 48% in 1965 to 78% in 1995. Forty six countries moved downward into a lower income quintile, of which 13 countries fell by two or more quintile bands, while only 5 countries moved into a higher quintile. Thus upward movements were rare, and developing countries were almost evenly divided between those whose quintile position declined and those for which it remained unchanged.

Thus there are growing signs that the emerging knowledge economy may be one of increasing rather than declining inequality, both within and between nations. The creation and application of knowledge tends to concentrate in particular social groups, regions and nations, for many reasons. For example, the process of knowledge creation is a cumulative one, which builds on past successes; it involves a substantial transfer of tacit knowledge, through personal interaction, and it is very expensive. The Industrial Revolution, based on the application of the new scientific knowledge, led to massive inequality between countries. In 1800 per capita incomes were roughly equal in what were to become the developed countries and the Third World; by 1970 average incomes were about seven times higher in the developed countries, which had been able to access and apply the new sciences. There is a danger of a new surge in inequality in coming decades, with further increases in relative incomes in those advanced countries that control the next generation of knowledge.

The global community could not survive a further massive increase in inequality, especially in a globalised world where differences are readily apparent. The issue of how this is to be avoided will be a fundamental one over the period to 2020. In particular, it may require some radical rethinking about how knowledge is controlled and shared. For example, current policy settings encourage the development of technologies by private firms and provide protection for the intellectual property of those firms. While this encourages investment in R&D, it also means that private firms in the advanced countries control most important technologies. This in turn limits their application by firms in developing countries, except under terms beneficial to the owners. It is arguable that the greatest successes in postwar development – in health and in agriculture – were due to the public control of advanced technologies, and their consequent ready availability to poor countries.

Output, Growth and Welfare

A central theme underlying this paper is the meeting of human needs as the rationale for the economy. In advanced economies today these needs are mainly met through the production and distribution of goods and services through the market. Overall national welfare is measured by the total level of value added in the production of goods and services (GDP). Two centuries of experience with a market based, capitalist system has shown that while it is a superb generator of output in response to market demand, that demand is often a poor signal of underlying human need. This is for many reasons: the manipulation of demand through advertising, the dominance of the well-off in terms of purchasing power, the lack of provision in areas where returns cannot be privately appropriated, the lack of market signals for communal products, and so on.

Most discussions of the growth of nations use national accounting methods and measures, which were themselves developed during the industrial era to measure change in national and regional economies over time. But the objective of economic growth has always been increased welfare for the individuals served by the economy, rather than a continuing increase in the output of goods and services as an end in itself. In recent decades it has been often noted that increases in per

capita GDP do not necessarily correlate with increased human welfare, and in some areas (e.g. environmentally) there may even be an inverse correlation.

The experience of China also illustrates this point, for China has achieved improvements in many aspects of human welfare well ahead of its GDP performance, and indeed some of these gains were achieved in the pre-reform period. As is evident from Table 2, in spite of still being a low income country China has lower illiteracy and infant mortality rates, and higher schooling and life expectancy levels, than the medium income countries as a whole. As noted above, levels in the best Chinese province are comparable with those in the high-income countries.

Table 2: Selected Human Development Indicators: China and the World

	China			World		
	Average	*Worst Province*	*Best Province*	*Low Income Economies*	*Medium Income Economies*	*High Income Economies*
Urbanisation (%)	27.5	13.3	70.1	27	60	78
Illiteracy Rates (%)	13.3	40.0	6.4	49	17	< 5
Mean Schooling (yrs)	6.1	2.2	8.7	1.6	5.3	11.1
Life Expectancy (yrs)	68.8	59.1	75.2	56	68	77
Infant Mortality (per '000 live births)	30.6	94.6	8.7	89	39	7

Source: Wang Shaoguang and Hu Angang (1999), based on World Bank, *World Development Report 1995* and other sources. China data are for 1994; other data are for 1993.

The point of this is that rethinking the relationship between GDP figures and human welfare will be an important aspect of responding to the knowledge economy. Not only may the GDP figures become increasingly misleading in this regard, but new technologies (such as communications, telemedicine and online learning) may offer direct increases in human welfare without any large, intermediate growth in the output of goods and services. On the other hand, many of the large firms that dominate the creation, production and distribution of goods specialise in the creation and management of demand, especially among those with the capacity to pay. It is hard to escape the conclusion that, if 'new manufacturing' is to achieve its enormous potential in the new century, it will have to be founded on a much firmer demand base than this. That is, it will have to address more directly the real human needs of individuals and communities globally, rather than the stimulated needs of the elite.

5. Conclusion

Manufacturing as we used to know it will be quite small by 2020. But 'new manufacturing' – the composite of firms involved in some part or another of the creation, production and distribution of goods – will be central to the economy, and

to the growth of regions and nations. That growth will in turn be driven by the application of new knowledge and new ideas, whether for firms and nations at the technological frontier or for those involved in a catch-up process. Clearly the quality of a nation's institutions for creating new knowledge, for accessing the global stock of knowledge and for facilitating innovation within firms will be central to its growth prospects.

In terms of the knowledge which might drive growth in 'new manufacturing' through to 2020, two areas seem likely to be especially important. One is the set of technologies operating at or near the atomic level. They should enable us, as it were, to introduce knowledge into the structure of matter itself, and hence to design and create products to meet the needs of firms and consumers in ways not yet conceived. The second is the imperative of sustainable development, and the systematic application of new technologies to this end. Again this process should, and indeed must, lead to the emergence of many new goods which humans need in ways that are sustainable in the long term.

Many issues arise, however, about how 'new manufacturing' might operate as a global system facilitating growth in nations and regions. One relates to the decline of traditional manufacturing firms, and the rise of large global 'information managers' which hold the business assets and manage the processes of the creation, production and distribution of goods through complex webs of networks, alliances, contracts and agreements.

Another relates to the concentration of knowledge in particular nations, regions and firms. This arises from several inherent features of the knowledge creation process: it is cumulative, building on past success; it involves a substantial transfer of tacit knowledge, through personal interaction, and it is very expensive. Quite new thinking, and quite new policies, might be necessary if a massive new increase in global inequality is to be prevented. Finally, if 'new manufacturing' is to achieve its potential it will have to address more directly than at present, the real human needs of individuals and communities on a global basis.

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