Centre of Policy Studies Working Paper

No. G-256 October 2015

The Macroeconomic and Sectoral Effects of Terrorism in the U.S.: A Reconciliation of CGE and Econometric Approaches

J. Nassios

and

J.A. Giesecke

Centre of Policy Studies, Victoria University

ISSN 1 031 9034 ISBN 978-1-921654-64-0

The Centre of Policy Studies (CoPS), incorporating the IMPACT project, is a research centre at Victoria University devoted to quantitative analysis of issues relevant to economic policy. Address: Centre of Policy Studies, Victoria University, PO Box 14428, Melbourne, Victoria, 8001 home page: www.vu.edu.au/CoPS/ email: copsinfo@vu.edu.au Telephone +61 3 9919 1877

The Macroeconomic and Sectoral Effects of Terrorism in the U.S.: A Reconciliation of CGE and Econometric Approaches

J. Nassios[1 2 *] and J. A. Giesecke[3 2 *]

[*]Centre of Policy Studies, Victoria University, Melbourne, Australia

Wednesday, October 21, 2015

Abstract

Government decision makers must make plans for a wide range of terrorism threat scenarios. In the formulation and evaluation of these plans, economic consequence analysis plays an important role in elucidating the benefits of successful deterrence, mitigation, and post-event management. However, planning in this regard is not easy, particularly when terrorism events have diverse characteristics defined along many dimensions, including the method, location, scale and frequency of attack(s). As discussed in previous work by [Giesecke et al. (2015)], CGE models are well-suited to the analysis of the economic consequences of a diverse range of threat scenarios; with a large number of exogenous variables, CGE models can be used to model shocks related to the many particular characteristics that can define a given individual terrorism event. This also makes them well suited to the analysis of the many hypothetical scenarios that must be investigated in contingency planning by defence and emergency management decision makers. In defining a terrorism event for input to a CGE model, two broad sets of shocks are typically recognised: (1) Physical impacts on observable economic variables, e.g., fatalities, asset damage, business interruption; and (2) Behavioural impacts on unobservable structural variables, e.g., the effects of fear and uncertainty on workers, investors, and consumers. Assembling shocks related to the physical characteristics of a terrorism event is relatively straightforward, since estimates are either readily available or plausibly inferred. However, assembling shocks describing the behavioural characteristics of terrorism events is difficult; with values for unobservable variables such as impacts on required rates of return, worker compensating wage requirements, and consumer willingness to pay having to either be inferred or estimated by indirect means. Typically, this has been achieved via reference to extraneous

[1] Jason.Nassios@vu.edu.au
[2] The authors would like to thank Prof. Peter Dixon for his suggestions and comments.
[3] James.Giesecke@vu.edu.au

literature. But how confidant can planners be that the impact magnitudes reported in such ex-ante analyses are plausible? Ex-post econometric studies of terrorism, such as those by [Blomberg et al. (2004)] and [Blomberg and Hess (2006)], present models for the response of observable economic variables, e.g., real GDP, investment, government expenditure and trade, to terrorism and other forms of conflict. [Dixon and Rimmer (2002)] demonstrate that a CGE model can be used to infer outcomes for unobservable structural variables using observable economic variables. In a similar way, in this paper we use the findings by [Blomberg et al. (2004)] to determine point estimates for the relevant (unobservable) structural variables impacted by terrorism events using the USAGE 2.0 dynamic CGE model of the US economy ([Dixon and Rimmer (2002)]; [Dixon and Rimmer (2004)]). This allows us to: (i) Explore the relative contributions of implicit structural and policy shifts in the results for observable variables reported in [Blomberg et al. (2004)]; (ii) Extend Blomberg's analysis of results for macro variables into the sectoral dimension, thereby elucidating the consequences of terrorism on prospects for individual industries; and (iii) Compare implicit structural shocks in Blomberg with the assumed structural shocks in earlier CGE papers.

Keywords: Terrorism, Economic impact; Dynamic CGE modelling.

JEL Codes: C68; F52

Table of Contents

1 Introduction

The interaction between conflict and economic prosperity has long concerned economists ([Keynes (1919)]; [Meade (1940)]; [Pigou (1940)]). Pertaining to the available data, these early analyses focused on the economic impacts of large-scale conflict such as the Great War and World War 2. More recent work has sought to ascertain the economic impacts of terrorism, which is distinguished from other forms of conflict and defined as ([Blomberg et al. (2004)]; [Mickolus et al. (2003)]):

> The use, or threat of use, of anxiety-inducing, extra-normal violence for political purposes by any individual or group, whether acting for or in opposition to established governmental authority, when such action is intended to influence the attitudes and behavior of a target group wider than the immediate victims and when, through the nationality or foreign ties of its perpetrators, its location, the nature of its institutional or human victims, or the mechanics of its resolution, its ramifications transcend national boundaries.

Terrorism events such as the September 2001 World Trade Center bombing, the Bali bombings, the London subway and bus bombings and the recent attack on satirical news magazine *Charlie Hebdo* illustrate the highly disparate nature of terrorism attacks. Whilst highly localized geographically, their direct economic and social impacts can have far reaching consequences. These typically fall within two broad categories: (1) Measurable physical characteristics, e.g., fatalities, asset damage or business interruption; and (2) Unobservable behavioral consequences, e.g., altered behavior of economic agents through heightened fear and uncertainty ([Fischhoff et al. (1978)]; [Kasperson et al. (1988)]; [Slovic (1987)]). This drives a variety of regional and macroeconomic consequences of terrorism ([Blomberg et al. (2004)]; [Enders and Sandler (2011)]; [Giesecke et al. (2012)]; [Giesecke et al. (2015)]).

Whilst a broad range of agent-based economic models of terrorism have been proposed to study the theoretical underpinnings and policy implications of terrorism (see for example [Enders and Sandler (2002)]; [Garfinkel (2004)]; [Lapan and Sandler (1988)]; [Lapan and Sandler (1993)]), econometric methods and computable general equilibrium (CGE) models have also been applied to quantify the economic impact of terrorism. Early econometric work by [Enders et al. (1990)] utilized time series analysis to study the effectiveness of several terrorism-thwarting policies; this analysis did not directly consider the economic impact of terrorism. In a follow up piece, [Enders et al. (1992)] considered the impact of terrorism mitigation on tourism. More recently, [Blomberg et al. (2004)] presented time series analyses of a pooled cross-sectional dataset of three distinct forms of conflict: (i) Terrorism (as defined previously in this article), (ii) Internal Conflict and (iii) External Conflict. Three key macroeconomic impacts of terrorism were identified in the terrorist event-year:

1. An *on-average* reduction in the proportion of investment to GDP;

2. An *on-average* increase in the proportion of public consumption to GDP;
3. An *on-average* reduction in the rate of real GDP growth.

Econometric models for the time-evolution of these variables were presented and their implications discussed. [Tavares (2004)] utilized an alternative dataset of terrorism events to present a similar analysis of the macroeconomic impact of terrorism, with real GDP growth taken as a measure of the welfare impact of terrorism. In later work, [Blomberg and Hess (2006)] extended the previous analysis by [Blomberg et al. (2004)] with a consideration of the corresponding impact of the three aforementioned forms of conflict on bilateral trade, i.e., exports plus imports.

CGE models have also been used to analyze the impact of terrorism events. Early work in this approach to costing the impact of terrorism by [Rose et al. (2009)] considered the economic impacts of the 9/11 World Trade Center attack, including an investigation of the impacts of business interruption and associated reductions in air travel. More recently, [Giesecke et al. (2012)] and [Giesecke et al. (2015)] considered the impact of (hypothetical) radiological dispersal device attack and a chlorine terrorist attack in the Los Angeles Financial District, respectively. On the basis of independently formulated scenarios and analyses (see also [DHS (2005)], [Barrett and Adams (2011)]), inputs to the CGE model were formulated to describe property damage, casualties and business interruption, quantifying the direct physical impacts of these events. A CGE approach naturally lends itself to the analysis of the full impact of terrorism on an economy at the macro, regional and industry level, with measurable physical impacts directly imparted through a series of shocks relative to a standard "base case" scenario. However, inputs to the CGE model describing movements in behavioural variables are also typically required. In [Giesecke et al. (2012)] and [Giesecke et al. (2015)], these were inferred from extraneous literature on stigmatized asset values, e.g., [Davis (2004)], and from survey work on the public's behavioural responses to actual and hypothetical threat scenarios, e.g., [Burns et al. (2011)], [Burns et al. (2012)].

This article serves to complement these previous pieces of research. Following a similar methodology to [Giesecke et al. (2015)], we utilize a dynamic CGE model to consider the impact of a single terrorism event. Rather than adopting a regional focus, we consider the epicentre to be general and occurring within the United States of America. We apply the USAGE 2.0 (United States of America General Equilibrium) model to investigate the impact of the terrorist event, which is based on the MONASH model of Australia and the USAGE model of the United States ([Dixon and Rimmer (2002)]; [Dixon and Rimmer (2004)]). The terrorism event is described in terms of the econometric findings of [Blomberg et al. (2004)]; that is, the effects of the terrorist event are described in terms of impacts on variables that are typically endogenous in a standard closure of the USAGE 2.0 model, viz. real GDP, the real investment-to-GDP ratio, and the real public-consumption-to-GDP ratio. These variables must be exogenous in USAGE 2.0 if they are to be shocked with values from [Blomberg et al. (2004)]. [Dixon and Rimmer (2002)] showed how observed results for naturally endogenous variables can be imposed on a CGE model as exogenous shocks, via the endogenous determination of certain (normally exogenous) structural variables, most relevant to the determination of the (normally endogenous) observable variables. As we shall discuss, in the context of the present application, closure changes of this type highlight three CGE variables as being central to carrying the structural and behavioural forces underlying the [Blomberg et al. (2004)] econometric estimates of the effects of a terrorist attack:

1. The relationship between expected rates of return on capital, and new capital formation;
2. Real public consumption spending;
3. Total primary-factor-augmenting technical change.

Our work therefore generates time-paths for these structural variables in response to a single terrorist attack in the U. S. Importantly, while the general response of these structural variables has been discussed extensively, point estimates for their potential magnitudes have not been established; as discussed earlier, this process typically requires a scenario analysis, inference from independent literature, or a survey ([Burns and Slovic (2007)]; [Burns et al. (2011)]; [Giesecke et al. (2015)]).

The outline of proceeding sections is as follows. In section 2, we summarize the key findings and equations arising from econometric analyses of terrorism. Section 2.2 focuses explicitly upon the CGE approach to modelling, with particular emphasis on the USAGE 2.0 model applied in this article. A discussion of key macro- and industry-level results is then provided in section 3, before we provide some concluding remarks in section 4.

2 Past Work

2.1 Econometric studies by [Blomberg et al. (2004)] and [Blomberg and Hess (2006)]

In this section, we describe the econometric studies by [Blomberg et al. (2004)] and [Blomberg and Hess (2006)] and outline the key equations presented therein; as we shall discuss in section 2.2.4, these will serve as a source for appropriate shocks in our CGE analysis of terrorism.

In an analysis of the macroeconomic impacts of terrorism, [Blomberg et al. (2004)] derive econometric models based on annual observations from 177 countries over the period 1968 to 2000.[4] Given the nature of the data and the composition of multiple data sources, it is not possible to confirm that some instances of terrorism (as defined in section 1) are not duplicated in the data set as larger-scale instances of internal conflict. Interestingly, terrorism was shown to be the most frequent form of conflict, with reported instances of terrorism more numerous in high-income OECD countries than developing nations.

