Fiscal Policy, Debt Consolidation and the Consequences of the Great Recession

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Dedication

To my wife, my parents and my siblings

Declaration

I certify that the thesis I have presented for examination for the award of PhD degree in Economics of the University of Sheffield is solely my own work.

I warrant that this authorisation does not, to the best of my belief, infringe on the rights of any third party.

I declare that my thesis consists of approximately 42,000 words.

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Abstract

This thesis examines the domestic and international transmission of fiscal shocks, especially in the wake of the European sovereign debt crisis after the Great Recession. The thesis is divided into three main chapters, with each chapter addressing contemporary policy questions in recent macroeconomic debates. The first chapter investigates the effect of fiscal consolidation on different types of household, and how the degree of household's financial constraints interacts with the government's debt-consolidation plan in a dynamic stochastic general equilibrium (DSGE) model estimated on UK data. In the second chapter, the analysis is extended to a two-country model in order to investigate the international transmission of fiscal shocks between the UK and the Euro area, and how the relative participation of these countries at the global asset market influence cross-border fiscal spillovers. Motivated by the recent calls on German government to increase its spending, the third chapter estimates the international spillover effects of an expansion in German government spending on output and bilateral exchange rates of 15 European (10 Euro and 5 non-Euro) economies within a sign-restricted structural VAR model.

Evidence from the closed-economy model shows that different types of households respond differently to fiscal consolidation shocks, depending on the degree of financial constraints they face. Tighter household's credit constraints dampen the responsiveness of fiscal instruments to government debt, thereby prolonging the actualisation of the consolidation plan. On the international transmission of fiscal shock, the results show that EA fiscal shocks have sizeable effects on the UK economy, while UK fiscal shocks have negligible effects on the EA economy. Also, relative countries' participation at the international asset market drives the amplification and propagation of cross-border fiscal spillovers. Furthermore, German government spending shock has moderate but short-lived effects on output of other European countries, with homogeneous responses in the Euro countries, but heterogeneous responses in non-Euro countries.

Key words: Fiscal Policy; Financial Constraints; Rule-of-thumb Consumers; Cross-border Spillovers; Open Economy Macroeconomic Model; Bayesian Estimation; Structural VARs; Sign Restrictions.

JEL classification: E62, F41, F42, H31, H63.

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Chapter 1

Introduction: Fiscal Policy in the Last Decade

In the last decade, fiscal policy has gained traction in macroeconomic discourse. A number of studies have been devoted to the analysis of fiscal policy in academic literature. For instance, several studies, including Mountford & Uhlig (2009) and Barro & Redlick (2011), have attempted to estimate the macroeconomic effects of government spending and taxes. Most studies find sizeable fiscal multipliers, though some other studies, such as Cogan et al. (2010), find much smaller multipliers. Auerbach & Gorodnichenko (2012), Candelon & Lieb (2013) and Ramey & Zubairy (2018) further find that these fiscal multipliers vary over the business cycle: they are relatively larger during the recession than in expansion. Leeper et al. (2017) also find that fiscal multipliers vary over the policy regimes: they are much larger under active fiscal/passive monetary regime than under active monetary/passive fiscal regime at long horizons.

Regarding the influence of macroeconomic conditions on fiscal transmission, Christiano et al. (2011) and Correia et al. (2013) show that fiscal multipliers are often larger and in excess of one when interest rate is constrained to the effective lower bound. Also, Galí et al. (2007) and Eggertsson & Krugman (2012) find that controlling for financial constraints among households has important implications for the transmission of fiscal policy: it is a mechanism through which an expansion in government spending leads to an increase in private consumption. On the timing of impact, Ramey (2011*b*), Leeper et al. (2012) and Leeper et al. (2013) show that private agents often anticipate the effect of fiscal policy well ahead of the time of impact due to legislative and implementation lags. Corsetti et al. (2010, 2012) further show that the anticipation of government spending reversal could alter the conventional responses of interest rate and exchange rate to fiscal policy shocks. Other studies, such as Auerbach & Gorodnichenko (2013) and Corsetti & Müller (2014), find that domestic fiscal policy have sizeable international spillover effects on foreign economies, and these effects are much larger when both the source and the recipient economies are in recession. While some other studies, such as Erceg & Lindé (2013) and Alesina, Favero & Giavazzi (2015), further debate the associated cost in output terms of implementing specific tax- and spending-based fiscal policy.

This thesis examines the domestic and international transmission of fiscal policy, especially as tools for debt consolidation after the Great Recession. The thesis is divided into three different but related chapters, with each chapter addressing policy-relevant questions in contemporary macroeconomic debates. The analysis is conducted within both theoretical business cycle models and empirical structural vector autoregressive models (SVAR).

Chapter 2 examines the heterogeneous effect of fiscal consolidation on different types of households, and the implications of household's financial constraints for the achievement of debt consolidation in the United Kingdom. This chapter is motivated by the recent implementation of consolidation measures in many European economies aimed at stemming the growth of public debt, which surge to record levels as a result of various fiscal stimulus packages to bail-out private businesses during the financial crisis. The consolidation policy generates significant debates in both academic and policy circles, but little consideration is given to the degree of financial constraints among households. The chapter addresses the following research questions: what are the effects of fiscal consolidation on different types of household? And, how do household's financial constraints influence the government's consolidation policy?

To address these questions, a dynamic stochastic general equilibrium (DSGE) model is developed and estimated on UK data for the period 1987:Q1 – 2010:Q2. Building on Leeper, Plante & Traum (2010), the model incorporates a fraction of households that are financially constrained and exhibits rule-of-thumb behaviours, and a rich fiscal sector that allows government services to have direct effects on household preferences, while government transfers have distortionary effects. Evidence from the results show that different types of households respond differently to fiscal consolidation shocks, depending on the degree of financial constraints they face. Irrespective of the choice of consolidation strategy, the financially constrained households consume less while working more, compared to the unconstrained households. Also, the degree of household's financial constraints has important implication for debt consolidation. More precisely, the responsiveness of fiscal instruments to government debt becomes weaker as the degree of household's financial constraints intensifies, thereby prolonging the achievement of the government's consolidation targets. Furthermore, responses of macroeconomic variables are sensitive to the choice of fiscal strategy while responding to consolidation shocks, and these have important implications for the achievement of the debt consolidation plan. The chapter concludes that the government should selectively implement fiscal consolidation policies in order to minimise output loss.

In Chapter 3, the analysis is extended to a two-country business cycle model in order to investigate the international transmission of fiscal policy shocks between the Euro Area (EA) and the United Kingdom (UK). The chapter also investigates the role of credit-constraints on cross-border fiscal spillovers. While several studies have been devoted to the analysis of international fiscal spillovers and multipliers, this paper is among the few to analyse the implication of EA fiscal policy for the UK economy. The paper is also one of the first to formally derive and analyse the effect of countries' international financial exposure on cross-border transmission of fiscal policy. The model follow closely that of Corsetti et al. (2010, 2012), but abstracts from nominal rigidities for simplicity and tractability. As a contribution, the model is enriched to reflect variation in responses of different types of household to fiscal adjustments by allowing different valuation of government services in household's effective consumption bundles. The model is estimated on time series data for the UK and EA using Bayesian methods.

The results of the analysis show that EA fiscal shocks have sizeable effects on UK economic activities, while UK fiscal shocks have negligible effects on EA economy. This result is driven mainly by the strong trade links between UK and the EA – nearly half of the total UK trade is with the EA, and the relatively small size of the UK economy. Also, the size of cross-border spillover effects varies considerably, depending on the choice of fiscal instruments. While the spending-based fiscal spillovers have strong procyclical effects, the tax-based spillover effects are relatively small and sometimes countercyclical. Furthermore, the relative degree of household's credit-constraints in the source country of the shock drives the propagation and amplification of cross-border fiscal spillovers through its effect on the net asset position. Asset holders respond much earlier to changes in relative participation at the global asset market by adjusting their portfolios accordingly within the first year. Whereas, non-asset holders mainly respond to this change in the medium-run. The chapter concludes that fiscal authorities should coordinate their policies in order to reduce uncertainties associated with cross-border policy spillovers.

Chapter 4 empirically investigates the international transmission of fiscal policy in Europe. This chapter is motivated by the recent calls by major international policy institutions – such as the International Monetary Fund and the European Union – for German government to increase its spending in order to boost economic activities in the rest of the Euro countries. The proponents of this call maintain that an expansion in German fiscal spending would boost domestic demand and stimulate output and inflation in the rest of the Euro Area. In contrast, the German government argues that such fiscal expansion would have relatively small spillover effects on other European economies due to the low import content of German public expenditure. This paper contributes to this debate by addressing the questions: what are the effects of government spending on demand for foreign goods? Does an increase in government spending leads to output expansion in foreign economies? And, is there heterogeneity in the responses of foreign countries to domestic fiscal shocks?

To address these questions, the paper follows the approach of Corsetti & Müller (2014) by estimating an open-economy fiscal VAR model for Germany and then extend the VAR model to include foreign output and exchange rates in order to analyse cross-border spillover effects of German government spending shock. The novelty of this paper is in both the methodology and scope. While existing similar studies in the literature are based on zero-restriction identification, this paper identifies the government spending shock using Uhlig (2005)'s agnostic identification method which imposes sign restrictions on the impulse response functions. Also, this paper estimates country-specific spillover effects of German government spending shock on fifteen European (ten Euro and five non-Euro) countries. These include all the 14 countries in the panel analysis of Beetsma & Giuliodori (2011) as well as Norway and Switzerland. Furthermore, unlike most recent empirical studies, this analysis incorporates the period after the financial crisis when fiscal policy is relatively active.

Evidence from the VAR estimation shows that a bond-financed expansion in German government spending depreciates the German real exchange rate and the terms of trade, and worsen the German trade balance position. The deterioration of the trade balance is driven by an increase in domestic demand for foreign goods, suggesting some output spillovers to foreign economies. Regarding the spillover effects, German government spending has moderate but short-lived effects on rest-of-Europe output. On impact, the cross-border output spillover is positive in non-GIIPS Euro countries, zero or negative in the GIIPS countries and has mixed effects in non-Euro countries. In the medium run, German spending spillover has no positive effect on rest-of-Europe output. The effects of German fiscal shock on bilateral real exchange rates are relatively larger and heterogeneous across non-Euro countries, but smaller and homogeneous for the Euro countries. In the non-GIIPS Euro countries, bilateral real exchange rate appreciates in the short run and depreciates in the medium run, while it depreciates with lags in the GIIPS countries. Whereas, for non-Euro countries, bilateral real exchange rates of the Scandinavian countries appreciate for an extended period and then return to preshock levels; while for UK and Switzerland, bilateral real exchange rates do not respond significantly to German spending shock. The chapter concludes that, while German government spending could lead to output expansion in Euro countries, low trade intensity and internal dynamics of some countries —such as high sovereign debt risks in the GIIPS countries— may inhibit gains from international fiscal spillovers.

Chapter 5 summarises the key findings of the thesis, discusses some limitations of the research, and suggests some possible extensions for future research.

Chapter 2

Fiscal Consolidation and Financial Constraints: An Estimated DSGE Model of the UK Economy

> *"The budget deficit is forecast to fall to 3.7% this year, which is less than half the 10% we inherited in 2010. But all that progress is at risk if we do not finish the job. While we move from deficit to surplus, this Charter commits us to keeping debt falling as a share of GDP each and every year. Only when... we have GDP growth of less than 1% a year... will that surplus no longer be required. [We] are continuing to devote a greater share of state support to the most vulnerable. [Those] with broadest shoulders are bearing the greatest burden.* ***For we are all in this together.****"*
>
> - George Osborne, 2015 Summer Budget Speech.

2.1 Introduction

Following the recent global financial crisis, public debt in many developed economies surge to record levels as the government stimulates the economy with direct bail-outs of private businesses while tax revenue falls. Between 2007 and 2009, public debt rose by about 75% in many developed countries with systemic financial risks – such as the United States, United Kingdom, Spain, Ireland and Iceland – and by about 20% in real terms for countries with less financial risks (Reinhart & Rogoff 2010). After the crisis, several European governments initiated various consolidation measures aimed at reducing public debt levels and stabilising growth.[1] In the UK, the government has implemented various consolidation measures since

[1] For instance, for each successive fiscal year between 2008 and 2015, the Irish government implemented specific consolidation measures, including pay cut for young people (ages 20-24 years), reduction in national minimum wage, increase in personal tax and a significant cut in social security payment. In Greece, the situation is similar with the addition of an increase in value-added tax (VAT) on consumption goods and a cut in the minimum wage.

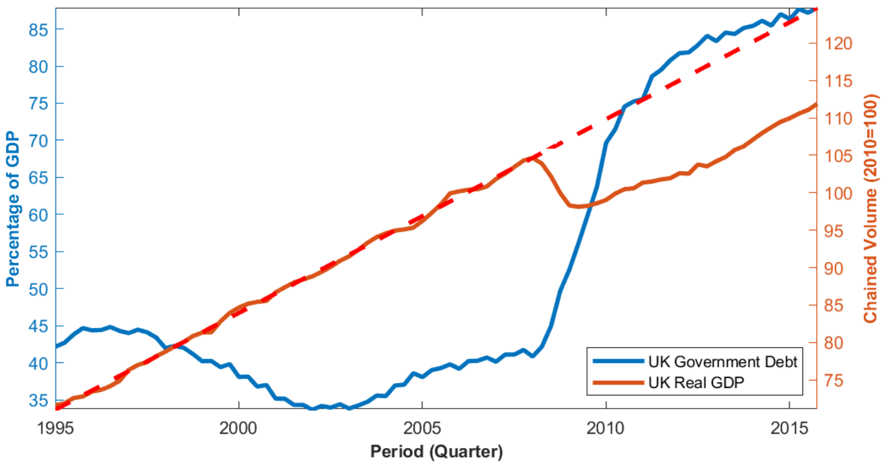


Figure 2.1: **Time series plot of UK government debt-to-GDP and UK real GDP.** *Source:* Eurostat and World Bank database

2010, including cuts in social benefit pay-outs, abolishment of housing benefits for young people (18-20 years old), limited tax credits, public wage freezes, and commercialisation of public enterprises among others. Despite these consolidation measures, public debt remains high and growth has not returned to its pre-crisis trend level (see Figure 2.1). Yet, the government consistently maintains that the consolidation policy is appropriate for the economy and its effect would spread to all households alike, with little consideration for the degree of financial constraints faced by some households.

However, a new set of literature has shown that fiscal consolidation can be self-defeating, especially in a depressed economy with excess capacity and when short-term interest rates are constrained to effective lower bounds (DeLong & Summers 2012, Holland & Portes 2012, Attinasi & Metelli 2017, Bandeira et al. 2018). More precisely, Jordà & Taylor (2016) show that a fiscal consolidation of 1% of GDP leads to an output loss of 3.5% over a five-year period when implemented in a slump, compared to 1.8% in a boom. In another more recent study, Barnichon & Matthes (2018) find that, irrespective of the identification strategy employed, fiscal contraction multiplier is larger than 1, and even much larger during recession; whereas, fiscal expansion multiplier is substantially less than 1 regardless of the state of the economy.

Also, as Cwik & Wieland (2011) and Eggertsson & Krugman (2012) note, the effect of the recent financial crisis —which preceded the current debt crisis— can cause more household agents to become financially constrained and live from "hand to mouth".[2] Thus, in this scenario, fiscal consolidation is likely to further depress the economy as higher proportion of financially con-

[2]Studies by Campbell & Mankiw (1989, 1990, 1991), Kaplan & Violante (2014) and Kaplan et al. (2014) use macro and micro dataset to prove the existence of this group of household. Their findings suggest an estimate of the proportion of hand-to-mouth household to be about 25-50%.

strained household would lead to loss of tax revenue and increase pressure on welfare spending, which in turn would necessitate more public borrowing and further worsen the debt crisis. Unlike the less financially constrained "wealthy" households who smooth consumption based on their permanent income, the financially constrained "hand-to-mouth" households exhibit rule-of-thumb behaviours by consuming their current income. This intrinsic heterogeneity among households has been documented to influence household responses to fiscal shocks and alter the macroeconomic effect of fiscal policy (for instance, see Galí et al. (2007), Drautzburg & Uhlig (2015)).

In this paper, we analyse the heterogeneous effects of fiscal consolidation on different types of households. We also examine the implication of household's financial constraints for the achievement of government's consolidation plan. Specifically, the paper addresses the following policy questions: What are the effects of fiscal consolidation on different types of households? How do household's financial constraints influence the government's consolidation policy? To address these questions, we develop a dynamic stochastic general equilibrium model and estimate it on UK data using Bayesian methods. We enrich the model of Leeper, Plante & Traum (2010) in three ways: First, we incorporate rule-of-thumb behaviours in order to capture the degree of financial constraints faced by some households, as in Galí et al. (2007) and Bilbiie (2008); second, we incorporate a fiscal sector that allows government consumption to have direct effect on households' preferences and allows government transfer to have distortionary effects, as in Coenen et al. (2013); and finally, following Kliem & Kriwoluzky (2014), we modify the fiscal rule by allowing distortionary taxes on capital and labour to respond to the investment component of the business cycle. These features are central to our analysis as we intend to take the model to the data.

This paper makes two key contributions. First, we are some of the first to analyse the effect of fiscal policy in an estimated DSGE model with heterogeneous households for the UK economy. We estimate the model on nine quarterly UK time series for the period 1987:Q1 – 2010:Q2. A similar study by Bhattarai & Trzeciakiewicz (2017) mainly quantifies the GDP multiplier of UK fiscal policy. This paper moves a step further to analyse the implications of household's financial constraints for UK fiscal policy and demonstrate its importance in achieving debt consolidation. Second, we analyse the heterogeneous responses of different types of households to fiscal policy shocks. Most studies with heterogeneous households rarely analyse household-specific responses to policy shocks. However, as Aiyagari (1994) notes, agent-specific responses differ considerably from aggregate responses, and this distinction is not just driven by differences in wealth endowment, but also by the intrinsic nature of different types of households. While few studies, such as Coenen & Straub (2005) and Bhattarai & Trzeciakiewicz (2017), analyse the differences in consumption response of different types of households, McManus (2015) further analyses the differences in employment response, but in a calibrated model. In this paper, we analyse the estimated responses of both aggregate and household-specific consumption and labour efforts to fiscal consolidation shocks.

The results of our analysis are in threefold. First, we find that households differ considerably in their responses to fiscal shocks, depending on the degree of financial constraints they face. Irrespective of the fiscal strategy adopted, fiscal consolidation causes the consumption of financially constrained households to fall more, which then forces them to work more, compared to unconstrained households. Secondly, our analysis shows that the degree of household's financial constraints influences the responsiveness of fiscal instruments to debt innovations. As the proportion of financially constrained households increases, fiscal adjustments to government debt becomes weaker. The implication of this result is that the achievement of government consolidation targets becomes prolonged with more financially constrained households. Thirdly, simulations based on the estimated parameters show that the responses of macroeconomic variables to consolidation shocks are sensitive to the choice of fiscal instruments inducing the debt innovations. Also, spending-based consolidation leads to smaller output contraction in the medium run compared to tax-based consolidation. Furthermore, consolidation targets are likely to be achieved in more reasonable time under a mix-instrument strategy, compared to when each fiscal instrument independently responds to debt. Additional analyses conducted to check the sensitivity of the estimated results to alternative specifications and sample periods show that the results are robust.

The rest of this paper is organised as follows. In Section 2.2, we discuss the theoretical model for our analysis. Section 2.3 describes the data and estimation procedure, the calibration of selected parameters, and the prior assigned to estimated parameters. In section 2.4, we report the results of the estimated model, analyse the impulse responses and conduct several sensitivity analyses. Section 2.5 concludes.

2.2 The Model

Our baseline model is adapted to the works of Leeper, Plante & Traum (2010) and Leeper, Walker & Yang (2010). Both studies are based on real business cycle models with representative agents, representative firms and the government; and they include real frictions such as investment adjustment costs, variable capacity utilisation and external habit in consumption.

In addition to four structural shocks (preference shocks, labour supply shock, technology shock, investment-specific technology shock), Leeper, Plante & Traum (2010) also include five fiscal shocks while Leeper, Walker & Yang (2010) incorporate six fiscal shocks. Specifically, we enrich the model of Leeper, Plante & Traum (2010) in three ways. First, following Galí et al. (2007) and Bilbiie (2008), we incorporate rule-of-thumb behaviours into the model to capture the degree of financial constraints among households. Second, we control for the direct effect of public services on households' effective consumption by including government consumption services in the utility preference in a non-linear form, as in Coenen et al. (2013) and Ercolani & e Azevedo (2014). Third, to properly identify the fiscal parameters, we follow the path of Kliem & Kriwoluzky (2014) by modifying the fiscal rules to allow distortionary taxes on capital and labour income to respond only to the investment component of the business cycle.

2.2.1 Households

There is a continuum of households, indexed with $i \in [0, 1]$, which comprises two groups: (i) Ricardian (also referred to as forward-looking or financially unconstrained) households, indexed with $r \in [\lambda, 1]$, have access to the financial market and accumulate physical and financial assets. As a result, this class of households can smooth consumption across time —intertemporal optimisation— in response to structural shocks. (ii) Non-Ricardian (also referred to as the rule-of-thumb, hand-to-mouth or financially constrained) households, indexed with $h \in [0, \lambda]$, are liquidity constrained and do not own any physical or financial assets. As a result of their limited asset market participation, rule-of-thumb households do not smooth consumption across time; rather, they simply consume their current labour income in each period —that is, intratemporal optimisation (Bilbiie 2008, Kollmann 2012).

Following Bouakez & Rebei (2007), Pappa (2009), Coenen et al. (2013), Ercolani & e Azevedo (2014) and Pappa et al. (2015), the effective consumption of household-i is specified as a non-separable constant elasticity of substitution (CES) aggregator of the household's own-private consumption and government consumption services:

$$\tilde{C}_t^i = \left[(1-\varrho)^{\frac{1}{\varphi}} {C_t^i}^{\frac{\varphi-1}{\varphi}} + \varrho^{\frac{1}{\varphi}} {G_t}^{\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}}, \quad i \in (r, h) \tag{2.1}$$

where C_t^i and G_t are the household-specific private consumption and government consumption services respectively, $\varrho \in (0, 1)$ is the share of government consumption in the effective consumption aggregator, and $\varphi \in (0, \infty)$ is the CES substitution elasticity between private and public consumption goods. As $\varphi \to 0$, private and public consumption tend to become perfect complements, while they tend towards perfect substitutes as $\varphi \to \infty$. A Cobb-Douglas case is obtained as $\varphi \to 1$. While some studies, such as Papageorgiou (2012) and Natvik (2009), assume separability of private and government consumption in the utility, this paper adopts non-separability to ensure that government consumption directly affects private consumption decisions, thereby leading to co-movement of both.[3]

Households derive utility from their effective consumption, $\tilde{C}_t^i$, and disutility from labour effort, N_t^i, in each quarter.[4] It is also assumed that each type of households internalises their consumption habit which is proxied by the past level of consumption, $\tilde{C}_{t-1}^i$. Formally, households maximise a lifetime expected utility function given by:

$$E_t \left\{ \sum_{t=0}^{\infty} \beta^t \varepsilon_t^u \left[\frac{(\tilde{C}_t^i - \kappa \tilde{C}_{t-1}^i)^{1-\sigma}}{1-\sigma} - \varepsilon_t^n \frac{N_t^{i\,1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right] \right\} \tag{2.2}$$

where $\beta \in (0,1)$ is the subjective discount factor, σ is the consumption rate of risk aversion (CRRA) and the inverse of intertemporal substitution elasticity, and η is the Frisch labour supply elasticity. $\kappa \in (0,1)$ measures the degree of habit formation in effective consumption.[5] ε_t^u and ε_t^n are the preference shocks to the subjective discount factor and labour supply respectively. Both shocks follow AR(1) processes given by:

$$\ln(\varepsilon_t^j) = \rho_j \ln(\varepsilon_{t-1}^j) + \epsilon_t^j, \quad \epsilon_t^j \sim NIID(0, \sigma_j), \quad \text{for} \quad j \in (u, n) \tag{2.3}$$

where ϵ_t^j are pure random errors to the preference shocks.

Ricardian Households

Ricardian households maximize utility subject to a flow budget constraint given by:

$$(1+\tau_t^c)C_t^r + I_t^r + \frac{B_{t+1}^r}{R_t} = (1-\tau_t^w)W_t N_t^r + [r_t^k - \tau_t^k(r_t^k - \delta)]K_t^r + \Pi_t^r + B_t^r + Z_t^r, \tag{2.4}$$

[3]For instance, government consumption spending on primary healthcare and basic education directly impacts on private consumption decisions.

[4]While Galí et al. (2004, 2007) adopt non-separable preferences in their models, this paper adopts separability in consumption and hours in order to track their unique responses to structural shocks while fully taking into account any wealth effect.

[5]Di Bartolomeo et al. (2011) assume that rule-of-thumb households can not engage in habitual consumption smoothing since they only consume their current income in each period. By implication, this assumption rules out steady state equality of consumption between the two groups of households since the Ricardian marginal utility of consumption is now discounted by the smoothing factor. This is a clear departure from most studies involving non-Ricardian households, such as Galí et al. (2004, 2007), Coenen et al. (2013), Cogan et al. (2013) and Rossi (2014).

and a capital law of motion, in the style of Christiano et al. (2005), given by:

$$K_{t+1} = (1-\delta)K_t + I_t\varepsilon_t^I\left[1 - \frac{\phi}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2\right]. \tag{2.5}$$

In each period, Ricardian households supply labour, N_t^r, to the firm in return for a real wage, W_t. They consume C_t^r unit of private goods, accumulate capital investment, I_t^r, and rent capital goods, K_t^r, to the firm at a real cost, r_t^k. They also receive profit, Π_t^r, from the ownership of the firm. They hold a one-period riskless government bond, B_{t+1}^r, which is purchased at time t for a gross real return, R_t, at period $t+1$, and also receive transfer, Z_t^r, from the government. In return, the households pay taxes to the government, with τ_t^c, τ_t^w and τ_t^k being the distortionary taxes on consumption, labour income and capital income respectively. ϕ is the adjustment cost parameter and δ is the depreciation rate of capital. The capital adjustment costs, $\phi(.)$, determine the degree to which costly investment spending affects changes in capital stock. At steady state, the function $\phi(.)$ has the property: $\phi(1) = 0$, $\phi'(1) = 0$, and $\phi''(1) > 0$. ε_t^I is the investment-specific technology shock which follows an AR(1) process, such that:

$$\ln(\varepsilon_t^I) = \rho_I \ln(\varepsilon_{t-1}^I) + \epsilon_t^I, \quad \epsilon_t^I \sim NIID(0, \sigma_I). \tag{2.6}$$

Hand-to-mouth Households

The hand-to-mouth (HtM) household maximises a single-period utility function subject to the following budget constraint:

$$(1+\tau_t^c)C_t^h = (1-\tau_t^w)W_t N_t^h + Z_t^h \tag{2.7}$$

In each period, they consume their labour income, $W_t N_t^h$, which is augmented with lump-sum government transfers, Z_t^h, as a form of social insurance. HtM households also pay taxes on consumption and labour income, but they do not pay capital taxes since, by construction, they do not own any physical or financial asset.

2.2.2 Firms

Firms operate in a competitive market with the aim of maximizing profits given by

$$\Pi_t = Y_t - W_t N_t - r_t^k K_t. \tag{2.8}$$

At the beginning of each period, firms employ labour, N_t, from both types of households, paying a universal wage, W_t, since there is no discrimination in the labour market. They also rent capital, K_t, from the Ricardian household at a rental cost, r_t^k. Following Cantore & Levine (2012), we assume that the firms apply a CES technology to the combination of inputs to produce output. Compared to the Cobb-Douglas technology which is often employed in business cycle models, this form of production technology is less restrictive and allows for flexible substitutability between capital and labour inputs.[6] The CES production technology is given by:

$$Y_t = \varepsilon_t^a \left[\alpha^{\frac{1}{\nu}} K_t^{\frac{\nu-1}{\nu}} + (1-\alpha)^{\frac{1}{\nu}} N_t^{\frac{\nu-1}{\nu}} \right]^{\frac{\nu}{\nu-1}} \tag{2.9}$$

where $\alpha \in (0,1)$ is the share of capital income, and $\nu \in (0, \infty)$ is the elasticity of substitution between capital and labour. ε_t^a is the technology shock, which follows an AR(1) process given by:

$$\ln(\varepsilon_t^a) = \rho_a \ln(\varepsilon_{t-1}^a) + \epsilon_t^a, \quad \epsilon_t^a \sim NIID(0, \sigma_a). \tag{2.10}$$

The firm's problem is to maximise the profit in equation (2.8) given the level of output defined in equation (2.9). Given that there is no price friction, the firm's profit is zero.