As discussed in section 1, [Blomberg et al. (2004)] considered the impact of terrorism

[4] This represents the amalgamation of the Penn World Table data set, the International Terrorism: Attributes of Terrorist Events (ITERATE) data set for terrorist events ([Mickolus et al. (2003)]), and data sets of external and internal conflict.

and other forms of conflict on three key macroeconomic variables, specifically: real GDP growth ΔY_t, and investment and government spending as proportions of GDP (IYR_t and GYR_t respectively). See Table 1 for a definition of all the variables presented herein. Panel regressions were presented to describe and quantify the impact of terrorist events and other types of conflict on these three key variables; see equations 2.1 - 2.4, which are reproduced herein from [Blomberg et al. (2004)] [5]. As indicated below, the relaxation path of these response variables are determined by the natural logarithm of (lagged) real bilateral trade as a proportion of GDP (BYR_{t-1}) and real GDP (Y_{t-1}), as well as lagged investment to GDP (IYR_{t-1}); see equations 2.1 - 2.4 with all variables represented therein defined in Table 1.

$$IYR_{t,\text{Blom}} - IYR_{t,\text{Base}} = 3.307^{***} \ln\left(\frac{BYR_{t-1,\text{Blom}}}{BYR_{t-1,\text{Base}}}\right) + 0.496 \ln\left(\frac{Y_{t-1,\text{Blom}}}{Y_{t-1,\text{Base}}}\right) - 0.389^{**} \frac{T_t}{P_t},$$

2.1

$$GYR_{t,\text{Blom}} - GYR_{t,\text{Base}} = 3.043^{***} \ln\left(\frac{BYR_{t-1,\text{Blom}}}{BYR_{t-1,\text{Base}}}\right) - 2.117^{***} \ln\left(\frac{Y_{t-1,\text{Blom}}}{Y_{t-1,\text{Base}}}\right) + 0.412^{*} \frac{T_t}{P_t},$$

2.2

$$\Delta Y_{t,\text{Blom}} - \Delta Y_{t,\text{Base}} = 0.184 \ln\left(\frac{BYR_{t-1,\text{Blom}}}{BYR_{t-1,\text{Base}}}\right) - 7.959^{***} \ln\left(\frac{Y_{t-1,\text{Blom}}}{Y_{t-1,\text{Base}}}\right)$$
$$+0.341^{***}\left(IYR_{t-1,\text{Blom}} - IYR_{t-1,\text{Base}}\right) - 0.513^{***} \frac{T_t}{P_t},$$

2.3

$$\ln\left(\frac{BYR^{\text{US}}_{t,\text{Blom}}}{BYR^{\text{US}}_{t,\text{Base}}}\right) = 0.502^{***} \ln\left(\frac{\Delta Y^{\text{US}}_{t,\text{Blom}}}{\Delta Y^{\text{US}}_{t,\text{Base}}}\right) + 0.502^{***} \ln\left(\frac{\Delta Y^{\text{RoW}}_{t,\text{Blom}}}{\Delta Y^{\text{RoW}}_{t,\text{Base}}}\right) - 0.188^{***} \ln\left(\frac{P^{\text{US}}_{t,\text{Blom}}}{P^{\text{US}}_{t,\text{Base}}}\right)$$
$$-0.188^{***} \ln\left(\frac{P^{\text{RoW}}_{t,\text{Blom}}}{P^{\text{RoW}}_{t,\text{Base}}}\right) - 0.043^{***} TV_t.$$

2.4

In equations 2.1 - 2.4, we have applied the following notational conventions:

- A subscript “Blom” denotes a variable that follows a time-path described by [Blomberg et al. (2004)] and/or [Blomberg and Hess (2006)] in response to a terrorist attack. This time-path is referred to herein as the *Blomberg Simulation*;

[5] We follow the convention established in [Blomberg et al. (2004)], with the notation ***, ** and * used to represent statistical significance of the estimated coefficients at the 1%, 5% and 10% levels respectively.

- A subscript “Base” denotes a variable following a Baseline Simulation path, e.g., a business-as-usual time-path where no terrorist event is observed. This business-as-usual scenario is denoted as the baseline herein;
- In section 2.2.1, we will introduce and discuss a third simulation, which we denote the Structural Simulation.

[Blomberg et al. (2004)] showed that terrorism, represented by the variable T_t/P_t herein and defined as the number of recorded terrorist events within a country per year (T_t) per million persons (P_t), has a statistically significant impact on real GDP growth in OECD countries. Therefore in any given year, a unit increase in the number of terrorist events per one million persons is shown to drive an (on average) fall of 0.513% in real GDP growth. This represents a negative and statistically significant impact on real GDP growth. From a theoretical standpoint, the authors put forward three mechanisms through which the terrorist events disrupt the real economy:

- Destruction of economic inputs;
- Disrupting household and business spending;
- Reallocation of economic activity to security.

Two of these possibilities were investigated, namely:

(i) The impact of terrorist events and other conflict on investment as a proportion of GDP, IYR_t; and
(ii) The response of Government to the terrorist event and the subsequent impact this has on the proportion of public consumption to GDP, GYR_t.

At this stage of the analysis, [Blomberg et al. (2004)] did not disaggregate the full dataset by region or economic development; only the absolute impact of terrorism across the full data set was considered, as opposed to the relative impact between high income OECD countries and African nations, for example. Interestingly, the authors show that terrorism per million persons is the only form of conflict to elicit a statistically significant impact on the investment ratio, whereas the ratio of public consumption to GDP was also significantly impacted by internal conflict. In general, the investment ratio in any given year was shown to fall by an average of 0.389% in response to a unit increase in terrorist events per million persons across all countries within the sample, and across all time periods represented in the sample. This was largely offset by a commensurate increase in government spending of (on average) 0.412%, in response to the same increase in reported terrorist events.

[Blomberg and Hess (2006)] extended the study by [Blomberg et al. (2004)] to a consideration of the impact of terrorism and other conflicts on real bilateral trade as a proportion of GDP (BYR_t); this was achieved using gravity models. In contrast to previous work by [Blomberg et al. (2004)], terrorism is defined via the following distinct dummy variable:

$$TV_t = \begin{cases} 0 \text{ if both the home country or trading partner experience no terrorist events,} \\ 1 \text{ otherwise.} \end{cases}$$

2.5

The resulting econometric model for BYR_t is summarized in equation 2.4 where, as before, all other variables are defined in Table 1. This distinction in definitions for the terrorism explanatory variable relative to conventions in [Blomberg et al. (2004)] restricts the capacity to analyse the implied shocks to bilateral trade as a proportion of GDP in conjunction with equations 2.1 - 2.3, particularly within a CGE framework. Nonetheless, the authors show that the report of a terrorist event in either the home or away country within a sample drives an (on average) fall of 5.1% in bilateral trade relative to the home country's GDP in any given year, all else being equal. This impact is found to be much smaller than the impact of internal conflict, whilst the impact of external conflicts is large in absolute terms however is not statistically significant.

Overall, the authors find that the magnitude of the impact on bilateral trade is significantly larger than the impact on investment and public consumption to GDP reported in [Blomberg et al. (2004)]; this is most likely due to the definition of the explanatory variable TV_{t-1}. Whilst results are also presented for subsets of the broader population, e.g., high income countries and East Asian countries, the models presented in this analysis do not distinguish between alternate forms of conflict; an aggregate variable is instead used to infer the impact of general conflict on bilateral trade, for each sub-sample in any given year.

2.2 A CGE approach

In this paper, we use the econometric equations for the three key macroeconomic indicators IYR_t, GYR_t and ΔY_t derived by [Blomberg et al. (2004)] to define shocks to a CGE model of the United States (the USAGE 2.0 model). These naturally endogenous and dependent variables are exogenised through a series of swaps in closure status with naturally exogenous structural variables, as we shall discuss. We consequently infer the impact of a terrorism event on a set of underlying structural variables within the CGE model; these structural variables are naturally exogenous and independent, with movements in the time-paths of these variables being used to infer fundamental properties regarding the economy's response to an economic shock. In the work presented herein, we refer specifically to the following three variables as structural variables:

1. Shifts in the required rate of return on new units of physical capital, denoted by the variable Λ;
2. Shifts in real public consumption spending, denoted as G;
3. Total primary-factor-augmenting technical change, denoted by the variable A.

With paths determined for a set of independent structural variables in response to a terrorism event, a decomposition analysis is then performed to analyse their relative impact on the overall macroeconomy. Our approach contrasts to previous work in this field, which has focused on a direct analysis of the macroeconomic or regional consequences of terrorism. Next, we present the USAGE 2.0 model in more detail, before outlining an appropriate "back-of-the-envelope" (BOTE) model in section 2.2.2. The paths taken by all shocked variables are then summarized in section 2.2.3.

2.2.1 The USAGE 2.0 model

The USAGE 2.0 model is a dynamic CGE model of the United States, based upon the MONASH model ([Dixon and Rimmer (2002)]) and developed in collaboration with the US International Trade Commission. This model and its predecessor (USAGE) have been widely applied as tools for forecasting and policy analysis; see [Dixon and Rimmer (2004)]; [Dixon and Rimmer (2009)]; [Dixon et al. (2011)]. The model is too large to be fully documented in a paper of this size, and we refer the reader to [Dixon and Rimmer (2002)] for a full account of the MONASH model upon which USAGE and USAGE 2.0 are based. In section 2.2.2 we present a BOTE model tailored to describe the economic mechanisms at play within USAGE 2.0. We rely on the BOTE model to explain the USAGE 2.0 model mechanisms responsible for our main findings. Before proceeding to the BOTE model, we first provide an overview of USAGE 2.0.

Each industry minimizes unit costs subject to given input prices and a constant-returns-to-scale (CRS) production function. Consumer demands are modelled via a representative utility maximizing household. Units of new industry-specific capital are formed as cost minimizing combinations of construction, machinery and other capital goods. Imperfect substitutability between imported and domestic varieties of each commodity is modelled using the Armington constant-elasticity-of-substitution (CES) specification. Export demand for any given US commodity is inversely related to its foreign currency price. Capital accumulation is specified separately for each industry. An industry's capital stock at the start of year $t+1$ is its capital at the start of year t plus its investment during year t, less depreciation. Investment during year t is determined as a positive function of the expected rate of return on the industry's capital.

A USAGE 2.0 simulation of the effect of a shock (such as a reduction in ratio of real investment to real GDP) typically requires two runs of the model: a business-as-usual run (referred to as a "baseline" herein) and a perturbed run (typically referred to as a "Counterfactual run"). The baseline is intended to be a plausible forecast, while in general the counterfactual run generates deviations away from the forecast caused by the shock under consideration. As we shall discuss in section 2.2.2, in this article we require two counterfactual simulations. First, we impose on USAGE 2.0 results for ΔY_t, IYR_t and GYR_t that track the implied paths in [Blomberg et al. (2004)]; the shock is a single terrorist event with epicentre being the USA. USAGE 2.0 then determines the required movements in the relevant structural variables (as discussed in section 2.1, we refer to this counterfactual run as the *Blomberg Simulation*). Next, we take the values for the Blomberg Simulation structural variables, and impose them on USAGE 2.0 under a standard closure; hereafter, we denote this as the *Structural Simulation*.

2.2.2 A BOTE model of USAGE 2.0

In this section, we introduce a BOTE model of USAGE 2.0 tailored to highlight the main economic mechanisms that are relevant to the application in this paper. We begin with a description of equations 6.1 - 6.14 that are summarised in Table 2, which provides a stylized representation of the key macroeconomic relationships in USAGE 2.0. Hereafter we will refer to equations 6.1 - 6.14 as the BOTE (back-of-the-envelope) model.

To begin, consider equations 6.1 - 6.9 that describe the general set of variables within any given year of a dynamic simulation, as distinct from equations 6.10 - 6.12 that are introduced to discuss and implement the results in [Blomberg et al. (2004)]. Equation 6.13 describes how a key stock variable, capital, moves through time. This equation holds between any two adjoining years of a dynamic simulation. Finally, equation 6.14 describes the lagged adjustment of real wages in the counterfactual simulation. Herein, this equation is relevant to the process of wage adjustment in the Blomberg and Structural simulations only.

Equation 6.1 describes the GDP identity in real terms. Equation 6.2 describes a CRS production function, relating real GDP to inputs of labour, capital and primary factor-augmenting technical change. Equation 6.3 relates real private consumption spending to real GDP and a function of the terms of trade.[6] Equation 6.4 makes investment a positive function of the rate of return on physical capital relative to the required rate of return on physical capital. Equation 6.5 defines the gross capital growth rate. Since the production function is CRS, marginal product functions are homogeneous of degree zero and thus can be expressed as functions of the ratio of labour and capital inputs. This accounts for equations 6.6 and 6.7. Equation 6.6 is the first-order-condition for the profit maximizing use of labour.[7] Equation 6.7 is the first-order-condition for the profit maximizing use of capital.[8] Equation 6.8 summarizes the determination of import volumes. In USAGE 2.0,

---

[6] The origin of equation 6.3 is $P_C \times C = APC \times Y \times P_0$, where P_0 and P_C are the GDP and consumption deflators respectively, and all other variables are as described in Table 2. Noting that that P_o/P_C is a positive function of the terms of trade, $g(TOT)$, we have equation 6.3.

[7] Via equation 6.2, and noting that $f(L,K)$ is homogenous of degree 1, the marginal product of labour is $f_L(K/L) / A$. The profit maximising use of labour requires: $P_0 \times f_L(K/L)/A = W \times P_C$, where P_0 and P_C are the price of output and consumption respectively, and all other variables are as defined in Table 2. Noting that P_o/P_C is an increasing function of the terms of trade, $g(TOT)$, we have equation 6.6.

[8] Via equation 6.2, and noting that $f(L,K)$ is homogenous of degree 1, the marginal product of capital is $f_K(L/K) / A$. The profit maximising use of capital requires: $P_0 \times f_K(L/K)/A = ROR \times P_I$, where P_0 and P_I are the price of output and investment respectively, and all other variables are as defined in Table 2. Noting that P_o/P_I is an increasing function of the terms of trade, $h(TOT)$, we have equation 6.7.

demands for commodity-specific imports by each agent are related to each agent's activity level (proxied in equation 6.8 by Y) and the ratio of the domestic to import price for each commodity (proxied in equation 6.8 by the terms of trade, TOT). Commodity exports in USAGE 2.0 are inversely related to foreign currency prices via commodity-specific constant elasticity of demand (CED) functions. This is summarized by equation 6.9, which relates the terms of trade (the ratio of export prices to import prices) to the volume of exports (X , movements along foreign demand schedules for U.S. exports) and a shift variable (V , movements in foreign demand schedules for U.S. exports). Equations 6.10 - 6.12 define key variables considered in [Blomberg et al. (2004)], which shall form the focus of our shocks under the Blomberg Simulation in section 3. Under a standard closure in the baseline simulation, these are endogenous variables.

While 6.1 **-** 6.9 describe the determination of key variables within any given year of a year-on-year simulation, equation 6.13 summarises how a key stock variable (capital) adjusts from one year to the next. Equation 6.14governs the path of real consumer wages in the Blomberg and Structural simulations. With equation 6.14 activated in these simulations, the deviation in the real consumer wage grows (declines) so long as employment remains above (below) its base-case level.

We now consider an appropriate closure for the equations in Table 2. In doing so, we must distinguish between equations that describe economic relationships within any given year (6.1 - 6.9 and 6.10 - 6.12), equations that describe movements in stock variables between years (6.13), and the equation describing sticky wage adjustment (6.14). Within any given year, K can be considered exogenous (we refer the reader to Table 1 for the definition of all variables). The movement in this variable between years depends on investment within years. As discussed, this accumulation relationship is described by equation 6.13. Equation 6.14 governs the transition of the Blomberg and Structural simulation labour market closure from a short-run to a long-run environment. When operational in each year of the respective counterfactual simulations, equation 6.14 gradually moves the labour market from a short-run situation of exogenous real wage (W) and endogenous employment (L), to a long-run situation of exogenous employment (L) and endogenous real wage (W). Recognizing that equations 6.13 and 6.14 govern dynamics across years, our task of characterising the BOTE model closure therefore narrows to choosing appropriate short-run and long-run closures for equations 6.1 **-** 6.12.

Equations 6.1 **-** 6.12 comprise **12** equations in **19** unknowns. In Table 2, model closure is described by rendering exogenous variables in **bold**. Two closures are presented: a short-run closure and an 'effective' long-run closure. By 'effective' long-run closure, we mean that while ROR, K and L are presented as long-run exogenous, no such exogeneity is actually imposed on these variables in USAGE 2.0 simulations. Rather, in year-on-year dynamic simulations, equations 6.4, 6.13 and 6.14 lead the economy to a long-run position that can be satisfactorily described by exogenous status of ROR, K and L.

A conventional short-run closure of equations 6.1 **-** 6.12 would have X , Y , C , I , Ψ ,

L, ROR, M, TOT, IYR, GYR and BYR determined endogenously, given exogenous values for A, K, G, APC, Λ, W and V. Under this closure, each equation can be readily associated with the determination of a specific endogenous variable. With relatively high export demand and import supply elasticity's, there is little scope for significant movements in TOT. Hence, with W, K, and A exogenous, equation 6.6 can be identified with the determination of L. Hence, with K and A exogenous, equation 6.2 determines Y. With Y thus determined, and APC exogenous, equation 6.3 determines real private consumption. Again, leaving aside for the moment the possibility of movements in TOT, with Y determined by equation 6.2, equation 6.8 determines M. With L determined by equation 6.6, and K and A exogenous, equation 6.7 determines ROR. This determines I via equation 6.4. With I thus determined, equation 6.5 determines Ψ. With Y, C, I, G and M explained, equation 6.1 determines X. With X determined and V exogenous, TOT is given by equation 6.9. With all of X, M, I, and Y determined, and G exogenous, equations 6.10 - 6.12 determine IYR, GYR, and BYR respectively.

Our description of the USAGE 2.0 long-run behaviour differs in two respects from the short-run closure described above. First, equation 6.14 ensures that the counterfactual simulation level of employment is eventually returned to its base-case level via real wage adjustment. This is represented by long-run exogeneity of L and endogeneity of W in the second column of Table 2. Second, the short-run operation of equations 6.4 and 6.13 gradually drive rates of return towards base-case via capital adjustment. The end-point of this process can be represented by long-run exogeneity of ROR and endogeneity of K. With ROR exogenous in the long-run, equation 6.7 largely determines K. With L also exogenous in the long-run, equation 6.6 largely determines W.

2.2.3 Paths for shocked variables

As with all CGE models, an initial solution of the model is required, which is derived from a variety of data sources including input-output tables; USAGE 2.0 is based on data sourced at the end of 2010. In this article, we assume the initial solution period (2011) proceeds under a business-as-usual closure, i.e., no terrorist event occurs in the U.S. in 2011. We then investigate the impact of a single terrorism event occurring in 2012; from equations 2.1 - 2.4 and Table 1 this yields:

$$T_2 = 1, \quad \textbf{2.6}$$

where the subscript "2" denotes that the terrorism event occurs in the second period (2012) of the Blomberg simulation, relative to the baseline where no terrorism event occurs in any simulation period. As discussed, period 1 of the Blomberg simulation is therefore equivalent to period 1 of the baseline. For simplicity, we regard the population at the end of period 1 of each simulation to be the population of the United States as at

2014; this was sourced via the IMF and stood at 318.5 million.[10] The required shock in equations 2.1 - 2.4 is therefore:

$$\frac{T_2}{P_2} = 0.00314.$$

2.7

The econometric equations derived by [Blomberg et al. (2004)] describe the impact of the variable reported in equation 2.7 on the levels of IYR and GYR, together with the growth rate of real GDP (ΔY_t). These equations can be re-written to describe relationships between the cumulative differences arising in the relative time-paths of the Blomberg and Baseline simulations; for brevity, we omit the mathematical detail regarding this transformation and instead describe the process in what follows. To begin, consider two sets of equations 2.1 - 2.4; one set specifies the Blomberg simulation levels and growth rate of real GDP, while the second set specifies the corresponding quantities for the baseline levels and associated GDP growth rate. Taking the difference between the two sets of equations, and considering equation 2.6, we arrive at the equations 2.8 and 2.9 that describe the cumulative percentage deviation of the investment and public consumption to GDP ratios in period t, i.e., $\Delta IYR_{t,\text{Blom-Base}}$ and $\Delta GYR_{t,\text{Blom-Base}}$, in the Blomberg simulation relative to the baseline. Equation 2.10 is the corresponding result for the growth rate in real GDP.

$$\Delta IYR_{t,\text{Blom-Base}} = \frac{1}{IYR_0}\left(3.307^{***}\ln\left(1+\frac{\Delta BYR_{t-1,\text{Blom-Base}}}{100}\right)+0.496\ln\left(1+\frac{\Delta Y_{t-1,\text{Blom-Base}}}{100}\right)\right.$$
$$\left.-0.389^{**}\frac{T_t}{P_t}\right),$$

2.8

$$\Delta GYR_{t,\text{Blom-Base}} = \frac{1}{GYR_0}\left(3.043^{***}\ln\left(1+\frac{\Delta BYR_{t-1,\text{Blom-Base}}}{100}\right)-2.117^{***}\ln\left(1+\frac{\Delta Y_{t-1,\text{Blom-Base}}}{100}\right)\right.$$
$$\left.+0.412^{*}\frac{T_t}{P_t}\right),$$

2.9

---

[10] See http://www.economywatch.com/economic-statistics/economic- indicators/Population/

$$\Delta Y_{t,\text{Blom}-\text{Base}} = \left(0.184 \ln\left(1 + \frac{\Delta BYR_{t-1,\text{Blom}-\text{Base}}}{100}\right) - 7.959^{***} \ln\left(1 + \frac{\Delta Y_{t-1,\text{Blom}-\text{Base}}}{100}\right) \right.$$
$$\left. +0.341^{***}\left(\Delta IYR_{t-1,\text{Blom}-\text{Base}}\right) - 0.513^{***}\frac{T_t}{P_t}\right),$$

2.10

In equations 2.8 - 2.10, IYR_0 represents the base period (or initial) investment-to-GDP ratio in percentage form; this is equivalent for both the baseline and Blomberg simulations, and a similar interpretation is implied by GYR_0. We therefore define

$$\Delta IYR_{t,\text{Blom}-\text{Base}} = \frac{IYR_{t,\text{Blom}} - IYR_{t,\text{Base}}}{IYR_0}, \qquad \textbf{2.11}$$

$$\Delta GYR_{t,\text{Blom}-\text{Base}} = \frac{GYR_{t,\text{Blom}} - GYR_{t,\text{Base}}}{GYR_0}, \qquad \textbf{2.12}$$

where as before, “Blom” denotes the Blomberg Simulation and “Base” denotes the Baseline Simulation. In the above equations, we also assume the impact of a single terrorism event on the relative populations between the two simulations is negligible, i.e., fewer than 1 000 fatalities. This assumption is consistent with the findings of [Sandler and Enders (2004)], who find that terrorism incidents in general result in few deaths (albeit for outlier events, such as the 9/11 World Trade Centre bombings). In addition, a study of the ITERATE terrorism database by [Anderton and Carter (2011)] showed an average of 2.6 casualties (fatalities plus injuries) were caused by each terrorist event within ITERATE, over the period 1968 to 2000; this justified the assumption regarding fatalities made herein.

As previously discussed, [Blomberg and Hess (2006)] derived an equation for the time-path of the variable BYR_t in response to shocks in the variable TV_t; see Table 1 and equation 2.5. However, as we previously discussed, the terrorism explanatory variable TV_t is not defined on a like-for-like basis with the corresponding variable appearing in equations 2.8 - 2.10, i.e., $TV_t \neq T_t$. In order to close the system of equations 2.8 - 2.10, we model $\Delta BYR_{t,\text{Blom-Base}}$ endogenously using USAGE 2.0 across all periods t under the Blomberg simulation; see section 2.2.2 for a discussion of the macroeconomic mechanisms driving this variable in USAGE 2.0. Under this assumption, we omit all terms involving $\Delta BYR_{t,\text{Blom-Base}}$ from equations 2.8 - 2.10; this yields a suitable closed system of equations to derive exogenous shocks for $\Delta IYR_{t,\text{Blom-Base}}$, $\Delta GYR_{t,\text{Blom-Base}}$ and $\Delta Y_{t,\text{Blom-Base}}$ over the full simulation time period.

2.2.4 Simulations

Using the methodology outlined in section 2.2.3, paths are derived for $\Delta IYR_{t,\text{Blom-Base}}$, $\Delta GYR_{t,\text{Blom-Base}}$ and $\Delta Y_{t,\text{Blom-Base}}$ over a 6 year time period in response to a terrorist shock delivered in 2012 of the simulation, through to 2016. These are summarized in Table 3, with plots of the shocks given in Figure 1.

Next, we apply the BOTE model to describe the required closure modifications to model the impact of terrorism.

2.2.4.1 Shock to investment relative to GDP

[Slovic (1987)] postulated that certain events drive economic disruption beyond their direct impacts, through a signalling mechanism of heightened uncertainty that increases perceived future risk. This concept was later considered formally in the context of a terrorist attack by [Burns and Slovic (2007)]; in this article, we utilize this as a premise for modelling of the impact shocks to IYR on the US economy. This is achieved via endogenisation of the shift variable in the required rate of return Λ, and exogenisation of the ratio IYR (see Table 2). Thus, in the short-run, shocks to IYR are accommodated through endogenous determination of the required rate of return on investment, i.e. through a short-term increase in the degree of risk aversion of investors in response to the terrorist event. The choice of this variable to accommodate exogenous determination of IYR is consistent with the approach adopted in ex-ante studies of hypothetical terrorist attacks, such as[Giesecke et al. (2012)] and [Giesecke et al. (2015)], in which the required rate of return is shocked directly to reflect terrorism-induced changes in investor risk perception.

2.2.4.2 Shock to public consumption relative to GDP

In both the short- and long-run, we endogenise public consumption (G) and exogenise GYR. Government expenditure is therefore permitted to adjust in order to yield the required path for real public consumption relative to real GDP, i.e., an increase in GYR (all else being equal), would therefore be modelled via an increase in G within the Blomberg simulation relative to the baseline (see Table 3).

2.2.4.3 Shocks to Real GDP

In line with previous work by [Pan et al. (2009)] and [Giesecke et al. (2012)], the impact of shocks to real GDP are delivered via endogenisation of total primary-factor augmenting technology A in both the short- and long-run, and exogenisation of real GDP growth. This represents the impact of business interruption driven by terrorism, which reduces the overall efficiency of the U.S. economy in using primary-factor inputs to generate real output.

3 Results

In this section, we present a discussion of the effect of a single U.S.-based terrorism event (in terms of [Blomberg et al. (2004)] with $T_2 = 1$) on selected macroeconomic and industry variables. The section is structured as follows. In section 3.1, we discuss the relaxation paths recovered from the Blomberg simulation in response to the shocks summarised in Table 3. Our explanation of the macroeconomic modelling results is presented in section 3.2. This focuses on a series of decomposition figures, detailing the contribution to the overall macro movements resulting from each of the three individual shocks, i.e., changes in the required return on capital Λ, changes in total primary-factor augmenting productivity A, and shifts in public consumption G. The decomposition figures are created by running the CGE model five times: one full (Blomberg) simulation in which all three sets of shocks from Table 3 are implemented simultaneously; a second (Structural) simulation in which the structural responses described in section 3.1 and summarised in Table 4 are passed as exogenous shocks into the model (see section 2.2.1 for a full description of this process); and a further three simulations in which each of the three sets of shocks are implemented individually, i.e., one simulation for each of columns (1) – (3) in Table 4. We explicitly focus on the percentage deviations in the Structural simulation from the baseline simulation results; the Blomberg results are also included for the reader's reference, and as expected are in line with the Structural simulation results. We conclude with an analysis of the industry-level impacts in section 3.3 and a comparison of our results with previous work in section 3.4.