2.2.3 Government

In each period, the government decides on a set of fiscal instruments that satisfy its budget constraint given by:

$$G_t + Z_t + B_t = \tau_t^c C_t + \tau_t^w W_t N_t + \tau_t^k (r_t^k - \delta) K_t + \frac{B_{t+1}}{R_t} \tag{2.11}$$

Rearranging this, the evolution of government debt can be written as:

$$\frac{B_{t+1}}{R_t} = B_t + D_t, \tag{2.12}$$

$$\text{where} \quad D_t = [G_t + Z_t] - \left[\tau_t^c C_t + \tau_t^w W_t N_t + \tau_t^k (r_t^k - \delta^p) K_t \right], \tag{2.13}$$

which states that the discounted level of public debt at the end of period t is the sum of the

[6] Cantore et al. (2017) show that empirical estimates from structural VAR are consistent with real business cycle (RBC) model with less than unitary elasticity of substitution between capital and labour. Also, Cantore et al. (2014) demonstrate that the response of hours depends on the capital-labour substitution elasticity in both New-Keynesian and standard RBC models.

stock of public debt at the beginning of period t and the primary deficit, D_t, in the current period. To ensure stability, a set of fiscal rules is specified to track the time-path of government debt for effective financing, deleveraging and moderation towards the steady state. In designing the fiscal rules, we consider recent experience in the UK, whereby the government is interested in cutting public consumption spending and social transfers, as well as raising taxes on income and wealth. Equipped with these facts, we assume that government consumption spending and transfers are counter-cyclical and respond negatively to public debt, while distortionary taxes on labour and capital income are pro-cyclical and respond positively to government debt. In addition, following the analysis of Kliem & Kriwoluzky (2014), we assume that distortionary taxes on capital and labour income respond mainly to the investment component of the business cycle. We further assume that consumption taxes neither respond to debt nor the business cycle, and that shocks to the taxes are correlated, since fiscal authorities often make decisions on taxes simultaneously. Formally, the following fiscal rules are specified for the UK economy:

$$\ln(G_t) = -\theta_g \ln(B_t) - \omega_g \ln(Y_t) + \varepsilon_t^g \tag{2.14}$$

$$\ln(Z_t) = -\theta_z \ln(B_t) - \omega_z \ln(Y_t) + \varepsilon_t^z \tag{2.15}$$

$$\ln(\tau_t^k) = \theta_{\tau^k} \ln(B_t) + \omega_{\tau^k} \ln(I_t) + \varepsilon_t^{\tau^k} + \chi_{kn}\varepsilon_t^{\tau^w} + \chi_{kc}\varepsilon_t^{\tau^c} \tag{2.16}$$

$$\ln(\tau_t^w) = \theta_{\tau^w} \ln(B_t) + \omega_{\tau^w} \ln(I_t) + \varepsilon_t^{\tau^w} + \chi_{kn}\varepsilon_t^{\tau^k} + \chi_{nc}\varepsilon_t^{\tau^c} \tag{2.17}$$

$$\ln(\tau_t^c) = \varepsilon_t^{\tau^c} + \chi_{nc}\varepsilon_t^{\tau^w} + \chi_{kc}\varepsilon_t^{\tau^k} \tag{2.18}$$

where θ_l and ω_l are the parameters of fiscal adjustments to government debt and business cycle variables respectively. χ_{kc}, χ_{kc} and χ_{kc} are the parameters of the cross-correlations of the tax shocks. ε_t^l are the fiscal policy shocks which follow AR(1) processes given by:

$$\ln(\varepsilon_t^l) = \rho_l \ln(\varepsilon_{t-1}^l) + \epsilon_t^l, \quad \epsilon_t^l \sim NIID(0, \sigma_l), \quad \text{for} \quad l \in (g, z, \tau^c, \tau^w, \tau^k). \tag{2.19}$$

Substituting the fiscal rules in equations (2.14) to (2.19) into the evolution of government debt in equation (2.12), we can derive the steady state stability condition for the model as:

$$|\theta_l| > (1-\beta)\frac{B/Y}{X/Y} \tag{2.20}$$

where $X/Y \in (\frac{G}{Y}, \frac{Z}{Y}, \frac{\tau^w WN}{Y}, \frac{\tau^k(r^k-\delta)K}{Y})$ are the ratios of government spending and tax revenue components to GDP. It is assumed that the government debt is non-zero at steady state.

2.2.4 Market Clearing Conditions

The market clearing condition for the economy implies that the sum of spending by all agents in the economy should be equal to the total output. Hence, the economy-wide resource constraint can be written as:

$$Y_t = C_t + I_t + G_t \tag{2.21}$$

The aggregate value of consumption, labour supply, investment, capital, government debt and transfers in the economy are given by:

$$C_t = (1-\lambda)C_t^r + \lambda C_t^h \tag{2.22}$$
$$N_t = (1-\lambda)N_t^r + \lambda N_t^h \tag{2.23}$$
$$I_t = (1-\lambda)I_t^r \tag{2.24}$$
$$K_t = (1-\lambda)K_t^r \tag{2.25}$$
$$B_t = (1-\lambda)B_t^r \tag{2.26}$$
$$Z_t = (1-\lambda)Z_t^r + \lambda Z_t^h \tag{2.27}$$

Unlike Galí et al. (2007) and Rossi (2014), this paper does not assume steady state equality in consumption across different types of households (see the Appendix for the computation of steady state values).[7] Rather, following Natvik (2012), the steady-state consumption for each type of household is endogenously derived from the model. Since there is no discrimination in the labour market, all households face the same real wage and equality of steady state hours is assumed across households.[8]

2.3 Estimation

To solve the model, we derive the first order solutions to the household's and firm's problems and combine them with the equilibrium conditions and constraints to generate a system of equations. Each equation of the model is then log-linearised, such that the responses of the variables can

[7]Several studies, such as Galí et al. (2007), assume steady-state equality in consumption across households, that is, $C^h = C^r = C$. The problem with this equality assumption is that individual private consumption of different classes of agents are forced to be equal irrespective of their income and wealth differentials at steady-state. For instance, Mankiw (2000) shows that an increase in government debt is a source of steady-state inequality in consumption between spender and saver households, since an increase in public debt implies higher wealth for the Ricardian households. However, this kind of equality constraint may be valid in models with no private capital accumulation and no wage differentials.

[8]As an alternative, Natvik (2012) analyses a case where each class of households belongs to different labour unions, which bargain for different levels of nominal wage on behalf of their members, and supplying different units of labour hour at steady state.

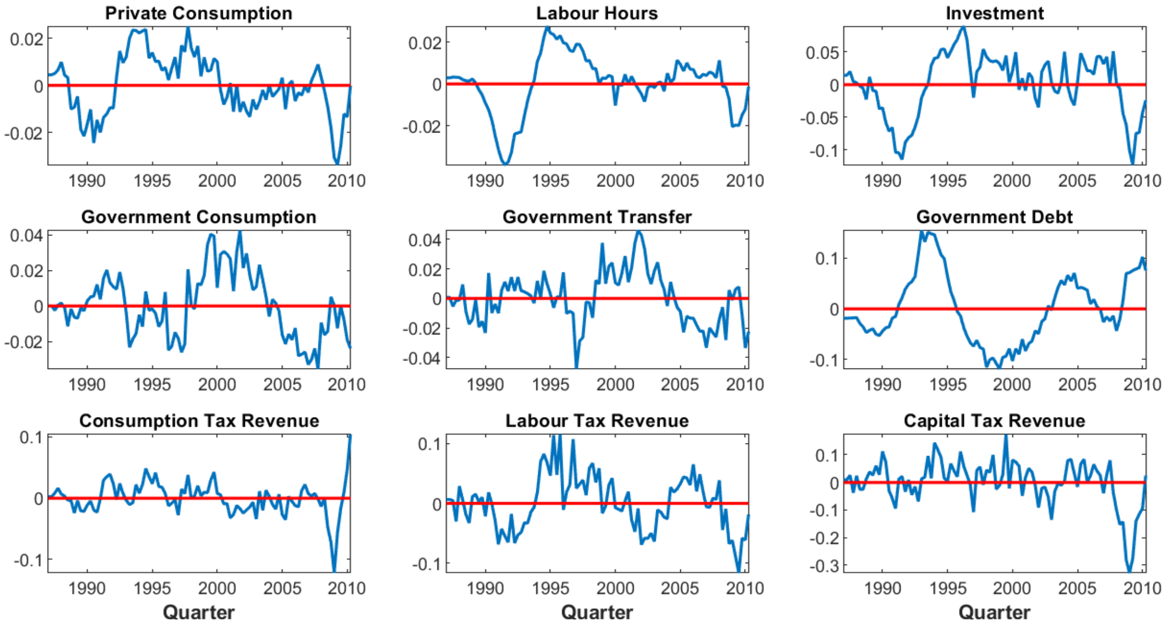


Figure 2.2: **The Observables (1987:Q1 – 2010:Q2)**.
Notes: This figure shows the one-sided HP-filtered series used in the estimation of this model. The vertical axis measures the percentage deviations from the (stochastic) steady-state, represented by the zero-line, while the horizontal axis measures the quarterly period.

be interpreted as percentage deviations from the steady-state. The linearised model (see the Appendix) is then estimated using the Bayesian estimation techniques as described by An & Schorfheide (2007).

2.3.1 Data and Estimation Procedure

The model is estimated on quarterly UK time series for the period 1987:Q1 – 2010:Q2, a total of 94 observations. The start period is motivated the availability of quality quarterly series, especially the government debt and fiscal data which are only available from 1987. The end period coincides with the period before the implementation of recent consolidation policy in the UK. In line with the standard practice in the literature, we exclude the recent period of consolidation (that is, post-2010:Q2) from the baseline estimation to avoid possible biasness.[9] In Section 2.4.5, we check the sensitivity of the estimated parameters to the consolidation era by extending the data period to 1987:Q1 – 2015:Q3 (a total of 115 observations). Nine variables are included in the model estimation: private consumption, hours worked, investment, government debt, government consumption, government transfers, consumption tax revenue, capital tax revenue and labour tax revenue. The data are collected from the online database of the Office for National Statistics (ONS). Since we are estimating a real business cycle model, all variables

[9]Recent empirical papers on fiscal policy often cut their data period before the financial crisis era in order to avoid possible biasness associated with that period. For instance, Corsetti & Müller (2014) estimate the effect of US government spending for the period 1980:Q1 to 2007:Q4, thereby cutting off the crisis period.

are expressed in per capita real terms using GDP price deflator and the active population (age 16 to 59/64). In line with the suggestion of Pfeifer (2018), the adjusted series are de-trended using the one-sided HP-filter and the filtered series are demeaned.[10]

Figure 2.2 shows the stochastically de-trended series of the observables. From the figure, it can be observed that during the financial crisis, all macroeconomic variables fell below their trend levels, with total investment and government revenues (especially capital tax revenue) witnessing much larger falls compared to other variables. On the other hand, the government-initiated bailout plans aimed at stemming the effects of the crisis led to a rise in government debt above its trend level, which confirms the earlier argument in this paper. On average, government debt tends to be highly persistent with large changes over time; whereas, tax revenues are less persistent.

The model is initially estimated in three different versions, inclusive of all fiscal instruments: the baseline model with estimated share of rule-of-thumb households ($\lambda \in (0, 0.5)$), the standard representative agent model with no rule-of-thumb behaviour ($\lambda = 0$), and the model with equal proportion of rule-of-thumb consumers ($\lambda = 0.5$) as it is the case in most existing analytical studies. Thereafter, the preferred model is re-estimated to include only a specific choice of fiscal instruments permitted to respond to debt; that is, government consumption only, government transfer only and taxes only.

To estimate the model, the observables (the detrended variables) are mapped directly to the model variables. Then, the data likelihood and prior are combined to maximise the log posterior function, followed by the initiation of the Metropolis-Hasting (MH) algorithm which samples from the posterior distribution using 1,000,000 draws over two chains, with the first 200,000 draws used as the burn-in period. The MH jump-scale (step-size) is sufficiently tuned up to give an average acceptance rate of about 30%, which is comfortably within the expected band of 25-33% (see Adjemian et al. (2011)). Finally, the Brooks & Gelman (1998)'s convergence diagnostics is performed to ensure that the Monte Carlo Markov Chains (MCMC) converge to unique posterior value.

2.3.2 Calibration

Table 2.1 presents the values assigned to calibrated parameters and steady state ratios. These parameters are kept constant because the observables cannot uniquely estimate many free

[10] The latter process of demeaning is necessary because detrended data from one-sided HP-filter have non-zero sum. In fact, in most cases, estimation results from the non-demean filtered series always show evidence of unit-roots and serial correlation.

Table 2.1: **Calibrated parameters and steady state ratios**

Parameter or steady-state ratio	Description	Value
Preference		
β	Subjective discount factor	0.9926
ϱ	Public consumption share in CES aggregate	0.25
Technology		
δ	Private capital depreciation rate	0.025
α	Share of capital in production CES	1/3
ν	Capital-labour elasticity of substitution	0.924
Fiscal Policy		
τ^c	Consumption tax rate	0.1976
τ^w	Labour income tax	0.2271
τ^k	Capital income tax	0.3082
G/Y	Government consumption to GDP ratio	0.2016
Z/Y	Government transfers to GDP ratio	0.1091
$B/4Y$	Government debt to GDP ratio	0.4772

Notes: This table shows the calibrated values of selected parameters and steady state ratios in the model. β is calibrated to match the annualised real interest rate of 3%. ϱ is calibrated as the ratio of government consumption spending to the sum of government and private consumption spending. Conditioned on α, ν is calibrated to match steady state investment ratio.

parameters and steady state values. The subjective discount factor, β, is set to 0.9926, implying an annualised real interest rate of 3%. Regarding the productivity of public consumption goods, the share of government consumption in the effective consumption CES, ϱ, is set to 0.25, which is an approximation of the ratio of government consumption to total final consumption for the UK. This value is similar to the one assigned by Coenen et al. (2013) for the Euro Area.

In line with existing literature, the depreciation rate of capital, δ, is set to 0.025, suggesting that capital stock depreciates at an annual rate of 10%. Following the literature on CES production technology, such as Cantore & Levine (2012), the share of capital technology, α, and the elasticity of substitution between capital and labour, ν, are interdependent. Given the model set-up in this paper, α can be computed and interpreted as the capital income share conditioned on the degree of discounting imposed by the substitution elasticity (ν) on the steady state real rental cost, r^k.[11] Given this interaction, we set α to 1/3 - which is the standard

[11] Based on the set-up of the CES production technology in this paper, from the firms' problem, the steady state first order condition for capital can be written as

$$r^k = \left(\alpha \frac{Y}{K}\right)^{\nu}$$
$$\therefore \alpha = \left(r^k\right)^{1/\nu} \frac{K}{Y},$$

which simply shows that ν is a discounting term on r^k, while the capital-output ratio is unaffected by the discounting term.

share of capital in the literature - and then compute the degree of discounting imposed to achieve that value by calibrating ν to match steady state investment-to-GDP ratio of 18.11%. This calibration yields a value of 0.924 for ν. This calibrated value of ν is consistent with the empirical findings of Cantore et al. (2017) which shows that the elasticity of substitution between capital and labour is less than unity, with the estimated mean value ranging between 0.2 and 0.9 (Cantore et al. 2017, p. 150).