3.1 Shocks and Responses

The exogenous shocks and subsequent structural responses are graphically illustrated in Figure 1 and Figure 2, and given numerically in Table 3 and Table 4. By choice of convention, a positive value for Λ describes an increase in the required rate of return on capital. We observe such an outcome in 2012 in Figure 2 in response to the terrorist event in that year. This implies that, when considered jointly with the effects in 2012 (see Table 4) of the rise in G (which will tend to raise IYR relative to baseline) and A (which will tend to lower IYR relative to baseline) we require a rise in the required return on capital to explain the observed outcome for IYR. This is consistent with heightened perceptions of risk and uncertainty on the part of investors, and a compensating increase in required rates of return on new units of capital.

Again, by choice of convention, a positive outcome for primary-factor augmenting technical change corresponds to diminished productivity. We observe such an outcome in the Blomberg simulation relative to the baseline (see Table 4). That is, the decline in real GDP observed in the Blomberg results is too high to be explained by the CGE model by the joint effects alone of the rise in G and Λ. A positive deviation in A in the event-year is consistent with short-term inefficiencies in the form of business interruption.

The sign convention for G is as expected, i.e., a positive value for G implies higher public consumption in the Blomberg simulation relative to the baseline. This is consistent with a rise in public spending on medical care and security in the event-year, and a proclivity for fiscal stimulus in an environment of weakened economic activity following a terrorist event. Indeed, as we shall see in section 3.2.1, an interesting feature of the Blomberg and Structural Simulation results is that they show the employment-generating effects of the increase in event-year public spending exactly offset the employment-damping effects of the rise in the required rates of return and decrease in productivity.

Importantly, the described behavior exhibited by Λ follows the pattern discussed by [Burns and Slovic (2007)]; we observe a sharp rise in risk aversion by investors via an increase in Λ in response to the terrorist attack in 2012. This corrects in the following year; as we shall discuss, this is driven by the lack of investment in 2012 causing a fall in the economy-wide capital stock and a rise in aggregate rental prices of capital. Interestingly, the level of public consumption remains slightly elevated relative to the baseline in the long-run, while primary-factor augmenting technical change also remains positively impacted by the terrorist event in the long-run. We discuss these paths and their implications for the US macroeconomy in Section 3.2. While the observed variables in Figure 1 return quickly to baseline following the event-year, the structural variables in Figure 2 take longer to return to baseline. As we shall discuss, this follows from the need to reconcile Blomberg's results for rapid return of Y, IYR and GYR to baseline from 2013 onwards, with the legacy effects in the CGE model results for important stock and lagged variables from 2013 onwards.

3.2 Macroeconomic deviations

To outline the interaction of the imposed shocks on the US macroeconomy, we begin with a discussion of the relative impact of each shock on employment, capital and real GDP in section 3.2.1. This leads to a discussion of rates of return and investment in section 3.2.2, and the balance of trade in section 3.2.3. We also discuss terms of trade and real exchange rate impacts in section 3.2.4, before concluding with some remarks on long-run trend behaviour in section 3.2.5.

3.2.1 Employment, capital and real GDP in the event-year

We begin our discussion with the employment outcomes reported in Figure 3. A striking feature of Figure 3 is the absence of a change in employment in the event-year. The decomposition simulation shows that this outcome is the net effect of the employment damping effects of the positive deviations in A and Λ, and the employment expanding effect of the positive deviation in G. As discussed in section 2.2.1, an important feature of the USAGE 2.0 model in this simulation is short-run wage stickiness. Via BOTE equation 6.6, with the real wage sticky in the event-year the deterioration in primary factor productivity causes employment to fall. In Figure 2 and Table 4 we see this expressed as a negative contribution by primary factor technical change to event-year employment. However it is clear from Figure 3 that the rise in required rates of return makes the largest (negative) contribution to event-year employment. As we shall discuss in reference to Figure 5, the rise in required rates of return causes a negative deviation in the terms of trade in the event-year. With the real wage sticky in the event-year, the negative deviation in the terms of trade generates a positive deviation in the real producer wage, causing employment to fall relative to baseline via equation 6.6.

Despite the negative impacts on event-year employment of the rise in A and Λ, event-year employment is unchanged from baseline. This is due to the employment-expanding effects of the rise in G. The increase in public consumption in the event-year has a positive impact on employment for two reasons. First, public consumption is highly labour intensive. Second, as we shall discuss later in reference to Figure 5, it generates a positive deviation in the terms of trade. Via equation 6.6, with the real wage sticky and the capital stock unchanged in the event-year, the positive deviation in the terms of trade generates a positive deviation in employment. It is important to note that the magnitude of the job creation driven by the rise in public consumption is not imposed upon the system; rather, it is a realisation of the path outlined for GYR by [Blomberg et al. (2004)]. As we discuss in section 3.4, this has potential implications for future modelling of the economic consequences of terrorism events.

Figure 8 reports the outcome for the aggregate capital stock, calculated as the (rental weighted) sum of the percentage deviations in industry-specific capital. As discussed in section 2.2.2, and described in BOTE by equation 6.13, industry-specific capital stocks in USAGE 2.0 adjust in year $t+1$ to movements in year t net investment. As such, there is no scope for industry-specific capital stocks to adjust in the event-year. Hence, in Figure 8, we see no change in the aggregate capital stock in the event-year.

Having explained the event-year outcomes for aggregate factor supply, we now turn to the outcome for real GDP (Figure 4). In understanding the proximate causes of deviations in real GDP, it is clear from BOTE equation 6.2 that we must couch our explanation in terms of movements in factor supply (K and L) and the efficiency of factor usage (A). To begin, we consider movements driven by factor supply impacts. With the capital stock (K) unable to respond in the event-year (see Figure 8), there is no scope for any one of the three structural shifts to influence event-year GDP via the route of capital supply. However event-year employment is influenced by the three structural shocks (see Figure 2 and Figure 3), and this does influence event-year real GDP via the route of labor supply (L) and equation 6.2. As explained in reference to Figure 3, the rise in required rates of return generates a negative deviation in event-year employment. Via equation 6.2 this generates a negative deviation in real GDP in the event-year. In Figure 4 we see that this contributes approximately -0.0007 percentage points to the negative deviation in real GDP in the event-year. Again, as explained in reference to Figure 3, the positive deviation in event-year public consumption generates a positive deviation in event-year employment. This contributes approximately +0.0007 percentage points to the deviation in event-year real GDP. These deviations therefore counter one another, and do not drive a material change in real GDP in the event-year.

The largest contributor to the negative deviation in real GDP in the event-year is the negative deviation in primary-factor productivity (A). This affects real GDP via two routes. First, as is clear from equation 6.2, productivity directly affects the capacity of a given level of primary factor inputs to generate GDP. As such, the deterioration in productivity in the event-year makes a direct contribution to the negative deviation in real GDP in the event-year. Second, the deterioration in productivity makes an indirect contribution to the real GDP deviation via equation 6.6. As explained in reference to Figure 3, the negative deviation in productivity generates a negative deviation in employment via equation 6.6. This negative deviation in employment then causes lower real GDP via 6.2. Via these direct and indirect routes, the negative deviation in productivity makes a relatively large contribution to the deviation in event-year real GDP, contributing approximately -0.0016 percentage points to the net outcome (Figure 4).

3.2.2 Rates of return and investment in the event-year

Figure 7 describes the deviation path for real investment, and its decomposition into the individual contributions made by the three structural shocks. To explain Figure 7, we begin with BOTE equation 6.4 which makes clear that that we can understand short-run movements in real investment in terms of outcomes for the ratio of realised rates of return to required rates of return (ROR and Λ).

As discussed in reference to Figure 2, the Blomberg simulation generates a large positive deviation in Λ in the event-year. When applied as part of the set of shocks in the Structural simulation, the rise in Λ explains the bulk of the event-year decline in real investment (Figure 7). This is also clear from equation 6.4, where a positive deviation in Λ drives a direct impact on real investment. However, via its effect on ROR, it also has an indirect impact on real investment, as do the rise in public consumption spending (G) and the deterioration in productivity (A).

To understand the effects of Λ, G and A on ROR, and thus their indirect influence on real investment, we turn to equation 6.7. As is clear from equation 6.7, we can explain the impact of Λ, G and A on ROR (and thus I) both in terms of direct channels (in the case of A, it appears directly in equation 6.7) and in terms of indirect channels (in the cases of Λ and G , which do not appear in 6.7, but nevertheless exert an influence via their impacts on event-year employment [L] and the terms of trade [TOT]).

We begin with the effect of the negative deviation in event-year productivity. This has a direct effect on rates of return on physical capital, because it lowers the marginal product of capital for any level of the terms of trade, employment, and the capital stock. In terms of equation 6.7, a rise in A, for any given level of TOT and K , requires ROR to fall in the short-run. However the rise in A also has an indirect effect on ROR via its impact on L and TOT . First, as discussed in section 3.2.1 in reference to Figure 3, the decline in productivity makes a negative contribution to the deviation in employment in the event-year. Via equation 6.7, this reinforces the direct impact of the movement in A on ROR, by increasing the capital-to-labour ratio K/L, and thus lowering the capital rental rate. Second, as is clear from Figure 5, and as will be discussed in section 3.2.4, the deterioration in event-year productivity makes a positive contribution to the event-year deviation in the terms of trade. Via equation 6.7, this makes a positive contribution to the deviation in the rate of return in the event-year, because it raises output prices more than capital construction costs. This offsets somewhat the aforementioned channels via which the decline in productivity damps the rate of return in the event-year. Nevertheless, as is clear from Figure 6, the net effect on rates of return of the deviation in event-year productivity is negative. As such, the movement in productivity makes a negative contribution to the real investment deviation in the event-year (Figure 7).

Turning to public consumption spending, this exerts indirect effects on short-run rates of return, and thus investment, via its impacts on employment and the terms of trade. As discussed in section 3.2.1 in reference to Figure 3, the rise in public consumption in the event-year increases employment relative to baseline. *Ceteris paribus*, this raises the marginal product of capital, increasing rates of return for any given level of the capital stock: in terms of 6.7 with K and A given, a rise in L requires ROR to increase for any given level of TOT. This effect is reinforced by the movement in the terms of trade induced by the rise in public consumption spending. As is clear from Figure 5 (to be discussed in section 3.2.4), the positive deviation in public consumption spending makes a positive contribution to the terms of trade deviation. This raises the value of the marginal product of capital by more than capital construction costs, generating a rise in the rate of return on capital: in terms of 6.7, with K and A given, a rise in TOT requires ROR to increase for any given level of L. With both the employment and terms of trade channels driving positive contributions to the rate of return movement attributable to the rise in *G*, in Figure 6 we see a relatively large event-year contribution made by public consumption to the deviation in the average gross rate of return on physical capital. Via BOTE equation 6.4, this explains the positive contribution to the real investment deviation in the event-year made by the rise in public consumption spending (Figure 7).

Finally, we return to the role of required rates of return in influencing real investment in the event-year. As already discussed, this has a direct impact on investment via equation 6.4. But it also exerts indirect effects via its impacts on employment and the terms of trade. However, in both cases these reinforce the direct effects of the rise in required rates of return. From Figure 3 and Figure 5, we note that the rise in required rates of return in the event-year drive negative contributions to both employment and the terms of trade. Via 6.7, it is clear that a decline in L and TOT, for any given level of K and A, requires ROR to fall. Via equation 6.4, the decline in ROR induced by the rise in Λ reinforces the direct effect of the rise in Λ on I. Returning to Figure 7, we see that the bulk of the event-year decline in investment is attributable to the positive deviation in required rates of return.

3.2.3 Real GNE and the balance of trade

We turn now to the effects of the structural shocks on real GNE, and by extension, the balance of trade. This will prove important in understanding outcomes for the terms of trade, the real exchange rate, and prospects for traded goods sectors. In understanding the role of movements in real GNE in determining movements in the balance of trade, we rely chiefly on equation 6.1. With employment largely determined by 6.6, real GDP in the short-run must be determined by 6.2. This allows us to rely on equation 6.1 to explain movements in the real balance of trade by focusing on movements in the components of real GNE (C, I and G) relative to real GDP (Y).

Figure 2, Figure 7 and Figure 9 describe the movements in the three components of real GNE: (i) public consumption (G), (ii) investment (I) and (iii) private consumption (C). We have dealt with investment in our discussion in section 3.2.2, while the outcomes for public consumption are imposed exogenously; see our discussion in section 3.1. Of the components of real GNE, this leaves only the private consumption outcome to be investigated. Equation 6.3 makes clear that we must explain the outcome for consumption in terms of the contributions made by movements in GDP and the terms of trade.

We begin with GDP, noting that in comparing the outcomes for real GDP (Figure 4) and real private consumption (Figure 9), we observe a high correlation between the two. As discussed in 3.2.1, the productivity deterioration drives the majority of the deterioration in real GDP; the stimulatory effect of increased public consumption in the event-year is offset by the downturn driven by increased required rates of return. *Ceteris paribus*, the fall in real GDP reduces national income and consequently reduces private consumption spending, via equation 6.3.

Considering Figure 9 once more, the rationale for the observed (i) positive deviation in private consumption driven by increased public consumption, and (ii) negative impact on private consumption of increased required rates of return, can also be understood via equation 6.3. Equation 6.3 reminds us that real private consumption spending is affected by the terms trade, via the latter's influence on real (consumption price deflated) national income. For both public consumption and required rates of return, the influence of the terms of trade on private consumption is of the same sign as that for real GDP, and thus the two effects are reinforcing. This is not the case for the negative deviation in productivity. As we noted in section 3.2.2 and shall discuss in greater detail in section 3.2.4, the negative deviation in productivity generates a positive deviation in the terms of trade (Figure 5). While the contribution of the decline in productivity on private consumption remains negative in the event-year (Figure 9), the net impact (relative to that given by the GDP effect alone) is damped by the positive contribution made by the terms of trade.