Turning to steady state values of the fiscal variables, the distortionary tax rates τ^c, τ^w and τ^k are set to about 20%, 23% and 31% respectively, which are close to the values assigned by Coenen et al. (2013) for the Euro Area. The consumption tax rate is obtained from the definition of consumption tax revenue in the model, which involves dividing the consumption tax revenue by total private consumption. Labour tax rate is set to the average marginal income tax rate for the period. Capital tax rate is set to the average capital gains tax over the sample period. Using the annualised Maastricht consolidated government debt statistics, the quarterly debt-to-GDP ratio is computed to be about 48%. Given these values, the ratio of government transfers to GDP is then calibrated endogenously from the model to be around 11%, which is consistent with the actual data for the UK.

2.3.3 Prior Distributions

The prior distributions of the estimated parameters of the model are presented in columns 1-3 of Table 2.2. The prior means are set in line with existing studies on UK and European economies, including Bhattarai & Trzeciakiewicz (2017), McManus (2015), Coenen et al. (2013) and Christoffel et al. (2008); while the standard errors are set to ensure that the estimated parameter values are within the empirically and theoretically acceptable domain. For the structural parameters, a gamma distribution is assumed for both relative risk aversion, σ, and Frisch labour elasticity, η, with the respective prior means set to 1.75 and 0.50, and standard deviations of 0.50 and 0.10. The habit formation parameter, κ, is assumed to follow a beta distribution with a prior mean of 0.50 and standard deviation of 0.10.

In setting the prior distribution for the proportion of rule-of-thumb households, λ, in the baseline model, this paper relies on the findings of Campbell & Mankiw (1989, 1990, 1991), Chyi & Huang (1997), Kaplan & Violante (2014) and Kaplan et al. (2014). To estimate the proportion of HtM agents in the economy with a range of 0-0.5, we assume that λ follows a beta distribution with a mean of 0.50 and a standard error of 0.10. For the elasticity of substitution between private and public goods, φ, we assume a gamma distribution with a mean of 0.30

Table 2.2: **Prior and Posterior Distributions**

Parameter	Prior distribution			Posterior distribution - Mean [5% and 95%]		
				Baseline	Representative	Gali-type
	Density	Mean	Std.	$\lambda \in (0, 0.5)$	Agent $\lambda = 0$	$\lambda = 0.50$
	(1)	(2)	(3)	(4)	(5)	(6)
A: Structural						
Risk aversion, σ	Gamma	1.50	0.50	1.67 [1.04, 2.35]	1.69 [1.05, 2.36]	1.53 [0.92, 2.15]
Frisch elast., η	Gamma	0.50	0.10	0.37 [0.22, 0.52]	0.33 [0.20, 0.47]	0.44 [0.27, 0.62]
Consump elast., φ	Gamma	0.30	0.10	0.31 [0.21, 0.44]	0.29 [0.18, 0.42]	0.34 [0.22, 0.47]
Habit, κ	Beta	0.50	0.10	0.37 [0.22, 0.52]	0.38 [0.23, 0.52]	0.35 [0.21, 0.50]
Share of HtM, λ	Beta	0.50	0.10	0.26 [0.15, 0.37]		
Adj costs, ϕ	Gamma	4.00	1.25	3.43 [2.11, 4.96]	3.47 [2.12, 4.96]	3.39 [2.02, 4.92]
B: Fiscal Rule						
Govt sp. adj. to B, θ_g	Gamma	0.25	0.15	0.049 [0.006, 0.10]	0.053 [0.007, 0.11]	0.043 [0.005, 0.09]
Transfers adj. to B, θ_z	Gamma	0.25	0.15	0.070 [0.010, 0.14]	0.075 [0.012, 0.15]	0.062 [0.009, 0.12]
Lab tax adj. to B, θ_{τ^w}	Gamma	0.25	0.15	0.100 [0.014, 0.20]	0.116 [0.018, 0.22]	0.082 [0.010, 0.17]
Cap tax adj. to B, θ_{τ^k}	Gamma	0.25	0.15	0.147 [0.016, 0.30]	0.149 [0.016, 0.31]	0.149 [0.015, 0.31]
Govt sp. adj. to Y, ω_g	Gamma	0.40	0.25	0.265 [0.026, 0.54]	0.268 [0.029, 0.55]	0.268 [0.029, 0.55]
Transfer adj. to Y, ω_z	Gamma	0.40	0.25	0.130 [0.008, 0.28]	0.130 [0.010, 0.28]	0.134 [0.010, 0.29]
Lab. tax adj. to I, ω_{τ^w}	Gamma	0.50	0.30	0.269 [0.075, 0.46]	0.258 [0.077, 0.45]	0.269 [0.070, 0.47]
Cap. tax adj. to I, ω_{τ^k}	Gamma	0.50	0.30	0.254 [0.036, 0.50]	0.251 [0.032, 0.49]	0.251 [0.034, 0.49]
Cap/lab co-term, χ_{kn}	Normal	0.00	0.20	0.093 [0.007, 0.18]	0.093 [0.006, 0.18]	0.091 [0.004, 0.18]
Cap/cons co-term, χ_{kc}	Normal	0.00	0.20	0.042 [-0.025, 0.11]	0.043 [-0.023, 0.11]	0.041 [-0.026, 0.11]
Lab/cons co-term, χ_{nc}	Normal	0.00	0.20	-0.002 [-0.098, 0.09]	-0.004 [-0.098, 0.09]	-0.004 [-0.099, 0.09]
C: AR(1) Coef.						
Preference, ρ_u	Beta	0.50	0.20	0.39 [0.25, 0.52]	0.37 [0.23, 0.50]	0.42 [0.29, 0.54]
Labour supply, ρ_n	Beta	0.50	0.20	0.94 [0.88, 0.99]	0.94 [0.88, 0.99]	0.94 [0.87, 0.99]
Inv-specific, ρ_i	Beta	0.50	0.20	0.11 [0.01, 0.22]	0.11 [0.01, 0.22]	0.12 [0.02, 0.23]
Technology, ρ_a	Beta	0.50	0.20	0.88 [0.78, 0.97]	0.89 [0.79, 0.97]	0.87 [0.77, 0.96]
Govt Sp., ρ_g	Beta	0.50	0.20	0.77 [0.63, 0.91]	0.77 [0.63, 0.91]	0.78 [0.64, 0.91]
Transfer, ρ_z	Beta	0.50	0.20	0.70 [0.54, 0.86]	0.69 [0.53, 0.85]	0.71 [0.55, 0.86]
Consump. tax, ρ_{τ^c}	Beta	0.50	0.20	0.65 [0.47, 0.83]	0.64 [0.45, 0.83]	0.66 [0.48, 0.84]
Cap. tax, ρ_{τ^k}	Beta	0.50	0.20	0.61 [0.44, 0.76]	0.60 [0.43, 0.76]	0.62 [0.46, 0.78]
Lab. tax, ρ_{τ^w}	Beta	0.50	0.20	0.43 [0.23, 0.62]	0.42 [0.23, 0.61]	0.46 [0.26, 0.66]
D: Std. of Shocks						
Preference, σ_u	Inv. Gam	0.10	2.00	0.041 [0.033, 0.051]	0.039 [0.031, 0.047]	0.047 [0.038, 0.058]
Labour supply, σ_n	Inv. Gam	0.10	2.00	0.031 [0.024, 0.038]	0.033 [0.026, 0.041]	0.028 [0.022, 0.034]
Inv-specific, σ_i	Inv. Gam	0.10	2.00	0.086 [0.056, 0.120]	0.086 [0.055, 0.120]	0.086 [0.055, 0.120]
Technology, σ_a	Inv. Gam	0.10	2.00	0.012 [0.012, 0.013]	0.012 [0.012, 0.013]	0.012 [0.012, 0.013]
Govt sp., σ_g	Inv. Gam	0.10	2.00	0.015 [0.012, 0.017]	0.015 [0.012, 0.017]	0.015 [0.012, 0.017]
Transfer, σ_z	Inv. Gam	0.10	2.00	0.016 [0.014, 0.018]	0.016 [0.014, 0.018]	0.016 [0.014, 0.018]
Consump. tax, σ_{τ^c}	Inv. Gam	0.10	2.00	0.021 [0.018, 0.024]	0.021 [0.018, 0.024]	0.021 [0.018, 0.024]
Cap. tax, σ_{τ^k}	Inv. Gam	0.10	2.00	0.059 [0.051, 0.068]	0.059 [0.051, 0.068]	0.059 [0.051, 0.068]
Lab. tax, σ_{τ^w}	Inv. Gam	0.10	2.00	0.034 [0.029, 0.039]	0.034 [0.029, 0.039]	0.034 [0.029, 0.039]
E: Model Comp.						
Log data density				2004.60	2014.38	1997.41
Bayes factor				1.00	$\exp(-9.78)$	$\exp(7.19)$

Notes: This table presents the prior and posterior distributions of estimated parameters in the baseline model, compared to an alternative representative model with no rule-of-thumb behaviour, and a Galí et al. (2007)-type model with an equal proportion of Ricardian and rule-of-thumb consumers. The values in the brackets are the 5% and 95% posterior intervals. Each variant of the model is estimated using the Bayesian method with 1,000,000 MCMC draws over two chains. 20% of the draws are used for the burn-in period. All the models are estimated on UK data for the period 1987:Q1 – 2010:Q2.

and a standard deviation of 0.10, implying that private and public consumption are close complements as the literature suggests (see Bouakez & Rebei (2007), Coenen et al. (2013), Ercolani & e Azevedo (2014)). The investment adjustment costs parameter, ϕ, is assumed to follow a gamma distribution with a mean of 4.00 and a standard error of 1.25.

The priors for fiscal rule parameters are set to ensure stability of the model as described in equation (2.20). The parameters of fiscal adjustments to government debt, θ_l, are assumed to follow a gamma distribution with a mean of 0.25 and standard deviation of 0.15, which allow them to take on only non-zero values. Similarly, parameters of fiscal adjustments to the business cycle are assumed to follow a gamma distribution. We set a prior mean of 0.40 and a standard deviation of 0.20 for ω_g and ω_z, while ω_{τ^w} and ω_{τ^k} take on a mean of 0.50 and a standard deviation of 0.30. The parameters of the interactions between shocks to distortionary taxes, χ_{ij}, are assumed to follow a normal distribution with zero mean and a standard deviation of 0.20. In line with existing literature, AR(1) coefficients of the exogenous shock processes, ρ_x, are assumed to follow a beta distribution with a prior mean of 0.50 and standard deviation of 0.20, which sufficiently allow the parameters to reflect their level of persistence. Finally, an inverse gamma distribution is assumed for the standard deviation of the shocks, σ_x, with the mean and standard error set to 0.10 and 2.00 respectively.

2.4 Results

In this section, the results of the Bayesian estimation are discussed and the impulse responses for the various specifications of the model are analysed comparatively. Following An & Schorfheide (2007), Canova & Sala (2009), Iskrev (2010) and Ratto & Iskrev (2011), we check the identification strength of the estimated parameters relative to the prior assigned to them in the preceding section. The result shows that all the parameters are uniquely identified, with no serial correlation (see the Appendix for the graphical result). This suggests that each estimated parameter plays a distinctively significant role in the dynamics of the model.

2.4.1 Posterior Distributions

The results of the Bayesian estimation for the baseline model, as well as the two alternative specifications of the model, are presented in columns 4-7 of Table 2.2. The results show the posterior mean for each parameter along with the 5% and 95% posterior intervals in the square brackets. From the table, all the parameters are estimated to be significantly different from zero, except for the comovement terms between capital and consumption taxes, as well as that between labour and consumption taxes. With the exception of the preference shock, investment-specific technology shock and labour tax shock, all other shocks are estimated to be relatively persistent with the autoregressive parameter much higher than the assumed prior mean of 0.5.

We estimate the proportion of hand-to-mouth households, λ, for the UK economy to be about 26% at mean, while the upper bound is about one-third. Our estimate of λ is consistent with a recent report by the Office for National Statistics (2018) which shows that about 26% of all UK households can not make ends meet for more than a month if they lost their main source of income. The estimate is also consistent with figures documented in the literature. For instance, using seasonally adjusted quarterly data for the period 1957:Q2 – 1988:Q2, Campbell & Mankiw (1991) empirically estimate λ to be in the range of 20.1 – 37.2% for the UK. Di Bartolomeo et al. (2011) estimate the proportion of rule-of-thumb consumers in the UK to be 43.3% and 26.1% for the G7 countries (including UK) in a New-Keynesian DSGE model. In a more recent study which utilises micro-level data, Kaplan et al. (2014) estimate the proportion of hand-to-mouth households in the UK to be around one-third. All these previous findings corroborate our results.

For the non-policy structural parameters, all estimated values are relatively the same across the three specifications and are consistent with the estimates in the literature. The estimated value of the intertemporal elasticity of substitution, $\frac{1}{\sigma}$, is less than one in all variants of the model, suggesting that the elasticity of real interest rate to consumption growth is less than one-for-one. Similarly, the Frisch elasticity, η, is between one-third and one-half; the habit stock is estimated to be just about one-third of past consumption level; while the consumption elasticity, φ, is estimated to be around the assumed prior mean of 0.30, suggesting close substitutability of public and private consumption goods. Interestingly, as we move away from a representative agent specification, with no rule-of-thumb behaviour, to a specification in which half of the households are rule-of-thumb consumers, σ decreases from about 1.7 to 1.5 (a 12 percentage point decrease), while η increases from 0.33 to 0.44 (a 33 percentage point increase). This result suggests that, as the proportion of financially constrained households increases, real interest rate becomes less responsive to aggregate consumption growth while aggregate labour effort becomes more responsive to after-tax real wage.

Turning to the fiscal policy parameters, the result shows that all the fiscal instruments respond considerably to government debt. The estimates of the fiscal rule parameters are all positive, since sign restrictions have been imposed on them in equations (2.14) – (2.19). However, the responses of expenditure-based instruments to debt innovations are relatively weaker compared to tax-based instruments, with capital tax rates having the highest response while government consumption has the least response. Comparing the results across model specifications, it can be observed that, at higher values of λ, the parameter estimates of fiscal adjustment to debt diminish in value – most notably for transfers and labour tax rates. This suggests that fiscal instruments targeted at reducing public debt become weaker when the proportion of financially constrained households is higher. The implication of this result is that the achievement of government consolidation targets becomes prolonged as the degree of household's financial constraints intensifies. Furthermore, the responses of fiscal instruments to the business cycle are moderate and relatively stable across specifications. The counter-cyclical response of government spending to output is nearly twice that of transfers, while labour and capital taxes have similar pro-cyclical responses to investment.