The net outcome on GNE of the movements in C, I and G discussed above is a negative deviation relative to baseline. This generates a positive deviation in the balance of trade / GDP ratio in the event-year (Figure 10). This is due to the rise in required rates of return on capital, which, as discussed above, causes a negative deviation in real investment. Via 6.1, this in turn generates a positive deviation in the balance of trade. However, the net movement towards balance of trade surplus in the event-year is attenuated by the negative deviation in productivity and the positive deviation in public consumption spending. In terms of BOTE equations 6.1 and 6.2, the rise in A reduces Y relative to GNE, and the rise in G increases GNE relative to Y. The effect of both is to move $X - M$ towards surplus, which is apparent in the decomposition results for required rates of return and public consumption in Figure 10.

3.2.4 The terms of trade and the real exchange rate

In our discussion of the outcomes for employment, investment, and consumption, we have made frequent reference to the deviation in the terms of trade. As described by BOTE equation 6.9 and discussed in section 2.2.2, movements in the terms of trade are explicable in terms of movements in export volumes. In Figure 5, we see that the terms of trade increases relative to baseline in the event-year, the net outcome of a negative contribution made by the rise in required rates of return, and positive contributions made by the rise in government spending and the decline in productivity. We consider these factors in turn.

The positive deviation in required rates of return moves the balance of trade towards surplus in the event-year (see section 3.2.3). In Figure 11 and Figure 12, we see this expressed as a fall in import volumes and a rise in export volumes respectively. The rise in export volumes involves a movement down foreign export demand schedules, requiring export prices to fall in foreign currency terms and thus the terms of trade to decline relative to baseline; see BOTE equation 6.9. However, this is more than offset by the effects on the terms of trade of the increase in public consumption and deterioration in productivity.

As discussed in section 3.2.3, the balance of trade is moved towards deficit relative to baseline by both the positive deviation in public consumption, and the negative deviation in productivity. In Figure 11 and Figure 12, we see this expressed as contributions by these two factors to a positive deviation in import volumes and a negative deviation in export volumes. Via BOTE equation 6.9, the negative deviations in export volumes make positive contributions to the terms of trade deviation in the event-year. This more than offsets the negative contribution to the terms of trade made by the rise in required rates of return, leading to a net increase in the terms of trade (Figure 5).

In our description of BOTE in section 2.2.2, we noted that the variable TOT served the dual function of describing both the terms of trade and the real exchange rate, the latter being defined as:

$$\Phi = \frac{P_{GDP}}{P_M}, \qquad \textbf{3.1}$$

where P_{GDP} is the GDP deflator, and P_M is the import price deflator in domestic currency. The close correspondence between these two variables in the present USAGE 2.0 simulation is apparent by comparing the terms of trade results (Figure 5) with those for the real exchange rate (Figure 13). As discussed in section 3.2.3, the event-year shock to required rates of return moves the balance of trade towards surplus. This requires domestic prices to fall relative to foreign prices; that is, it requires real depreciation (Figure 13). However the net outcome for the real exchange rate in the event-year is real appreciation. As discussed in section 3.2.3, the event-year shocks to both public consumption and productivity move the balance of trade towards deficit, requiring appreciation of the real exchange rate (Figure 13). These exchange rate movements will be important in understanding outcomes for individual sectors, to which we turn in section 3.3.

3.2.5 Summary and long-run behavior

To summarize, we discussed the short-run behaviour of the macroeconomy in sections 3.2.1 - 3.2.4 in response to the three unique shocks to Λ, A and G. This was achieved with decomposition diagrams, which were used to describe the relative proportion of the total deviation in the structural simulation from the baseline driven by each respective shock, i.e., the proportion explained by independent movements in Λ, A and G. In this section, we briefly summarize the overall short-run behaviour, and provide a short discussion of the long-run impact of terrorism on the macroeconomy.

In the short-run, the negative deviations in private consumption and investment generated by the positive deviations in Λ and A are offset in part by a positive deviation in public consumption. Net exports fall, requiring appreciation of the real exchange rate and generating a terms of trade improvement relative to baseline. Overall, these effects culminate in a small decline in real GDP relative to baseline; critically, growth in employment driven by increased public consumption largely offsets falls caused by the reduction in investment and productivity. With capital stocks sticky, the rental price of capital falls to adjust for a lower value of the marginal product of capital relative to baseline.

In the long-run, Λ returns to its baseline value. Whilst employment returns to its baseline value also, aggregate capital stock remains sluggish in its recovery; however, with a lower base from which to cover depreciation costs and required rates of return in line with the baseline, the increasing trend in capital formation observed in Figure 8 is expected to drive capital stock back to base line in the longer-term. The lower level of capital however continues to depress the real wage and drives the rental price on capital higher, due to the diminished (higher) marginal product of labor (capital) respectively. Despite this diminished capital stock, real GDP is in line with the baseline due to improved overall productivity, while public consumption remains slightly in excess of its baseline levels. Importantly, both private consumption and household income are broadly in line with the baseline in the long-run; consequently, the impact from lower real wages on household income is offset largely by the marginally higher rate of return to capital.

3.3 Industry impacts

In this section, we consider briefly the short- and long-run impact of terrorism at the industry level. The USAGE 2.0 model applied herein spans 74 industries. In lieu of a discussion of the impact across all industries, we restrict our analysis to a discussion of the industries that experience the greatest increase in output, and those that experience the largest falls in output, as a result of the terrorist event; this is presented across both the short- and long-run.

With regards to the short-run, consider Figure 14 where we plot the deviation in output growth of six industries in the structural simulation relative to the baseline. As discussed in Section 3.2, we noted the following significant short-run impacts of terrorism:

(i) Increased public consumption, which positively impacts industries where public consumption represents a large proportion of sales;

(ii) A reduction in private consumption and investment. Hence, those industries with large proportions of sales to private consumers or investors are expected to be negatively impacted.

As expected, in the event-year the industries that experience positive output deviations in response to the terrorism event are National Defense, Education and Non-Defense spending; these industries are exclusive public service industries. In contrast, output of the Construction industry falls markedly in response to the terrorism event; this industry has a high proportion of total sales (80%) to investors as a final demand category, and is therefore heavily exposed to the rise in required rates of return. Wood products and non-metal mining products are also key intermediate inputs to Construction; 80% of each sector's respective total domestic output is purchased for use as an intermediate input, and of this, 40% flows to the Construction sector. These two sectors therefore suffer the flow-on consequences from the downturn in investment spending.

In the long-run (see section 3.2.5), the lingering effects of the terrorist event are the lower real wage relative to the baseline, along with lower capital stocks and higher rental prices for capital. As such, we expect industries requiring significant use of capital as a factor input to production, particularly where imports of the commodity are a suitable alternative, to experience a fall in domestic output. This explains the fall in output observed for Oil and Gas extraction in Figure 15, which is capital intensive in domestic production (50% of total costs of production are capital costs); imports also comprise a significant share of local commodity supply. This proportion increases from 58.8% prior to the terrorist event, to 60.2% in 2016. Mining services experiences the sharpest fall in output however; with 63% of sales to investment activity, this industry is impacted initially by the sharp rise in required rates of return. While investment recovers in the long-run, the remainder of total sales of Mining services is as an intermediate input to production, with flows of services to the Oil and Gas Extraction industry comprising 38% of total intermediate flows. This therefore depresses total output of this industry over the long-run also, relative to the baseline.

With regards to the Foreign Vacation sector (which represents foreign holidays of US citizens), the short-run output of this industry benefits from the appreciation in the US$, i.e., as the US$ depreciates (appreciates), output of this sector will fall (rise) relative to the baseline. As the long-run exchange rate depreciates, the output of this sector trends slightly below that of the baseline, as expected. Sectors that experience the strongest rise in output relative to the baseline over the long-run are Other State and Local Government services, Ambulance and Health Care services, and Vacations. We note that these relative increases are small, and represent an increase in output of less than 0.1% in cumulative terms over the 5 year period from 2012 to 2016 relative to the baseline. With regards to Vacation (which represents vacations of US residents in the US), the behavior of this sector once again reflects movements in exchange rates, i.e., as the US$ depreciates (appreciates), output of this sector will rise (fall) relative to the baseline. This is a direct consequence of substitutability of domestic consumers between foreign and domestic vacations, in response to movements in the exchange rate. The remaining two sectors utilize a significant proportion of labor in production, or alternatively have labor-intensive goods as inputs, e.g., Administration services. As such, they each derive benefit from the lower real wage in the long-run.

3.4 Comparison with previous work

As discussed in section 1, an important application of CGE models is the ex-ante analysis of hypothetical terrorism events. These studies can be of value to policy makers in planning for diverse threat scenarios. For example, [Giesecke et al. (2012)] and [Giesecke et al. (2015)] used a CGE approach to study scenarios relating to attacks on downtown Los Angeles using radiological dispersal device and chlorine. In these studies, values for shocks to such variables as required rates of return, business interruption, and public consumption spending had to be assembled from independent sources before input to the model. This paper presents an opportunity to assess some of the assumptions adopted in these papers against the movements in CGE structural variables implicit in the Blomberg econometric results. In so doing, we must be cognizant of the fact that the Blomberg results are based upon the ITERATE database of broad-ranging, global terrorism events; whereas [Giesecke et al. (2012)] and [Giesecke et al. (2015)] relate to specific terrorism events in a specific locale. Nevertheless, Table 5 attempts a comparison of the studies, by scaling relevant region-specific shock inputs in [Giesecke et al. (2012)] and [Giesecke et al. (2015)] up to the U.S.-wide level. Beginning with the first column, we see that the shifts in required rates of return in [Giesecke et al. (2012)] and [Giesecke et al. (2015)] are about five times larger than those in Blomberg. Given that the two sets of studies come to the task of assessing the change in required rates of return from different directions, we find this result encouraging. More so, when we remember that the two ex-ante studies are high-casualty events (see column 4 of Table 5) , with both using means (radiological dispersion and chlorine) likely to generate high degrees of dread and uncertainty, they are expected to drive high levels of aversion behavior. Turning to column 2, we see that the extent of business interruption is similar for [Blomberg et al. (2004)] and [Giesecke et al. (2015)] ($200 m. and $149 m. respectively) but significantly larger for [Giesecke et al. (2012)] ($1,427). Again, this points to the specific nature of the latter study, which notes a long and extensive period of shutdown of affected areas as radiological contamination is removed from a wide area. Column 3 notes a large implicit shift in public consumption spending in Blomberg that is absent in the two comparison studies. This highlights an overlooked role of government in these studies in abating the macroeconomic impacts of terrorism in the event-year, particularly through efforts to support employment. This is evident in our discussion in section 3.2.1, where we highlight that the impact on employment of the fall in total factor productivity and rise in required rates of return on capital are offset entirely in the event-year by an increase in public consumption.

4 Concluding remarks

In this article, we analyzed the time-path of the economic impacts of a terrorist attack on the United States. This was achieved using econometric equations for the paths taken by three key macroeconomic variables: (1) Real GDP; (2) The ratio of real investment to real GDP; and (3) The ratio of real public consumption to real GDP. The paths predicted for these variables were imposed as exogenous shocks in our analysis. This elucidates point estimates for the time-paths taken in response to these macroeconomic shocks by three independent structural variables: (1) Expected rates of return on investment; (2) Government expenditure; and (3) Total primary- factor augmenting technical change. Previous analyses of terrorism events have utilized inference or indirect estimates for these structural variables, e.g., through the use of investor surveys.

As the structural variables are independent, the broader impacts of these shocks were then analyzed using a decomposition analysis; this provided an attribution of the overall impact of terrorism, in terms of the proportionate impact of each of the three responses. Interestingly, it was shown that the econometric path for government expenditure (which represents the average response of governments historically to terrorist events) leads to sufficient job creation in the short-run to offset the fall in employment driven by shocks to productivity and shifts in the expected rate of return schedule. In the long-run, capital stocks and the real wage were depressed relative to the baseline, where no terrorist events occurred, while the rental rate of capital remained elevated.

This drove several short- and long-run industry impacts; in particular, sectors with a high proportion of total sales to Government experienced a boost in short-run outputs, while the Construction industry and others who served as key domestic intermediaries to Construction suffered. Long-run beneficiaries included labor-intensive industries, or industries with labor-intensive intermediate inputs, while capital-intensive industries (and those with a high proportion of sales as intermediate inputs to these industries) were also negatively impacted. Overall deviations from the baseline were found to be small, registering less than ±0.3% on a cumulative basis over the five-year period from 2012 to 2016.

How should future researchers undertaking ex-ante CGE studies of hypothetical terrorist events use the findings in this paper? First, it appears that a comprehensive ex-ante assessment of the economy-wide consequences of a terrorist event should take account of the possibility that government consumption spending will adjust in response to the event. In this paper, we found that the public consumption response is sufficient to neutralize the adverse employment effects generated by the movements in rates of return and productivity. This might be an appropriate way of benchmarking the size of the fiscal stimulus in future ex-ante studies. Second, the magnitude and pattern of the movements in required rates of return and productivity implicit in the Blomberg study conform to those assumed in previous ex ante studies. This should provide some comfort to researchers undertaking ex-ante studies as they assemble the inputs necessary to drive shocks to exogenous variables describing resource loss and behavioral effects. Finally, the Blomberg results suggest some scope for post-event recovery of lost production, as evidenced by the positive deviation in post-event primary factor productivity, suggesting it might be appropriate to give some consideration to this effect in future ex-ante studies.

5 References

[Anderton and Carter (2011)] Anderton, C. H. and J. R. Carter (2011). Conflict Datasets: a Primer for Academics, Policymakers, and Practitioners. *Defence and Peace Economics 22*(1), 21–42.

[Barrett and Adams (2011)] Barrett, A. M. and P. J. Adams (2011). Chlorine truck attack consequences and mitigation. *Risk Analysis 31*(8), 1243–1259.

[Blomberg and Hess (2006)] Blomberg, S. B. and G. D. Hess (2006). How Much Does Violence Tax Trade? *Review of Economics and Statistics 88*(4), 599–612.

[Blomberg et al. (2004)] Blomberg, S. B., G. D. Hess, and A. Orphanides (2004). The macroeconomic consequences of terrorism. *Journal of Monetary Economics 51*(5), 1007–1032.

[Burns et al. (2012)] Burns, W. J., E. Peters, and P. Slovic (2012). Risk Perception and the Economic Crisis: A Longitudinal Study of the Trajectory of Perceived Risk. *Risk Analysis 32*(4), 659–677.

[Burns et al. (2011)] Burns, W. J., C. Reilly, and P. Slovic (2011). The attack on Flight 253, the Haiti earthquake, and the Japanese disaster: a longitudinal look at emotional reactions, risk-related behaviors, and support for policy measures. *The CIP Report 10*(6), 22–24.

[Burns and Slovic (2007)] Burns, W. J. and P. Slovic (2007). The Diffusion of Fear: Modeling Community Response to a Terrorist Strike. *The Journal of Defense Modeling and Simulation: Applications, Methodology, Technology 4*(4), 298–317.

[Davis (2004)] Davis, L. W. (2004). The effect of health risk on housing values: Evidence from a cancer cluster. *American Economic Review 94*(5), 1693–1704.

[DHS (2005)] DHS, U. D. o. H. S. (2005). National Planning Scenarios: Executive Summaries. Technical report.

[Dixon and Rimmer (2002)] Dixon, P. B. and M. Rimmer (2002). *Dynamic general equilibrium modelling for forecasting and policy. A practical guide and documentation of Monash*. Elsevier.

[Dixon et al. (2011)] Dixon, P. B., J. A. Giesecke, M. T. Rimmer, and A. Rose (2011). The Economic Costs to the U.S. of Closing its Borders: A Computable General Equilibrium Analysis. *Defence and Peace Economics 22*(1), 85–97.

[Dixon and Rimmer (2004)] Dixon, P. B. and M. T. Rimmer (2004). The US economy from 1992 to 1998 : Results from a detailed CGE model. *Economic Record 80*(1), S13–S23.

[Dixon and Rimmer (2009)] Dixon, P. B. and M. T. Rimmer (2009). Restriction or Legalization? Measuring the Economic Benefits of Immigraiton Reform. *Center for Trade Policy Studies 40*, 40.

[Enders and Sandler (2002)] Enders, W. and T. Sandler (2002). What Do We Know About the Substitution Effect in Transnational Terrorism? (April).

[Enders and Sandler (2011)] Enders, W. and T. Sandler (2011). *The Political Economy of Terrorism*. Cambridge University Press.

[Enders et al. (1990)] Enders, W., T. Sandler, and J. Cauley (1990). Assessing the impact of terrorist thwarting policies: An intervention time series approach.

[Enders et al. (1992)] Enders, W., T. Sandler, and G. F. Parise (1992). An

Econometric Analysis of the Impact of Terrorism on Tourism. *Kyklos 45*(4), 531–554.

[Fischhoff et al. (1978)] Fischhoff, B., P. Slovic, S. Lichtenstein, S. Read, and B. Combs (1978). How safe is safe enough? A psychometric study of attitudes towards technological risks and benefits. *Policy Sciences 9*(2), 127–152.

[Garfinkel (2004)] Garfinkel, M. R. (2004). Global threats and the domestic struggle for power. *European Journal of Political Economy 20*(2), 495–508.

[Giesecke et al. (2015)] Giesecke, J. A., W. Burns, A. Rose, T. Barrett, and M. Griffith (2015). Regional Dynamics Under Adverse Physical and Behavioral Shocks: The Economic Consequences of a Chlorine Terrorist Attack in the Los Angeles Financial District. In *Regional Science Matters*, Volume 732, Chapter 16, pp. 319–350. Springer International Publishing.

[Giesecke et al. (2012)] Giesecke, J. a., W. J. Burns, a. Barrett, E. Bayrak, a. Rose, P. Slovic, and M. Suher (2012). Assessment of the Regional Economic Impacts of Catastrophic Events: CGE Analysis of Resource Loss and Behavioral Effects of an RDD Attack Scenario. *Risk Analysis 32*(4), 583–600.

[Kasperson et al. (1988)] Kasperson, R. E., O. Renn, P. Slovic, H. S. Brown, J. Emel, R. Goble, J. X. Kasperson, and S. Ratick (1988). The Social Amplification of Risk: A Conceptual Framework. *Risk Analysis 8*(2), 177–187.

[Keynes (1919)] Keynes, J. M. (1919). *The Economic Consequences of the Peace*. London: Courier Corporation.

[Lapan and Sandler (1988)] Lapan, H. E. and T. Sandler (1988). To Bargain or Not To Bargain: That Is The Question. *The American Economic Review, Papers and Proceedings of the One-Hundredth Annual Meeting of the American Economic Association 78*(2), 16–21.

[Lapan and Sandler (1993)] Lapan, H. E. and T. Sandler (1993). Terrorism and signalling.

[Meade (1940)] Meade, J. E. (1940). *The Economic Basis of a Durable Peace*. New York: Oxford University Press.

[Mickolus et al. (2003)] Mickolus, E. F., T. Sandler, J. M. Murdock, and P. A. Flemming (2003). International Terrorism: Attributes of Terrorist Events (ITERATE), 1968-2002 Data Codebook. Technical report, Mimeo.

[Pan et al. (2009)] Pan, Q., H. Richardson, P. Gordon, and J. Moore (2009). The Economic Impacts of a Terrorist Attack on the Downtown Los Angeles Financial District. *Spatial Economic Analysis 4*(2), 213–239.

[Pigou (1940)] Pigou, A. C. (1940). *The Political Economy of War*. Macmillan and Company, limited.

[Rose et al. (2009)] Rose, A., B. Lee, G. Oladosu, and G. Asay (2009). The Economic Impacts of the September 11 Terrorist Attacks: A Computable General Equilibrium Analysis.

[Sandler and Enders (2004)] Sandler, T. and W. Enders (2004). An economic perspective on transnational terrorism. *European Journal of Political Economy 20*(2), 301–316.

[Slovic (1987)] Slovic, P. (1987). Perception of Risk. *Science 236*(4799), 280–285.

[Tavares (2004)] Tavares, J. (2004). The open society assesses its enemies: Shocks, disasters and terrorist attacks. *Journal of Monetary Economics 51*(5), 1039–1070.

6 Tables and Figures

Table 1: Summary of key variables and their respective mathematical abstraction.

(a) Macroeconomic variables introduced by **[Blomberg et al. (2004)]**			
IYR	Real investment as a proportion of real GDP.	GYR	Real public consumption as a proportion of real GDP.
BYR	Real imports plus exports as a proportion of GDP.	TV_t	Dummy variable defined in equation 2.5
ΔY_t	Real GDP growth over year t.	P_t	Population at time t in millions
T_t	Number of terrorist events recorded in a particular country in year t.		
(b) Back-of-the-envelope (BOTE) model variables.			
A	Primary factor augmenting technical change	ROR	Rate of return on capital.
APC	Average propensity to consume.	TOT	Terms of Trade.
C	Real private consumption.	V	Shift in export demand schedule.
G	Real public consumption.	W	Real (CPI-deflated) wage.
I	Real Investment.	X	Export volumes.
K	Capital stock.	Y	Real GDP.
L	Employment.	Λ	Shift in rate of return schedule for I.
M	Import volumes.	Ψ	Investment-to-Capital ratio.
W_t^s	Real (CPI-deflated) wage at time t for $s \in \{\text{Policy,Base}\}\cdot$	ΔK_t	Change in K between years t and $t-1$.
		L_t^s	Employment at time t for $s \in \{\text{Policy,Base}\}\cdot$

Table 2: Back-of-the-envelope (BOTE) representation of USAGE 2.0

	(a) Short-run closure.	**(b) Effective long-run closure.**
(i)	Equations holdings within any given year of the year-on-year base case, Blomberg and Structural simulations.	
6.1	$Y = C + I + \boldsymbol{G} + X - M$	$Y = C + I + \boldsymbol{G} + X - M$
6.2	$Y = f(L, \boldsymbol{K}) / \boldsymbol{A}$	$Y = f(\boldsymbol{L}, K) / \boldsymbol{A}$
6.3	$C = \boldsymbol{APC} \cdot Y \cdot g(TOT)$	$C = \boldsymbol{APC} \cdot Y \cdot g(TOT)$
6.4	$I = u(ROR / \boldsymbol{\Lambda})$	$I = u(\boldsymbol{ROR} / \Lambda)$
6.5	$\Psi = I / \boldsymbol{K}$	$\boldsymbol{\Psi} = I / K$
6.6	$f_L(\boldsymbol{K} / L) \cdot g(TOT) = \boldsymbol{W} \cdot \boldsymbol{A}$	$f_L(K / \boldsymbol{L}) \cdot g(TOT) = W \cdot \boldsymbol{A}$
6.7	$f_K(L / \boldsymbol{K}) \cdot h(TOT) = ROR \cdot \boldsymbol{A}$	$f_K(\boldsymbol{L} / K) \cdot h(TOT) = \boldsymbol{ROR} \cdot \boldsymbol{A}$
6.8	$M = j(Y, TOT)$	$M = j(Y, TOT)$
6.9	$ToT = z(X, \boldsymbol{V})$	$ToT = z(X, \boldsymbol{V})$
(i)	Relevant equations from [Blomberg et al. (2004)] holding within any given year of the year-on-year base case, Blomberg and Structural simulations.	
6.10	$IYR = I/Y$	$IYR = I/Y$
6.11	$GYR = G/Y$	$GYR = G/Y$
6.12	$BYR = \left(X + M\right)/Y$	$BYR = \left(X + M\right)/Y$
(ii)	Relevant equations holding between consecutive years of the year-on-year base case, Blomberg and Structural simulations.	
6.13	$\Delta K_t = I_{t-1}$	
(i)	Lagged wage adjustment.	
6.14	$\frac{W_t^{\text{Policy}}}{W_t^{\text{Base}}} = \left(\frac{W_{t-1}^{\text{Policy}}}{W_{t-1}^{\text{Base}}} - 1\right) + \alpha \cdot \left(\frac{L_t^{\text{Policy}}}{L_t^{\text{Base}}} - 1\right)$	

Table 3: Shock and subsequent relaxation paths for the variables described by [Blomberg et al. (2004)] as presenting a measurable and significant response to terrorism. All results are presented to six decimal places as percentage deviations of the Blomberg simulation from the baseline.

Period	$\Delta IYR_{t,\text{Policy-Base}}$	$\Delta GYR_{t,\text{Policy-Base}}$	$\Delta Y_{t,\text{Policy-Base}}$
2011	0	0	0
2012	-0.008277	0.008751	-0.001611
2013	-0.000054	0.000231	-0.000288
2014	-0.000010	0.000041	0.000020
2015	0.000001	-0.000003	-0.000002
2016	0	0	0

Table 4: Deviations in the structural response variables from the baseline, driven by the Blomberg simulation shocks in Table 3. The required rate of return in period t is denoted by $\Lambda_{t,\text{Policy-Base}}$, while the deviation in the rate of growth in public consumption is $g_{t,\text{Policy-Base}}$ and all primary-factor augmenting technical change is $a_{t,\text{Policy-Base}}$

Period	$\Lambda_{t,\text{Policy-Base}}$ (1)	$g_{t,\text{Policy-Base}}$ (2)	$a_{t,\text{Policy-Base}}$ (3)
2011	0	0	0
2012	0.000019	0.007134	0.001354
2013	-0.000005	-0.000055	-0.000174
2014	-0.000003	0.000064	-0.000364
2015	0	-0.000003	-0.000301
2016	-0.000001	0.000002	-0.000259

Table 5: Comparison of event-year shocks, standardised to a U.S.-wide basis

	Required rate of return (U.S.-wide, change) (1)	Business interruption & other direct resource loss impacts (U.S.-wide, $m.) (2)	Government consumption (U.S.-wide, $m.) (3)	Casualties (fatalities and serious injuries) (4)
Blomberg (implicit) [Event: average event]	0.000019[(a)]	$200[(b)]	$155[(c)]	2.6[(h)]
Giesecke et al. (2012) [Event: dirty bomb]	0.000110[(d)]	$1,427[(e)]	$0[(f)]	450[(i)]
Giesecke et al. (2015) [Event: chlorine gas]	0.000100[(d)]	$149[(e)]	$4[(g)]	286[(j)]

Notes to Table 5:

(a) See Table 4 .
(b) Percentage change in productivity (Table 4) multiplied by GDP.
(c) Percentage change in public consumption (Table 4) multiplied by government expenditure.
(d) Change in required rate of return in downtown Los Angeles, multiplied by share of downtown Los Angeles investment in economy-wide U.S. investment.
(e) Business interruption, fatalities and capital damage.
(f) No change in government consumption in [Giesecke et al. (2012)].
(g) Event-related medical expenditure only.
(h) [Anderton and Carter (2011)] studied the ITERATE database upon which the analysis by [Blomberg et al. (2004)] is based. [Anderton and Carter (2011)] did not distinguish between fatalities and injuries in their analysis, combining the two to study overall casualties of terrorism. Average casualties per incident from 1968 to 2001 quoted herein were calculated from the average number of casualties per terrorism event per year and the number of terrorism events per year reported by [Anderton and Carter (2011)].
(i) 180 fatalities and 270 serious injuries.
(j) 182 fatalities and 104 serious injuries.