Finally, the last panel of Table 2.2 presents some statistics for model comparison across different specifications. The log-marginal data density is computed using the modified harmonic mean estimator of Geweke (1999). The Bayes factor is the ratio of conditional probabilities of observing the data from a given model, which are reflected in the marginal data densities (Koop 2003, Ch. 1, p. 1-4). The Bayes factor for each specification is computed relative to the baseline model; hence, the Bayes factor of one for the baseline specification. From the results presented in Panel E of the table, the Bayes factor favours the representative agent specification with no rule-of-thumb behaviour, but discriminates against models with higher proportion of non-Ricardian households. One possible explanation for this could be that, while introducing non-Ricardian households is one mechanism through which increases in government spending are associated with increases in private consumption (Galí et al. 2007), this mechanism appears to be weak in the data. However, based on the results, we can actually compare the models and say how much preferable the baseline specification is, compared to the counterfactual models.

2.4.2 Impulse Responses

Figures 2.3-2.7 display the estimated impulse responses to a one standard deviation fiscal consolidation shock. The impulse responses are generated from model simulations based on the estimated posterior mean of the parameters. The plots also show how changes in the proportion of financially constrained households influence the dynamic responses of the variables to fiscal shocks. The solid lines, dotted lines and dashed lines represent the mean impulse responses from the baseline model, the representative agent model and the Galí-type model respectively. In each plot, the first row displays the response of the fiscal instrument being analysed as well as aggregate and household-specific consumption responses, the second row displays the responses of the labour market variables, while the third row displays the aggregate macroeconomic and bond market variables. The horizontal axis measures the quarters after the initial impact of the shock, while the vertical axis measures the percentage deviation from steady state or percentage

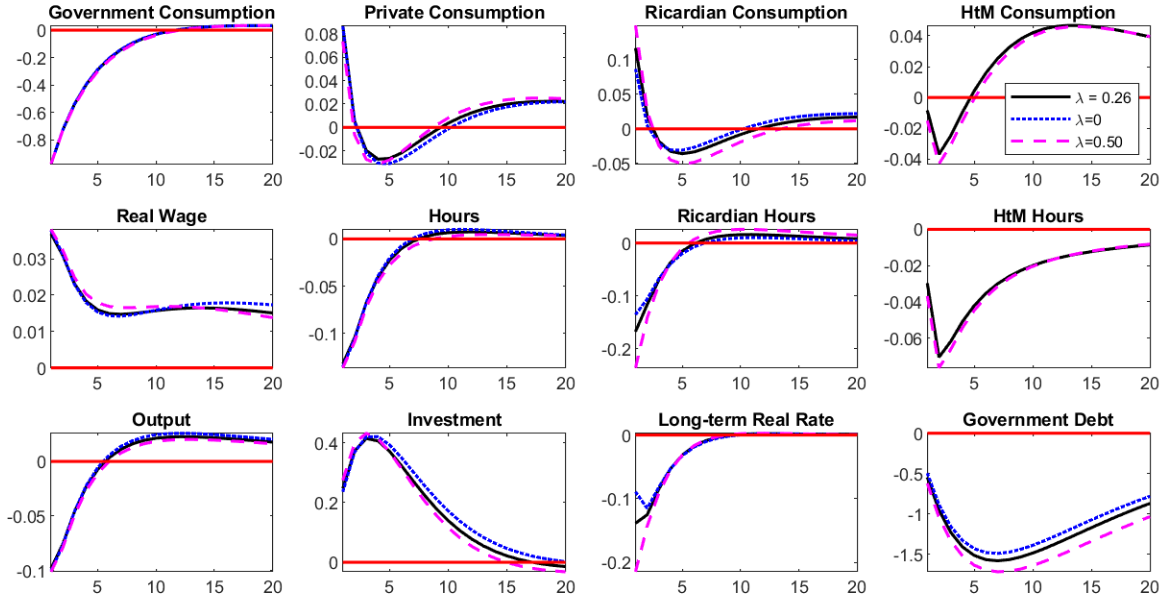


Figure 2.3: **Estimated Impulse Responses to a One Standard Deviation Decrease in UK Government Consumption Spending.**
Notes: Solid line denotes mean impulse response from the baseline model with estimated $\lambda = 0.26$. Dotted line denotes the representative model with $\lambda = 0$, while the dashed line denotes the model with equal proportion of Ricardian and HtM consumers, that is $\lambda = 0.50$.

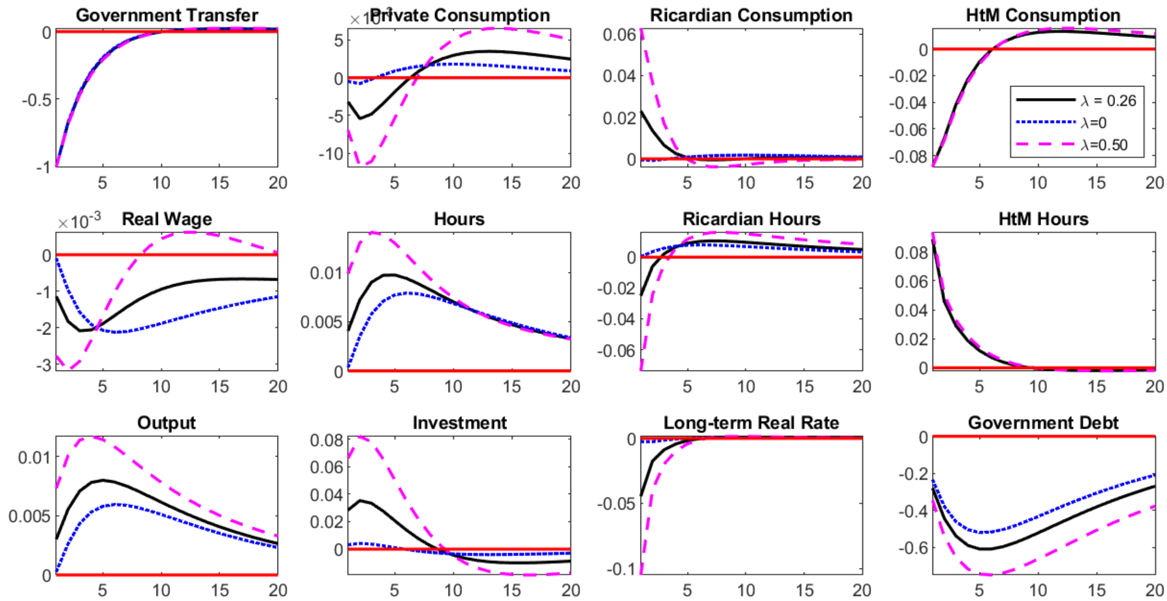


Figure 2.4: **Estimated Impulse Responses to a One Standard Deviation Decrease in UK Government Transfers.**
Notes: See Figure 2.3

points deviation for long-term real rate.

Figure 2.3 shows the effect of a spending cut in government consumption. Private consumption initially rises on impact, but then falls below its steady state level after the second quarter until the end of the consolidation in the third year before rising again.[12] The response of private consumption is driven by two forces: the substitution effect of a public spending cut which drives up private consumption on impact and the complementarity effect of productive government spending which drives the subsequent fall. Aggregate labour effort falls while real wage rises, thereby causing output to fall contemporaneously. Also, government debt falls in response to the spending cuts, leading to a sharp fall in long-term real interest rate. The fall in real rate crowds-in private investment, which in turn improves the marginal productivity of labour, and leads to output expansion after six quarters. This result confirms the findings of Ercolani & e Azevedo (2014) that government spending shock has a counter-cyclical effect on private consumption, but negates the results of Bouakez & Rebei (2007) and Galí et al. (2007) which observed a pro-cyclical response of private consumption to government spending shock.

Turning to household-specific responses, Ricardian consumption rises on impact and then falls after two quarters in a pattern similar to the response of aggregate consumption. On the other hand, government spending cut crowds out the consumption of hand-to-mouth households on impact, but the effect is reversed after one year. The result shows that the complementarity effect of government consumption dominates the substitution effect in HtM effective consumption bundle in the short run. Also, government spending cut discourages labour effort in both households, but the decline in Ricardian labour effort is about three times as much as that of HtM households. While Ricardian hours marginally rises above its steady state level after six quarters, HtM hours persistently remain below its potential level for at least five years. Also, while non-Ricardian consumption comoves with government consumption response, Ricardian and aggregate consumption responses move in opposite directions. This result is in line with the findings of Coenen & Straub (2005) which show that, in response to government spending shock, Ricardian consumption accounts for most changes in aggregate consumption.

Figure 2.4 plots responses to a spending cut in government transfers aimed at financing public debt innovations. Consumption falls on impact while hours rise, implying that government transfer has distortionary effects. However, output rises across all horizons suggesting an expansionary effect of fiscal consolidation. Long-term real rate falls as government's borrowing falls. The relative degree of household's financial constraints significantly influences the dynamic responses of aggregate variables to debt innovations induced by transfer cut. The larger the share of rule-of-thumb consumers, the higher the impact and amplification effects of the shock, and the more persistent is the responses of key macroeconomic variables. Specifically, the output multiplier effect of government transfer increases with the share of rule-of-thumb

[12]Note that government consumption spending adjusts close to its steady state level by the third year.

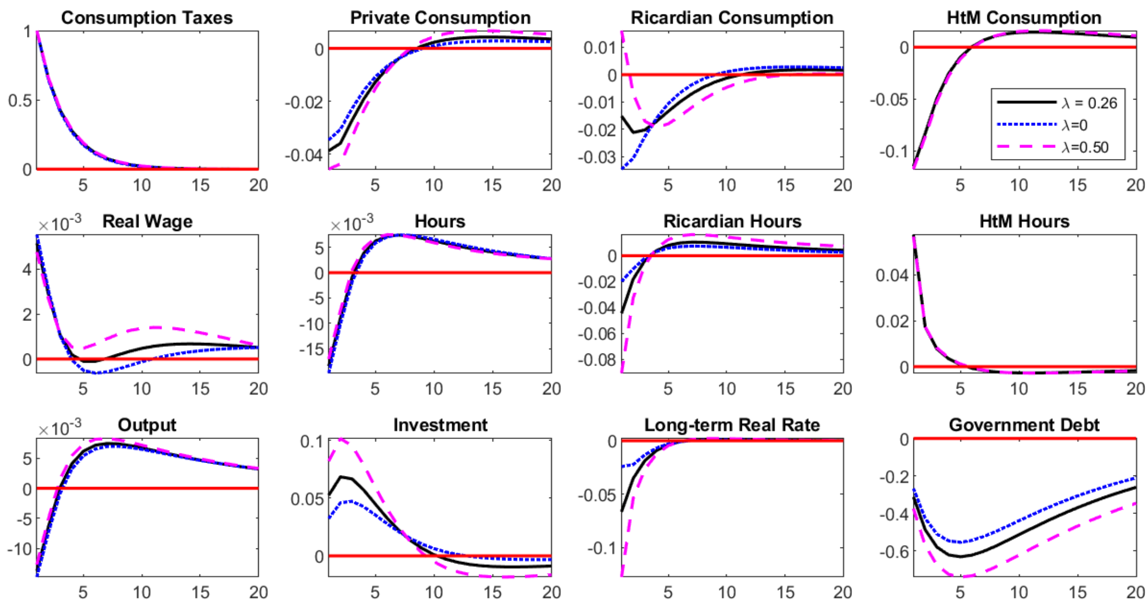


Figure 2.5: **Estimated Impulse Responses to a One Standard Deviation increase in the Consumption Tax Rate.**
Notes: See Figure 2.3

consumers. This result is in line with the findings of Drautzburg & Uhlig (2015) which show that the proportion of government transfers to the financially constrained households influences the fiscal multiplier. Since government transfers constitute a major part of HtM household income, HtM consumption falls significantly in response to transfer cuts, while their labour effort rises to compensate for the loss of unearned income.[13] On the other hand, Ricardian consumption rises in the first year, while labour effort falls. This is because, for Ricardian households, public transfer to the HtM households is equivalent to a lump-sum tax.

The effect of a rise in consumption tax rate is displayed in Figure 2.5. As the theory suggests, both aggregate and household-specific consumption fall in the short run, investment rises and aggregate hours fall, which in turn causes output to fall on impact. However, the dynamic responses of household-specific consumption and employment differ considerably. On impact, HtM consumption falls by more than twice the decrease in aggregate consumption, causing them to work more in order to boost their consumption level. The increased hours pay off after a year as HtM consumption rises above its trend level. On the other hand, the rise in consumption tax rate is sufficient to discourage Ricardian labour effort on impact, but this effect is reversed after three quarters. Also, as the proportion of financially constrained households rises, Ricardian households increase their investment in capital goods as real rate falls even more, thereby motivating them to substitute more labour for leisure, which translates into

[13]Note that the government transfers analysed in this paper are unearned income to the households. They are synonymous to 'social benefit other than social transfer' in the 2008 System of National Accounts.

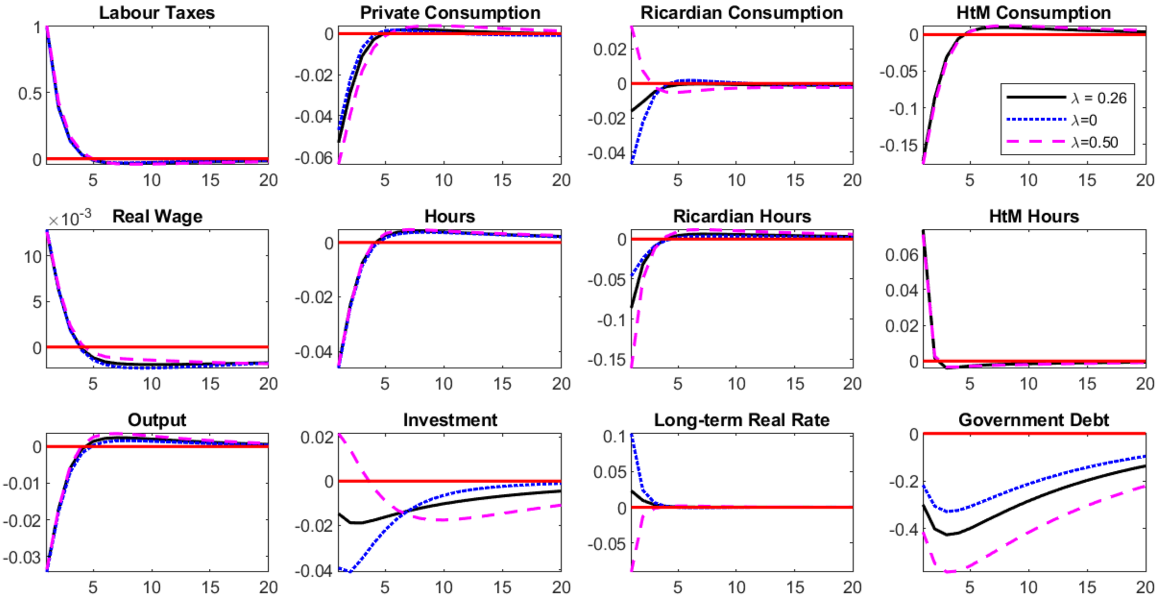


Figure 2.6: **Estimated Impulse Responses to a One Standard Deviation increase in the Labour Tax Rate.**
Notes: See Figure 2.3

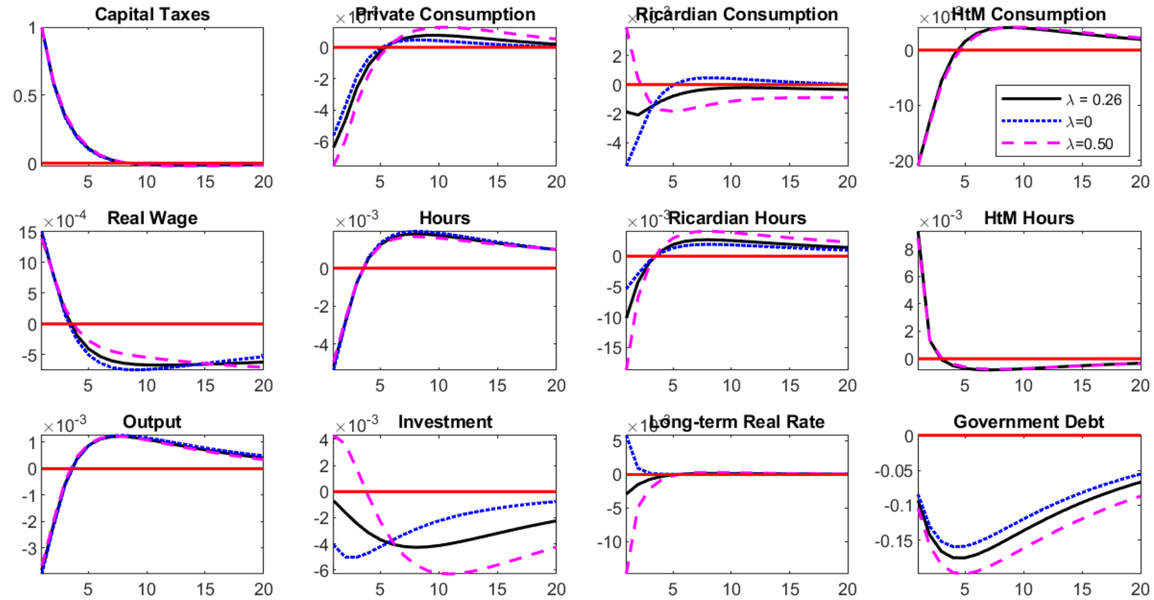


Figure 2.7: **Estimated Impulse Responses to a One Standard Deviation increase in the Capital Tax Rate.**
Notes: See Figure 2.3

higher Ricardian consumption response on impact.[14] Furthermore, as λ increases, government debt response is amplified across all horizons, while the response of real wage is amplified in the medium-run.

In Figure 2.6, a rise in tax rate on labour income discourages labour efforts due to the

[14] See also Figures 2.6 and 2.7.

negative wealth effect of distortionary taxes. As a result, output falls while real wage rises as the demand for labour outweighs supply. Aggregate and household-specific consumption also fall as after-tax income declines. Compared to Ricardian households, HtM consumption falls much more – by about three times the initial decrease in aggregate consumption, causing HtM labour effort to rise on impact to compensate for the loss in after-tax income. On the other hand, the increase in labour tax is strong enough to discourage Ricardian labour efforts, which outweighs the positive response of HtM labour effort; hence, the decline in aggregate labour effort. The positive interaction between capital and labour tax shocks further interacts with the low labour supply to dampen the marginal productivity of capital, thereby causing investment to fall, though the impact effect is dependent on the size of λ through its effect on long-term real rate.

Figure 2.7 reports responses to a rise in capital tax rate. As capital and labour taxes are correlated, a rise in capital tax rate causes aggregate consumption and hours to fall on impact. The fall in labour supply reinforces the negative effect of a rise in capital taxes on the demand for new capital goods, causing output to contract. However, output rises in the medium run as the marginal productivity of labour improves. Given the response of hours, real wage rises on impact but falls as employment increases. This result is in line with the findings of Leeper, Plante & Traum (2010) which shows that an increase in capital tax rates crowds out private consumption, investment, employment and output. Regarding household-specific responses, HtM consumption falls while HtM hours rises in response to a rise in capital tax rate. On the other hand, the relative degree of household's financial constraints drives the responsiveness of Ricardian households to capital taxes: as λ becomes larger, Ricardian households work less and consume more, while spending more on investment goods as long-term real rate falls even more.

Comparing the results across various instruments, in response to debt innovations, labour tax rate is relatively less persistent, dying out after just a year, compared to other fiscal instruments that return to steady state level after two to three years. In line with the findings of Erceg & Lindé (2013), Pappa et al. (2015) and Alesina, Barbiero, Favero, Giavazzi & Paradisi (2015) and Alesina, Favero & Giavazzi (2015), our results show that expenditure-based consolidations are less costly in terms of output loss compared to tax-based consolidation. However, in contrast to their findings, fiscal consolidation based on cuts in government consumption spending tends to be more costly in the short run compared to other fiscal instruments. In cumulative terms, fiscal consolidation based on labour tax hike tends to be costlier compared to any other fiscal instrument since it does not lead to output expansion in the medium run after the initial output contraction. Hence, the cumulative multiplier effect of a labour tax hike remains negative both in the short and long runs. Comparing the response of government debt to a one-standard deviation shock to each fiscal instrument, our results show that, for the UK economy, expenditure-based fiscal adjustments have much larger effects on government debt in the short-run compared to tax-based fiscal adjustments. More so, irrespective of the choice of fiscal instrument, the larger the proportion of HtM consumers in the economy, the more amplified and persistent is the response of government debt.

In summary, the above results show that household agents respond quite differently to government debt-financing strategies. Irrespective of the choice of fiscal instrument, the Ricardian households work less and consume more compared to the HtM households. One way to interpret this result is that government's fiscal financing of public debt, which is solely held by the Ricardian households, translates into higher interest-income on government bond for the Ricardian households. This, in turn, raises the level of Ricardian consumption, causing leisure to rise while labour hour falls. On the other hand, in response to consolidation shocks, HtM agents intensify their labour efforts in order to meet up with their current consumption level.

2.4.3 Alternative Fiscal Consolidation Strategies

To further investigate the results reported in the previous section, we re-estimate the baseline model under various alternative fiscal arrangements. Following Leeper, Plante & Traum (2010), we examine cases where only government spending, only transfers or only the taxes respond to government debt innovations. The estimated posterior mean of parameters in these alternative specifications are reported in column 7-9 of Table 2.3, while the impulse responses based on the estimated results are displayed in Figures 2.8 and 2.9. The reported results in Table 2.3 shows that the estimated parameters of the three alternative specifications are qualitatively similar to those in the baseline model. Even the fiscal adjustment parameters in the alternative models with individual policy instrument are quite close to that of the baseline model with all fiscal instruments inclusive, save for marginal differences.

In Figures 2.8 and 2.9, the estimated impulse responses to government consumption spending shocks are displayed in the first row, responses to transfer shocks are displayed in the second row, while the third and fourth rows display the impulse responses to labour and capital tax shocks respectively. Solid lines denote impulse responses from the baseline model with all fiscal instruments simultaneously responding to government debt innovations. Dotted lines, dashed lines and dotted-dashed lines respectively denote specifications in which only government con-

Table 2.3: **Further Results**

Parameter	Govt Spending only Adjust (7)	Transfer Only Adjust (8)	Taxes Only Adjust (9)	$\varrho = 0$ (10)	$\varrho = \lambda = 0$ (11)	Extended Data (12)
A: Structural						
σ	1.65	1.69	1.68	1.83	1.88	1.78
η	0.35	0.36	0.36	0.38	0.34	0.35
φ	0.34	0.30	0.30	–	–	0.32
κ	0.37	0.36	0.37	0.35	0.36	0.36
λ	0.27	0.27	0.27	0.26	–	0.24
ϕ	3.43	3.36	3.40	3.33	3.44	3.18
B: Fiscal Rule						
θ_g	0.053	–	–	0.052	0.056	0.042
θ_z	–	0.077	–	0.069	0.074	0.062
θ_{τ^w}	–	–	0.099	0.098	0.114	0.102
θ_{τ^k}	–	–	0.150	0.145	0.146	0.136
ω_g	0.238	0.258	0.261	0.236	0.234	0.213
ω_z	0.127	0.131	0.128	0.130	0.131	0.113
ω_{τ^w}	0.252	0.259	0.268	0.270	0.261	0.224
ω_{τ^k}	0.240	0.244	0.252	0.251	0.250	0.257
χ_{kn}	0.083	0.081	0.093	0.097	0.098	0.068
χ_{kc}	0.045	0.044	0.041	0.043	0.044	0.046
χ_{nc}	0.002	0.002	-0.002	-0.004	-0.004	-0.008
C: AR(1) Coefficients						
ρ_u	0.40	0.38	0.38	0.33	0.32	0.36
ρ_n	0.93	0.94	0.94	0.93	0.93	0.95
ρ_i	0.11	0.12	0.12	0.12	0.11	0.10
ρ_a	0.88	0.88	0.88	0.88	0.89	0.88
ρ_g	0.77	0.79	0.79	0.78	0.78	0.79
ρ_z	0.69	0.70	0.69	0.70	0.69	0.70
ρ_{τ^c}	0.65	0.65	0.65	0.65	0.64	0.61
ρ_{τ^k}	0.58	0.60	0.61	0.60	0.59	0.58
ρ_{τ^w}	0.41	0.42	0.43	0.42	0.41	0.45
D: Std. of Shocks						
σ_u	0.041	0.042	0.042	0.039	0.036	0.039
σ_n	0.031	0.031	0.031	0.030	0.032	0.029
σ_i	0.086	0.085	0.085	0.084	0.086	0.076
σ_a	0.012	0.012	0.012	0.012	0.012	0.012
σ_g	0.015	0.015	0.015	0.015	0.015	0.014
σ_z	0.016	0.016	0.016	0.016	0.016	0.015
σ_{τ^c}	0.021	0.021	0.021	0.021	0.021	0.021
σ_{τ^k}	0.059	0.059	0.059	0.059	0.059	0.064
σ_{τ^w}	0.034	0.033	0.034	0.034	0.034	0.031
E: Model Comparison						
Log-marginal data density	2010.24	2011.86	2011.57	2004.62	2013.82	
Bayes factor	$\exp(-5.64)$	$\exp(-7.26)$	$\exp(-6.97)$	$\exp(-0.02)$	$\exp(-9.22)$	

Notes: This table presents the posterior mean of other variants of the baseline specification. Columns 7-8 report the estimation results of alternative fiscal strategies where government spending only, transfer only or taxes only adjust to government debt. Column 10 reports the result for the model with no government-in-utility, while column 11 reports the result for the model with no government-in-utility and no rule-of-thumb behaviour. Column 12 reports the result for the baseline model estimated on an extended dataset that include the period of fiscal consolidation, that is, 1987:Q1-2015:Q3.

sumption adjusts, only transfers adjust, and only taxes adjust to debt innovations. From these figures, the choice of fiscal consolidation strategy seems to have some influence on the dynamics of macroeconomic variables. The responses of output, consumption, investment and hours are very sensitive to the choice of fiscal strategy, especially when responding to transfer and labour tax shocks, while only investment is sensitive to the choice of fiscal strategy when responding

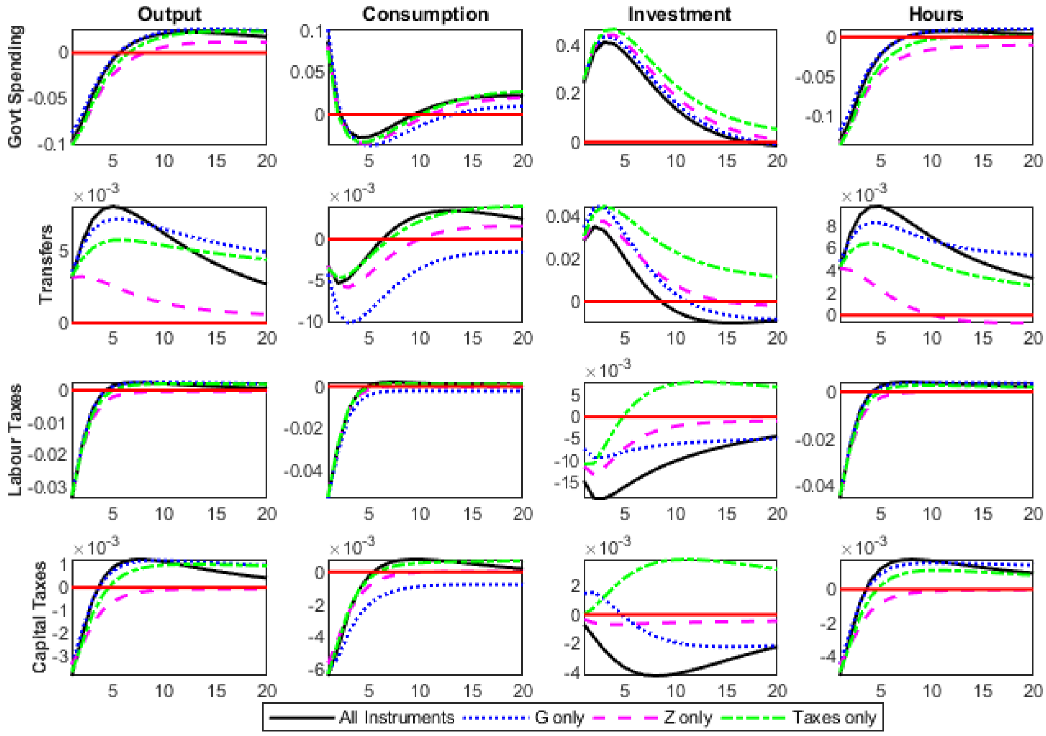


Figure 2.8: **Estimated Economy-Wide Responses to Consolidation Shocks under Alternative Fiscal Strategies.**
Notes: Solid lines denote baseline model with all fiscal instruments simultaneous adjust to debt innovations. Dotted lines, dashed lines and dotted-dashed lines denote the specifications in which only government consumption spending adjusts, only government transfer adjusts, and only taxes adjust to debt innovations respectively.