Figure 1: Plot of shocks from Table 3

% Deviation from Baseline

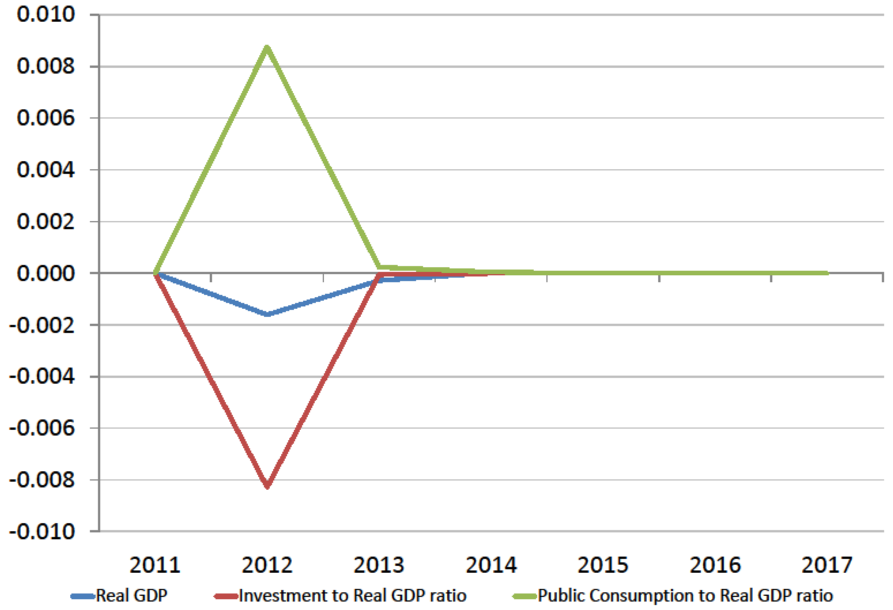

Figure 2: Plot of structural variable responses from Table 4

% Deviation from Baseline

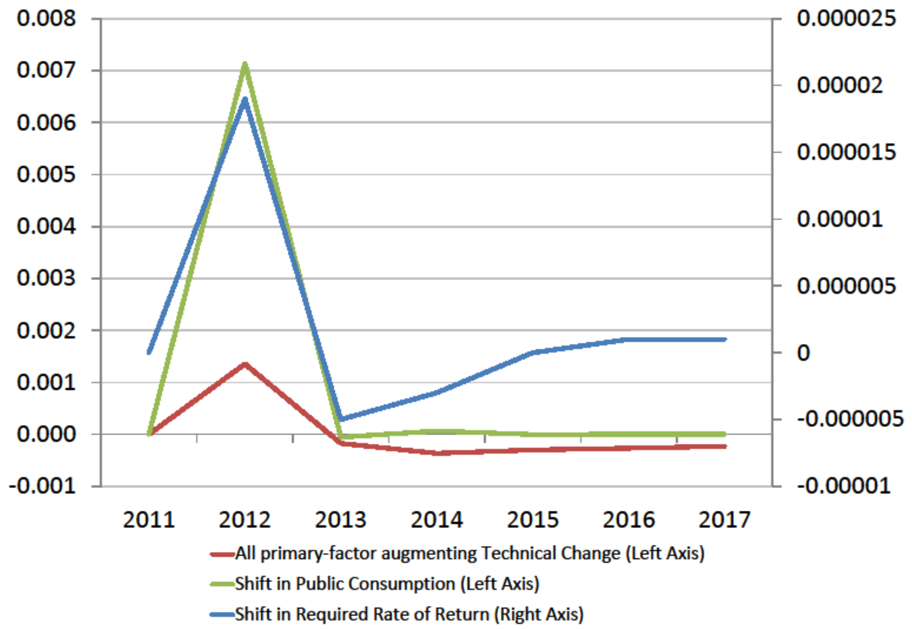

Figure 3: Aggregate employment

% Deviation from Baseline

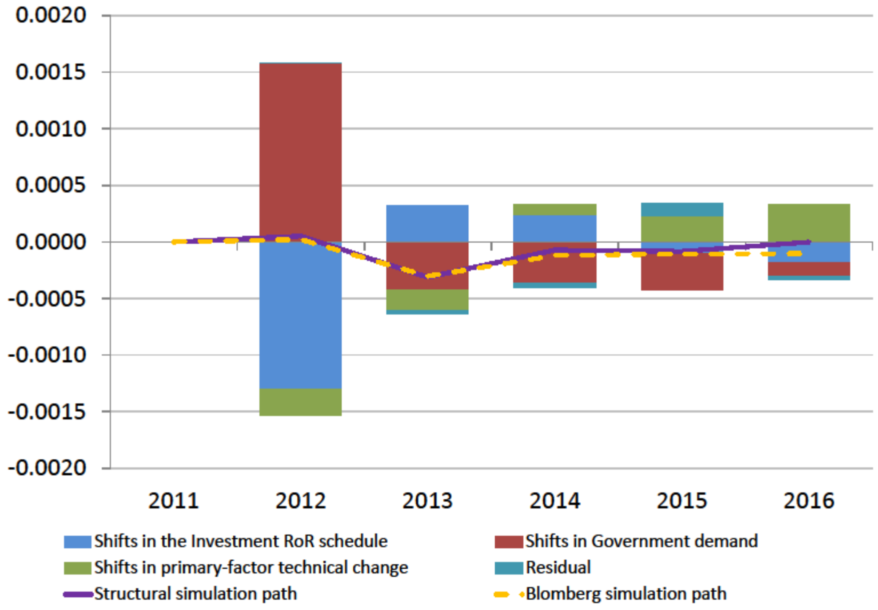

Figure 4: Real GDP

% Deviation from Baseline

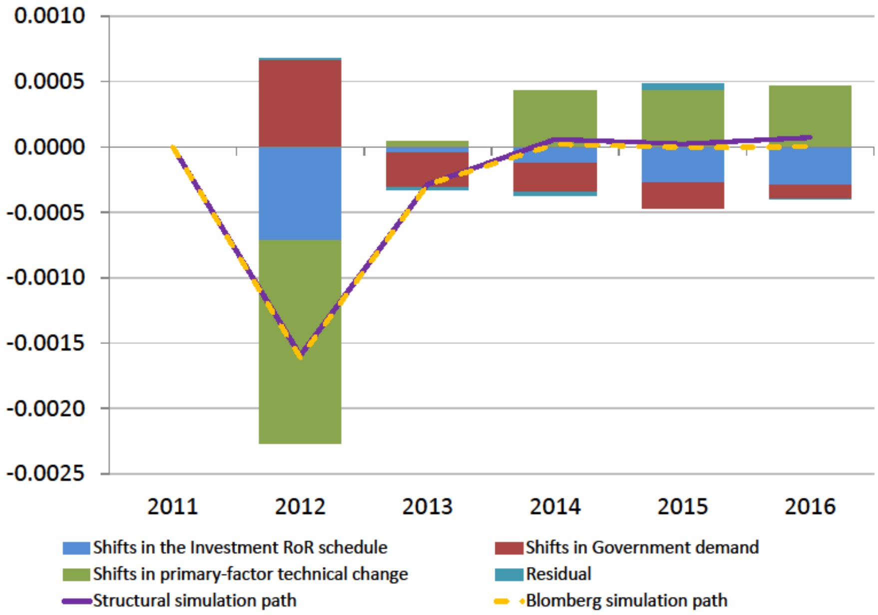

Figure 5: Terms of Trade

% Deviation from Baseline

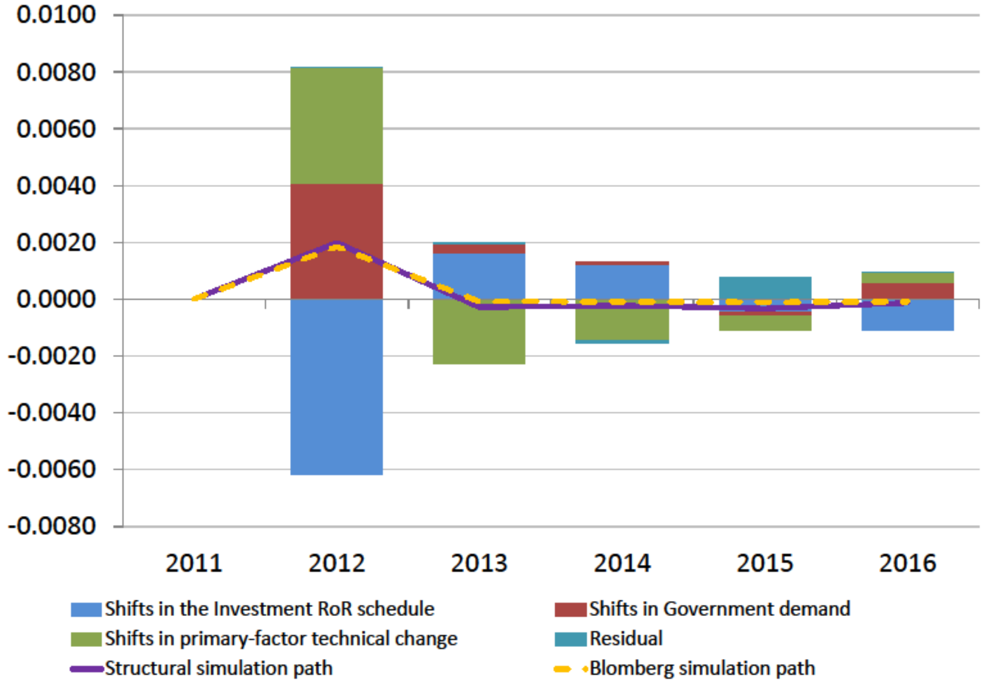

Figure 6: Ratio of the Average Capital Rental Price to the Investment Price Deflator

% Deviation from Baseline

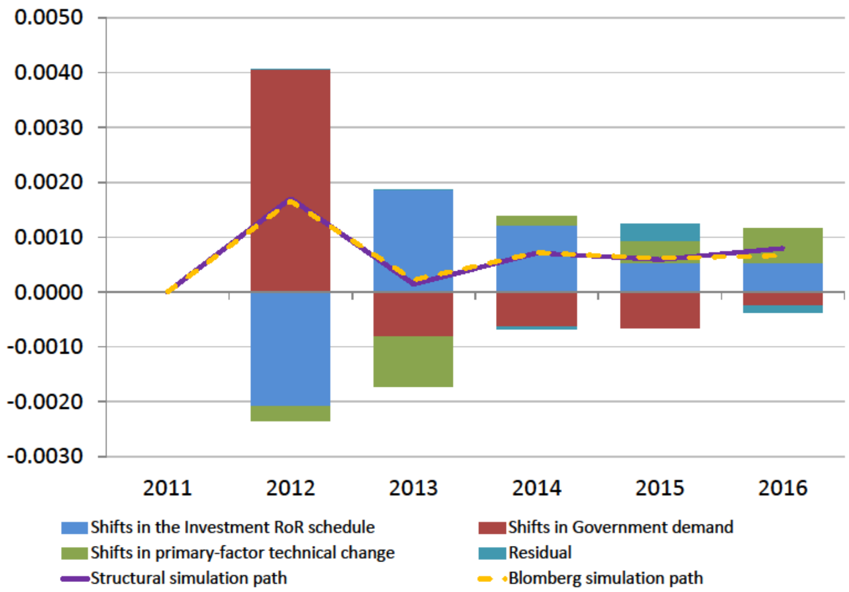

Figure 7: Real Investment

% Deviation from Baseline

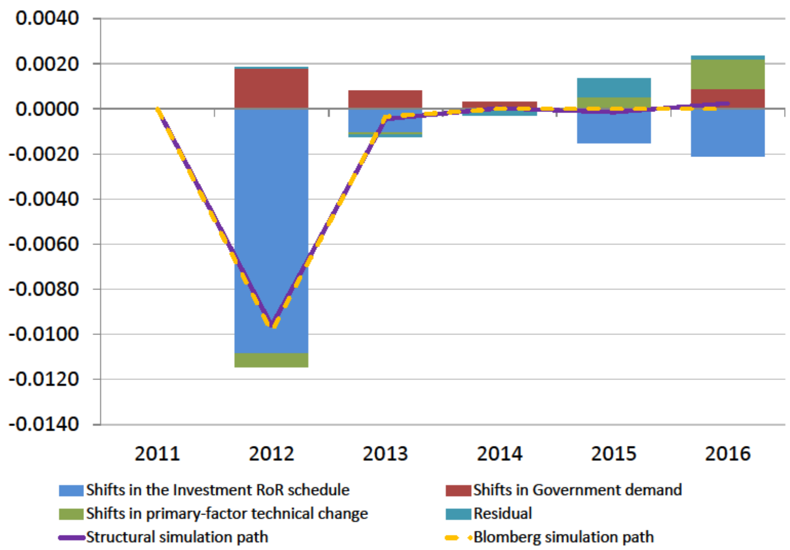

Figure 8: Capital stock (Rental-weighted)