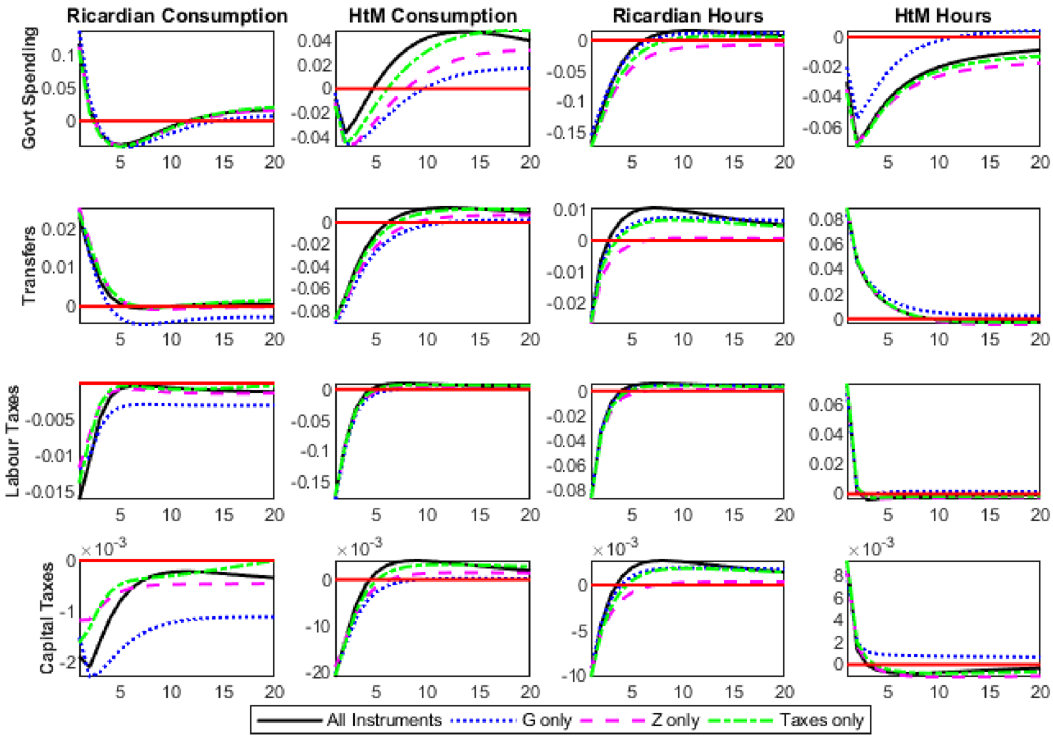


Figure 2.9: **Estimated Household-Specific Responses to Consolidation Shocks under Alternative Fiscal Strategies.**
Notes: See Figure 2.8.

to labour taxes. Responses of the variables to government spending shock are less sensitive to the choice of consolidation strategy. One possible explanation for this result could be the distortionary nature of taxes and transfer spending (automatic stabilisers) in our model. Since these automatic stabilisers are important components of government budget used in dampening business cycle fluctuations, macroeconomic variables respond accordingly to the choice of these instruments in financing government debt.

Meanwhile, irrespective of the consolidation shock hitting the economy, responses of output and hours are much lower when only transfer adjusts to debt innovations. Consumption is much lower when only government consumption spending adjusts to debt, which is possibly due to the complementarity effect of public consumption in households' effective consumption bundles. Surprisingly, the response of investment to all fiscal shocks is relatively higher and positive at most horizons when only taxes respond to government debt. Leeper, Plante & Traum (2010) find similar results and argue that agents' anticipation of a future decrease in taxes is the key driver of the positive response of investment to distortionary tax shocks.[15]

Furthermore, from Figure 2.9, the response of Ricardian consumption tends to be relatively smaller in the medium run when only government consumption adjusts to public debt, while the response of Ricardian labour effort is marginally smaller when only transfer adjusts to debt innovations. On the other hand, HtM households are relatively insensitive to the choice of consolidation strategy except when responding to government spending shock. In response to a negative government spending shock, HtM consumption decreases relatively more while HtM hours fall relatively less when only government consumption spending adjusts to debt innovations.

To conclude, macroeconomic variables are sensitive to the choice of fiscal strategy adopted to deleverage government debt. Hence, government should selectively adopt fiscal strategies that minimise output loss and have lower impact on consumption and labour preference decisions of different types of households. This can be achieved by specifically targeting economic sectors or household income-groups that are less sensitive or indifferent to a particular fiscal instrument.

2.4.4 Fiscal Consolidation and the Time-Path of Government Debt

In this section, the time-path of debt, as financed by alternative consolidation strategies, is discussed. Figure 2.10 display the proportion of a one-unit innovation in government debt in quarter t financed by each fiscal instrument in period $t + M$, where M represents the quarters

[15] See Figs 4 and 5 in Leeper, Plante & Traum (2010).

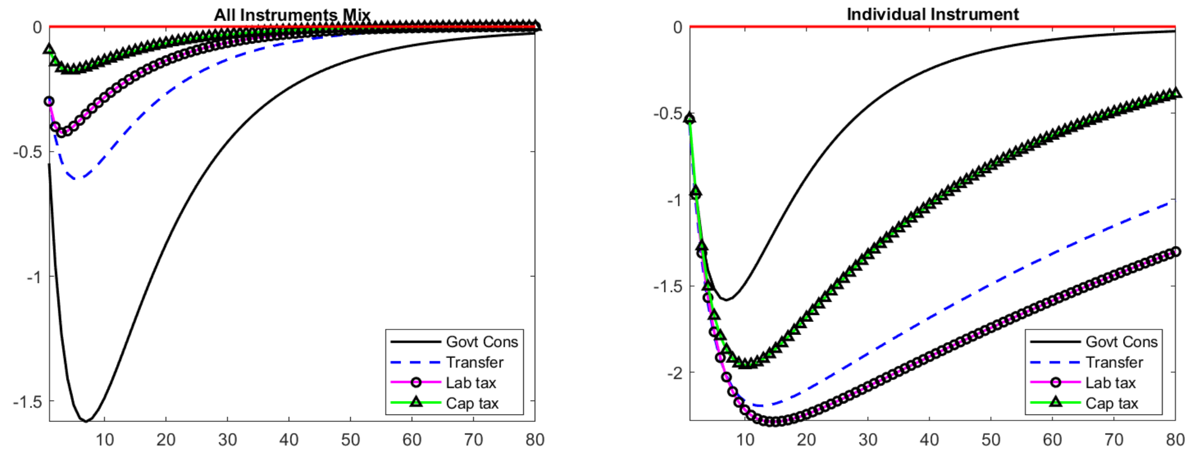


Figure 2.10: **Time-path of Government Debt under Alternative Consolidation Strategies.**
Notes: This figure plots the response of government debt to one standard deviation consolidation shocks under alternative fiscal strategies. The left panel plots government debt responses from the baseline model with all instruments simultaneously adjusting to debt innovations, while the right panel plots responses from the alternative models with only specific fiscal instruments adjusting to debt.

on the horizontal axis. Given the earlier findings of this paper, we considered only variants of the baseline model with estimated proportion of rule-of-thumb households in this section. The figure shows the time-path of government debt in the baseline model with all fiscal instruments simultaneously adjusting to government debt (the left panel) compared to cases where only specific fiscal instruments adjust to government debt (the right panel). Solid lines, dashed lines, bubble lines and diamond lines represent fiscal adjustment of government consumption, transfers, labour taxes and capital taxes to government debt respectively.

Evidence from Figure 2.10 shows that the deleveraging of government debt takes a considerable period of time to be fully financed. From the left panel of the figure, it takes about 12 to 15 years for debt innovations induced by distortionary fiscal instruments (taxes and transfers) to be fully financed, and about 20 – 23 years for debt innovations induced by government consumption spending in the baseline model. This result is not quite surprising as earlier simulated results show that tax hikes significantly affect both the supply (discourages labour supply and crowds-out investment) and the demand (reduced households income and consumption) sides of the economy, thereby causing more leakages in order to finance government debt within a short period of time; whereas, spending cuts on government consumption and transfers mainly affect the demand side. As a result, the peak effects of spending-induced debt innovation are much stronger in the short run, while the rest are gradually financed over a longer horizon.

The right panel of Figure 2.10 shows that fiscal financing of debt innovation involves a relatively different approach and takes much longer time when individual fiscal instruments are considered to finance debt innovations. Compared to the gradualist approach in the baseline model, the models with individual distortionary fiscal adjustments seem to adopt a stronger cold-turkey approach within the first 2-5 years and a perpetual gradualist approach afterwards; whereas, debt innovations induced by only government spending initialised from the same position as in the baseline model with all instruments, and is fully financed within the same 20 – 23 years. This result shows that models in which distortionary fiscal instruments individually adjust to debt innovation are less tenable for policy purpose for a social planner constrained by medium run deleveraging targets.

In summary, the results of this analysis suggest that the speed of fiscal-financing of debt innovation depends on the adopted consolidation strategies and the extent to which such fiscal instruments affect households' preference decisions and macroeconomic productivity.

2.4.5 Further Sensitivity Analysis

We further check the sensitivity of estimated parameters to different specifications of our model and to data sample. Specifically, we consider the standard RBC models in which government consumption spending does not directly affect household preferences (that is, no government consumption in utility), both with or without the assumption of rule-of-thumb behaviours among some households. The estimated posterior mean of the parameters of these models are presented in Columns 10 and 11 of Table 2.3. The results show that all common parameters across the various specifications are qualitatively similar, except for the coefficient of relative risk aversion (CRRA) which is slightly larger in models with no government in utility. Surprisingly, the Bayes factor is relatively indifferent between the richer models with more parameters, as reported in Columns 4 and 5 of Table 2.2, and the corresponding parsimonious models with no government-in-utility.

Furthermore, the baseline model is re-estimated on an extended dataset that covers the period of fiscal consolidation in the UK after the financial crisis, that is, 1987:Q1-2015:Q3. The aim of this analysis is to check whether the estimated parameters are sensitive to the data sample. The result of this exercise is reported in Column 12 of Table 2.3 and they are directly comparable to the baseline results, save for slight differences in the CRRA and fiscal rule parameters. This suggests that the estimated parameters of our baseline model are robust to data sample and relatively stable over time. It is worth noting that the log data density of the model with extended data is not directly comparable to that of the baseline model since the two results are not obtained from the same data distribution.

2.5 Conclusion

Motivated by the recent trends of consolidation policies across Europe after the global financial crisis, this paper examines the effect of government debt financing strategies on the macroeconomy and its interaction with the degree of household's financial constraints. Building on the neoclassical growth model of Leeper, Plante & Traum (2010), we develop a business cycle model which features real frictions, such as rule-of-thumb behaviours to capture the degree of financial constraints among households, habit formation that accounts for the role of permanent consumption, investment adjustments costs, and a robust fiscal sector in which government consumption spending directly influences households' preference decisions and government transfers have distortionary effects. The model includes nine (four structural and five fiscal) shocks and is estimated on nine quarterly UK time series using Bayesian methods.

Three lessons stand out from our analysis:

1. Different types of households respond differently to fiscal policy shocks. Irrespective of the choice of debt-consolidation strategy, financially constrained households consume less while working more, compared to the unconstrained households. This implies that government's policies aimed at deleveraging public debt do not affect all households equally; hence, fiscal policy analyses based on representative agent models need to be reassessed. Also, based on our results, the common assertion among policy makers that "we are all in this together" can not be substantiated.

2. The degree of household's financial constraints plays a significant role in fiscal policy transmission and the achievement of debt consolidation. Specifically, the adjustments of fiscal instruments to government debt become weaker as the proportion of financially constrained households increases. This implies that the achievement of government consolidation targets becomes prolonged as household's financial constraints intensify.

3. The choice of fiscal instrument mix influences the dynamic response of macroeconomic variables to debt innovations, and this has implications for the achievement of debt consolidation. Our results favour models in which the government adopts a mix of spending cuts and tax hikes, compared to models with only spending cuts or only tax hikes.

In conclusion, this paper shows that the responses of different types of households to fiscal consolidation shocks vary considerably, depending on the degree of financial constraints they face; and this, in turn, affects the overall debt-consolidation plan of the government. Therefore, to achieve a growth-consistent debt consolidation plan, government should be cautious in implementing stringent fiscal policies. Rather than implementing a universal policy, which may hurt the economy, the government should selectively target distinct economic sectors and consumer groups that are less sensitive to specific fiscal instruments. Given the implications of our results that the income of financially constrained households falls more following fiscal consolidation, government should provide easier access to credit for financially constrained families.

Appendix

I: Linearised Solution of the Model

[Ricardian Household: Marginal Utility of Consumption]

$$\frac{(-\sigma)}{1-\kappa}\,\hat{\tilde{C}}_t^r + \frac{\sigma\,\kappa}{1-\kappa}\,\hat{\tilde{C}}_{t-1}^r + \frac{1}{\varphi}\,\left(\hat{\tilde{C}}_t^r - \hat{C}_t^r\right) = \hat{\mu}_t^r + \frac{\tau^c}{1+\tau^c}\,\hat{\tau}_t^c - \hat{\varepsilon}_t^u \tag{2.28}$$

[Ricardian Household: Effective Consumption]

$$\hat{\tilde{C}}_t^r = \hat{C}_t^r\;(1-\varrho)^{\frac{1}{\varphi}}\;\left(\frac{C^r}{\tilde{C}^r}\right)^{\frac{\varphi-1}{\varphi}} + \varrho^{\frac{1}{\varphi}}\left(\frac{G}{\tilde{C}^r}\right)^{\frac{\varphi-1}{\varphi}}\,\hat{G}_t \tag{2.29}$$

[Ricardian Household: Marginal Utility of Labour]

$$\frac{1}{\eta}\,\hat{N}_t^r + \hat{\varepsilon}_t^n = \hat{\mu}_t^r + \hat{W}_t - \frac{\tau^w}{1-\tau^w}\,\hat{\tau}_t^w - \hat{\varepsilon}_t^u \tag{2.30}$$

[Real Interest Rate on Government Bond]

$$\hat{\mu}_t^r - \hat{\mu}_{t+1}^r = \hat{R}_t \tag{2.31}$$

[Ricardian Household: Euler Equation]

$$\hat{\mu}_{t+1}^r - \hat{\mu}_t^r + \beta\,r^k\,\left(1-\tau^k\right)\,\hat{r}_{t+1}^k - \beta\,\tau^k\,\left(r^k-\delta\right)\,\hat{\tau}_{t+1}^k + \beta\,(1-\delta)\,\hat{Q}_{t+1} = \hat{Q}_t \tag{2.32}$$

[Tobin's Q]

$$\hat{Q}_t + \hat{\varepsilon}_t^i = \phi\,(1+\beta)\,\hat{I}_t - \phi\,\hat{I}_{t-1} - \beta\,\phi\,\hat{I}_{t+1} \tag{2.33}$$