% Deviation from Baseline

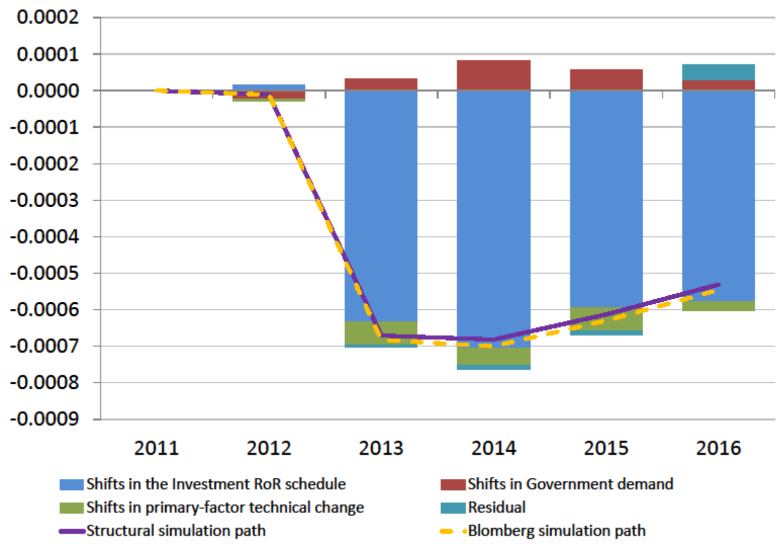

Figure 9: Real Private Consumption

% Deviation from Baseline

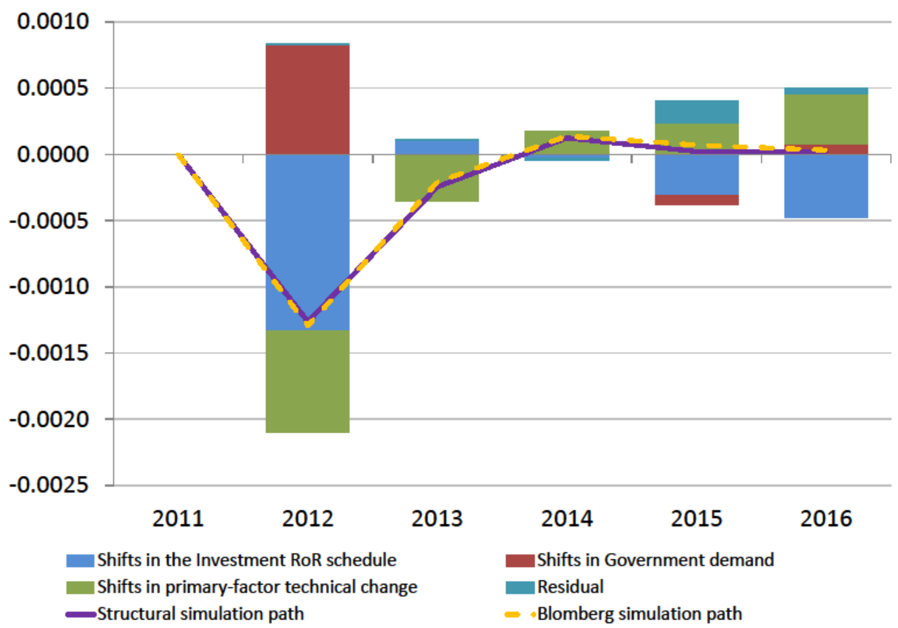

Figure 10: Balance of Trade / GDP ratio

% Deviation from Baseline

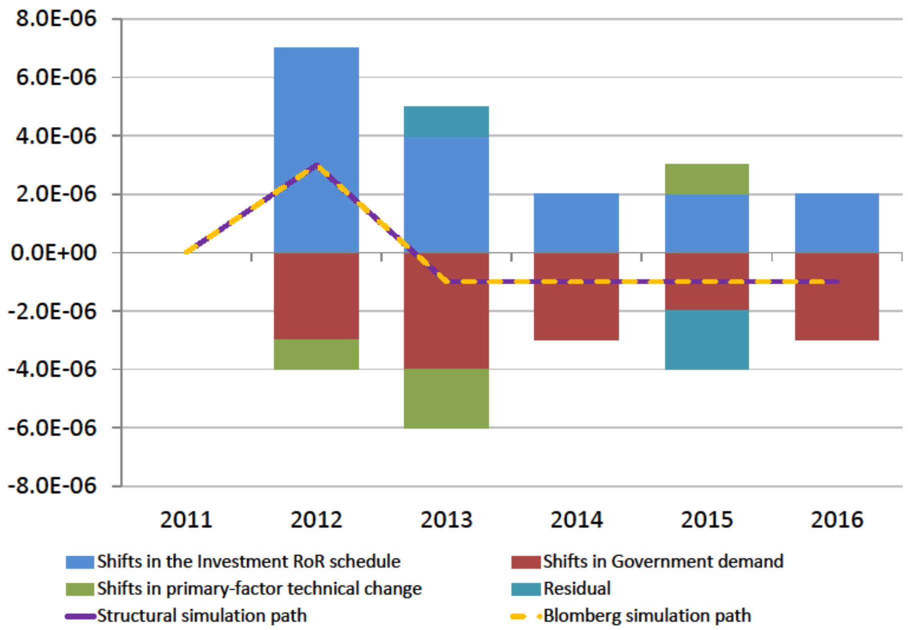

Figure 11: Import Volumes

% Deviation from Baseline

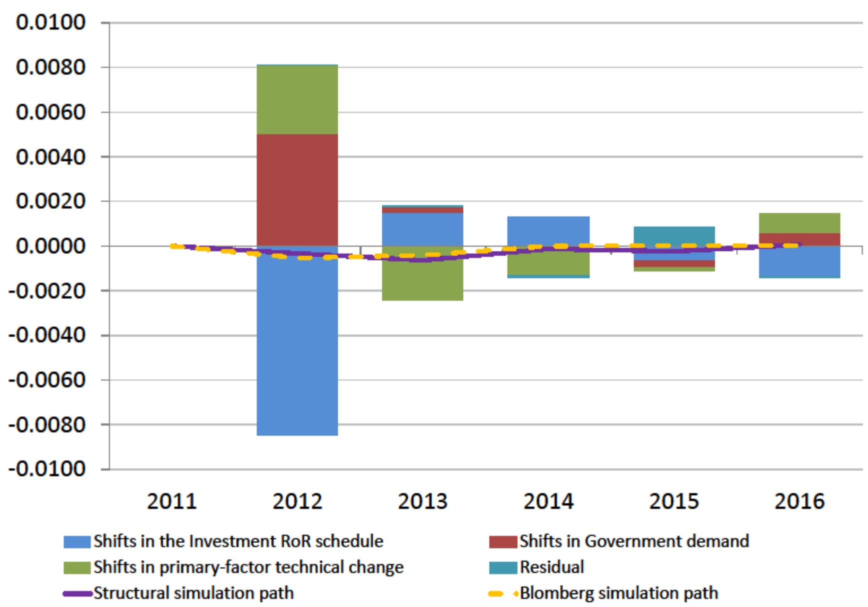

Figure 12: Export Volumes

% Deviation from Baseline

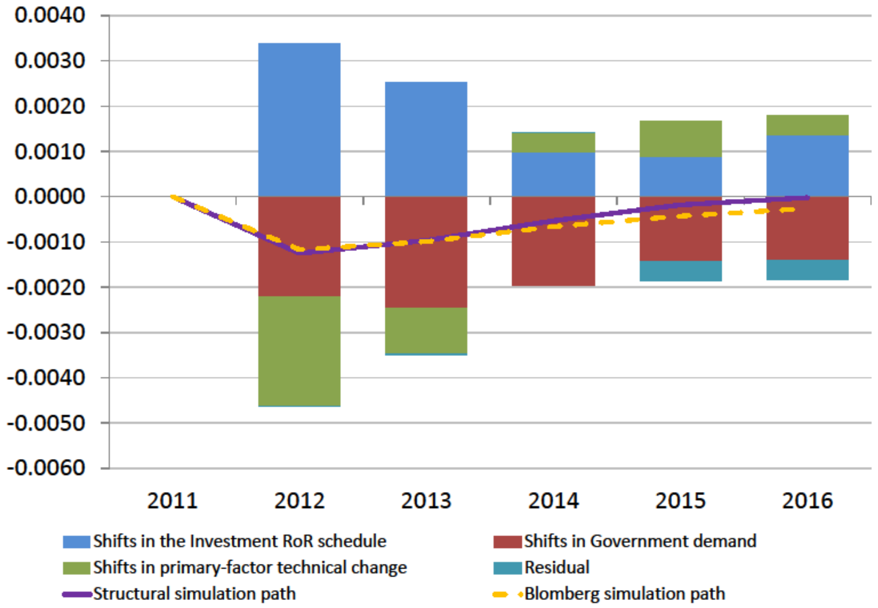

Figure 13: Real Exchange Rate

% Deviation from Baseline

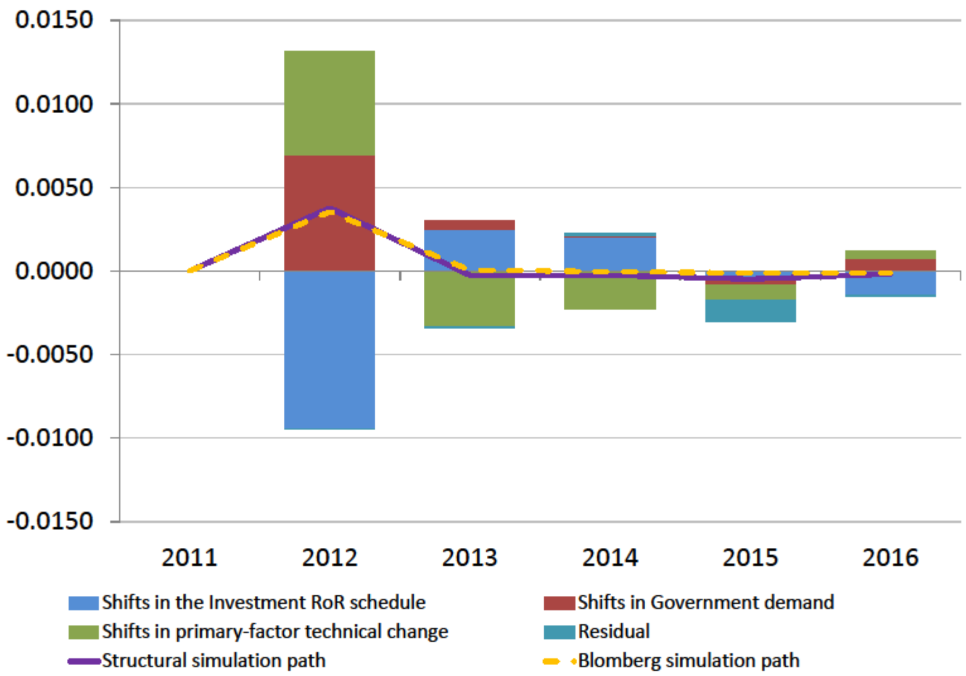

Figure 14: Industries experiencing the largest event-year output changes

% Deviation from Baseline

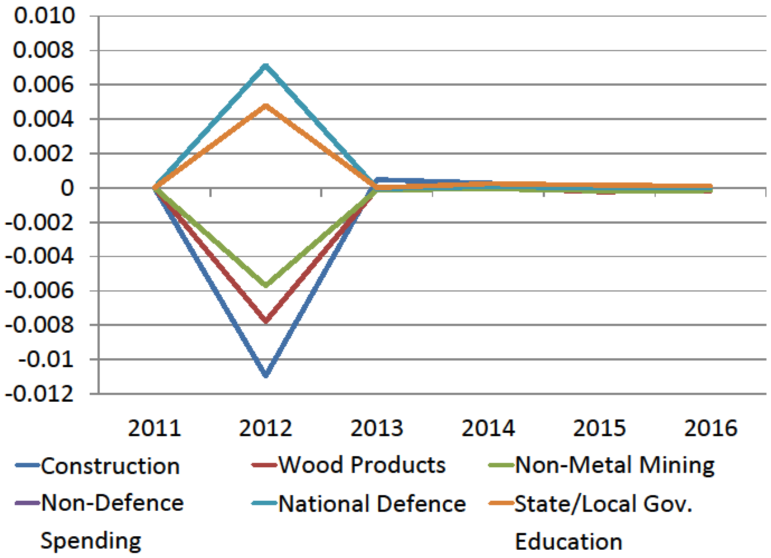

Figure 15: Industries experiencing the largest long-run output changes

% Deviation from Baseline