[Capital Law of Motion]

$$\hat{K}_t = \delta\,\left(\hat{\varepsilon}_t^i + \hat{I}_t\right) + (1-\delta)\,\hat{K}_{t-1} \tag{2.34}$$

[HtM Household: Marginal Utility of Consumption]

$$\frac{(-\sigma)}{1-\kappa}\,\hat{\tilde{C}}_t^h + \frac{\sigma\,\kappa}{1-\kappa}\,\hat{\tilde{C}}_{t-1}^h + \frac{1}{\varphi}\,\left(\hat{\tilde{C}}_t^h - \hat{C}_t^h\right) = \frac{\tau^c}{1+\tau^c}\,\hat{\tau}_t^c + \hat{\mu}_t^h - \hat{\varepsilon}_t^u \tag{2.35}$$

[HtM Household: Effective Consumption]

$$\hat{\tilde{C}}_t^h = \hat{C}_t^h\;(1-\varrho)^{\frac{1}{\varphi}}\;\left(\frac{C^h}{\tilde{C}^h}\right)^{\frac{\varphi-1}{\varphi}} + \hat{G}_t\,\varrho^{\frac{1}{\varphi}}\left(\frac{G}{\tilde{C}^h}\right)^{\frac{\varphi-1}{\varphi}} \tag{2.36}$$

[HtM Household: Marginal Utility of Labour]

$$\hat{\varepsilon}_t^n + \frac{1}{\eta}\,\hat{N}_t^h = \hat{W}_t + \hat{\mu}_t^h - \frac{\tau^w}{1-\tau^w}\,\hat{\tau}_t^w - \hat{\varepsilon}_t^u \tag{2.37}$$

[HtM Household: Budget Constraint]

$$(1+\tau^c)\,\frac{C^h}{Y}\,\left(\frac{\tau^c}{1+\tau^c}\,\hat{\tau}_t^c + \hat{C}_t^h\right) = (1-\tau^w)\,W\,\left(\frac{N}{Y}\right)\,\left(\hat{W}_t + \hat{N}_t^h - \frac{\tau^w}{1-\tau^w}\,\hat{\tau}_t^w\right) + \frac{Z}{Y}\,\hat{Z}_t \tag{2.38}$$

[CES Production Technology]

$$\hat{Y}_t = (1-\alpha)^{\frac{1}{\nu}} \left(\frac{N}{Y}\right)^{\frac{\nu-1}{\nu}} \hat{N}_t + \hat{\varepsilon}_t^a + \alpha^{\frac{1}{\nu}} \left(\frac{K}{Y}\right)^{\frac{\nu-1}{\nu}} \hat{K}_{t-1} \tag{2.39}$$

[Real Wage]

$$\hat{W}_t = \hat{\varepsilon}_t^a \frac{\nu-1}{\nu} + \frac{1}{\nu} \left(\hat{Y}_t - \hat{N}_t\right) \tag{2.40}$$

[Real Rental Cost of Capital]

$$\hat{r}_t^k = \hat{\varepsilon}_t^a \frac{\nu-1}{\nu} + \frac{1}{\nu} \left(\hat{Y}_t - \hat{K}_{t-1}\right) \tag{2.41}$$

[Economic Resource Constraint]

$$\hat{Y}_t = \frac{C}{Y} \hat{C}_t + \hat{I}_t \frac{I}{Y} + \hat{G}_t \frac{G}{Y} \tag{2.42}$$

[Aggregate Consumption]

$$\frac{C}{Y} \hat{C}_t = \hat{C}_t^h \frac{C^h}{Y} \lambda + \hat{C}_t^r \,(1-\lambda)\, \frac{C^r}{Y} \tag{2.43}$$

[Aggregate Labour Supply]

$$\hat{N}_t = \hat{N}_t^h \lambda + \hat{N}_t^r \,(1-\lambda) \tag{2.44}$$

[Government Budget Constraint]

$$\frac{Z}{Y} \hat{Z}_t + \hat{G}_t \frac{G}{Y} + \frac{B}{Y} \hat{B}_{t-1} = \tau^c \frac{C}{Y} \left(\hat{\tau}_t^c + \hat{C}_t\right) + \left(\frac{N}{Y}\right) \tau^w W \left(\hat{N}_t + \hat{W}_t + \hat{\tau}_t^w\right) + \left(\frac{K}{Y}\right) \tau^k \left(r^k - \delta\right) \left(\hat{r}_t^k \frac{r^k}{r^k - \delta} + \hat{\tau}_t^k + \hat{K}_{t-1}\right) + \beta \frac{B}{Y} \left(\hat{B}_t - \hat{R}_t\right) \tag{2.45}$$

[Fiscal Rules]

$$\hat{G}_t = \hat{\varepsilon}_t^g + (-\theta_g)\, \hat{B}_{t-1} - \hat{Y}_t \,\omega_g \tag{2.46}$$

$$\hat{Z}_t = \hat{\varepsilon}_t^z + (-\theta_z)\, \hat{B}_{t-1} - \hat{Y}_t \,\omega_z \tag{2.47}$$

$$\hat{\tau}_t^w = \chi_{kn} \,\hat{\varepsilon}_t^{\tau^k} + \chi_{nc} \,\hat{\varepsilon}_t^{\tau^c} + \hat{\varepsilon}_t^{\tau^w} + \hat{I}_t \,\omega_{\tau^w} + \theta_{\tau^w} \hat{B}_{t-1} \tag{2.48}$$

$$\hat{\tau}_t^k = \hat{\varepsilon}_t^{\tau^w} \chi_{kn} + \hat{\varepsilon}_t^{\tau^c} \chi_{kc} + \hat{\varepsilon}_t^{\tau^k} + \hat{I}_t \,\omega_{\tau^k} + \theta_{\tau^k} \hat{B}_{t-1} \tag{2.49}$$

$$\hat{\tau}_t^c = \hat{\varepsilon}_t^{\tau^c} + \hat{\varepsilon}_t^{\tau^k} \chi_{kc} + \hat{\varepsilon}_t^{\tau^w} \chi_{nc} \tag{2.50}$$

[AR(1) Shock Processes]

$$\hat{\varepsilon}_t^u = \rho_u \,\hat{\varepsilon}_{t-1}^u + \epsilon_t^u \tag{2.51}$$

$$\hat{\varepsilon}_t^n = \rho_n \,\hat{\varepsilon}_{t-1}^n + \epsilon_t^n \tag{2.52}$$

$$\hat{\varepsilon}_t^i = \rho_i \, \hat{\varepsilon}_{t-1}^i + \epsilon_t^i \tag{2.53}$$

$$\hat{\varepsilon}_t^a = \rho_a \, \hat{\varepsilon}_{t-1}^a + \epsilon_t^a \tag{2.54}$$

$$\hat{\varepsilon}_t^g = \rho_g \, \hat{\varepsilon}_{t-1}^g + \epsilon_t^g \tag{2.55}$$

$$\hat{\varepsilon}_t^z = \rho_z \, \hat{\varepsilon}_{t-1}^z + \epsilon_t^z \tag{2.56}$$

$$\hat{\varepsilon}_t^{\tau^c} = \rho_{\tau^c} \, \hat{\varepsilon}_{t-1}^{\tau^c} + \epsilon_t^{\tau^c} \tag{2.57}$$

$$\hat{\varepsilon}_t^{\tau^k} = \rho_{\tau^k} \, \hat{\varepsilon}_{t-1}^{\tau^k} + \epsilon_t^{\tau^k} \tag{2.58}$$

$$\hat{\varepsilon}_t^{\tau^w} = \rho_{\tau^w} \, \hat{\varepsilon}_{t-1}^{\tau^w} + \epsilon_t^{\tau^w} \tag{2.59}$$

II: Steady State Derivation

$$
\begin{aligned}
R &= \frac{1}{\beta} \\
r^k &= \frac{1-\beta}{\beta(1-\tau^k)} + \delta \\
\frac{K}{Y} &= \frac{\alpha}{r^{k\nu}} \\
\frac{N}{Y} &= \left[\left(\frac{1}{1-\alpha}\right)^{\frac{1}{\nu}} - \left(\frac{\alpha}{1-\alpha}\right)^{\frac{1}{\nu}} \left(\frac{K}{Y}\right)^{\frac{\nu-1}{\nu}}\right]^{\frac{\nu}{\nu-1}} \\
W &= \left[(1-\alpha)/\frac{N}{Y}\right]^{\frac{1}{\nu}} \\
\frac{I}{Y} &= \delta\frac{K}{Y} \\
\frac{C}{Y} &= 1 - \frac{I}{Y} - \frac{G}{Y} \\
\frac{Z}{Y} &= (1+\tau^c)\frac{C}{Y} - (1-\tau^w)W\frac{N}{Y} - \tau^k(r^k-\delta)\frac{K}{Y} - (1-\beta)\frac{B}{Y} \\
\frac{C^h}{Y} &= \frac{\left[(1-\tau^w)W\frac{N^h}{Y} + \frac{Z}{Y}\right]}{1+\tau^c} \\
\frac{C^r}{Y} &= \frac{1}{1-\lambda}\frac{C}{Y} - \frac{\lambda}{1-\lambda}\frac{C^h}{Y} \\
\frac{\tilde{C}^r}{Y} &= \left[(1-\varrho)^{\frac{1}{\varphi}}\left(\frac{C^r}{Y}\right)^{\frac{\varphi-1}{\varphi}} + \varrho^{\frac{1}{\varphi}}\left(\frac{G}{Y}\right)^{\frac{\varphi-1}{\varphi}}\right]^{\frac{\varphi}{\varphi-1}} \\
\frac{\tilde{C}^h}{Y} &= \left[(1-\varrho)^{\frac{1}{\varphi}}\left(\frac{C^h}{Y}\right)^{\frac{\varphi-1}{\varphi}} + \varrho^{\frac{1}{\varphi}}\left(\frac{G}{Y}\right)^{\frac{\varphi-1}{\varphi}}\right]^{\frac{\varphi}{\varphi-1}} \\
\frac{C^r}{\tilde{C}^r} &= \frac{C^r}{Y} \div \frac{\tilde{C}^r}{Y} \\
\frac{C^h}{\tilde{C}^h} &= \frac{C^h}{Y} \div \frac{\tilde{C}^h}{Y} \\
\frac{G}{\tilde{C}^r} &= \frac{G}{Y} \div \frac{\tilde{C}^r}{Y} \\
\frac{G}{\tilde{C}^h} &= \frac{G}{Y} \div \frac{\tilde{C}^h}{Y}
\end{aligned}
$$

III: Parameter Identification Check

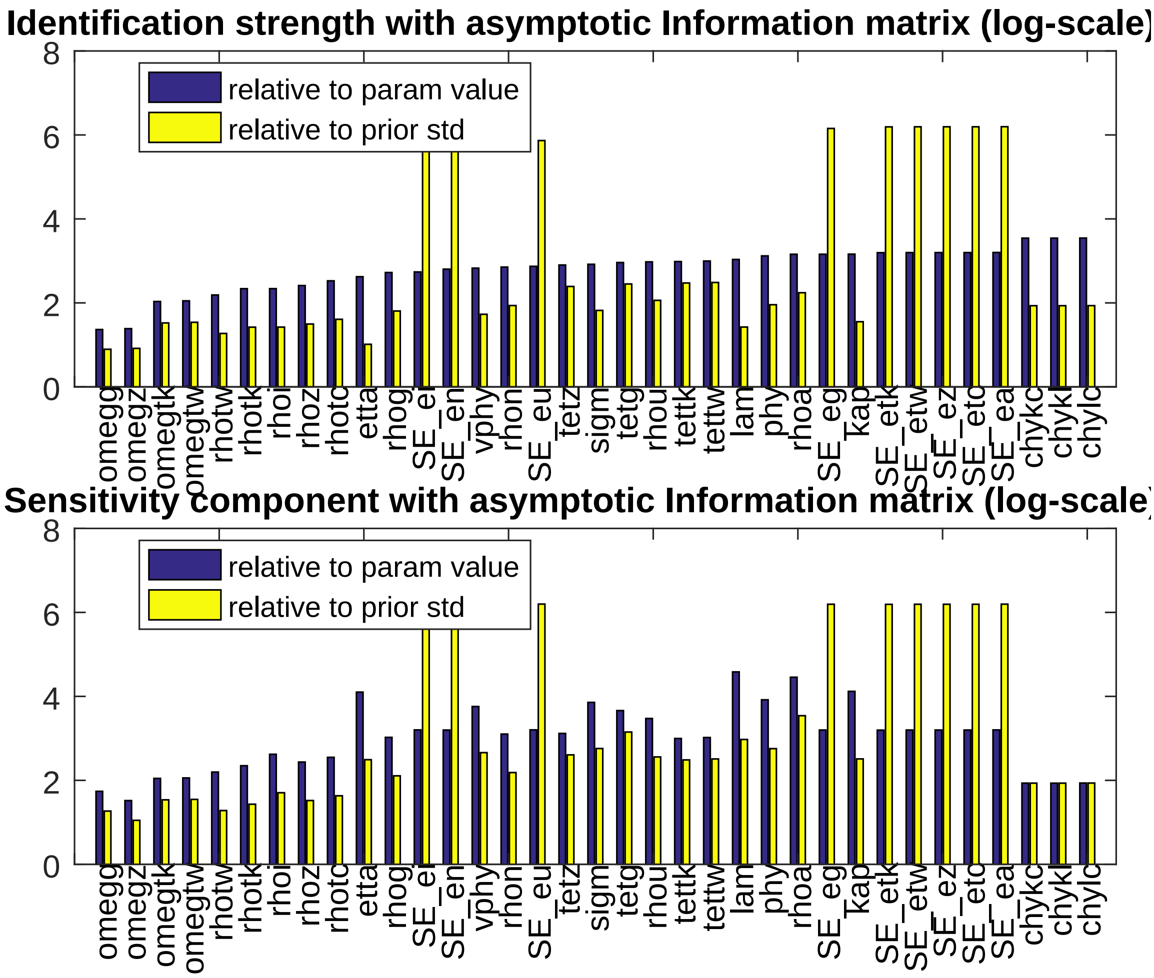


Figure 2.11: **Identification Strength of Prior Mean**

Notes: This figure shows the identification strength of the estimated parameters of the baseline model. The upper panel shows the identification strength of the parameters based on the Fischer information matrix normalized by either the parameter at the prior mean (blue bars) or by the standard deviation at the prior mean (yellow bars). The lower panel further decompose the relative sensitivity of the model behaviour to each parameter (Pfeifer 2017, Ratto & Iskrev 2011). Evidence from this identification check shows that the estimated parameters are uniquely identified – since their log-scale is significantly different from zero – and individually play distinctive roles in the dynamics of the model.

IV: Multivariate Convergence Diagnostics

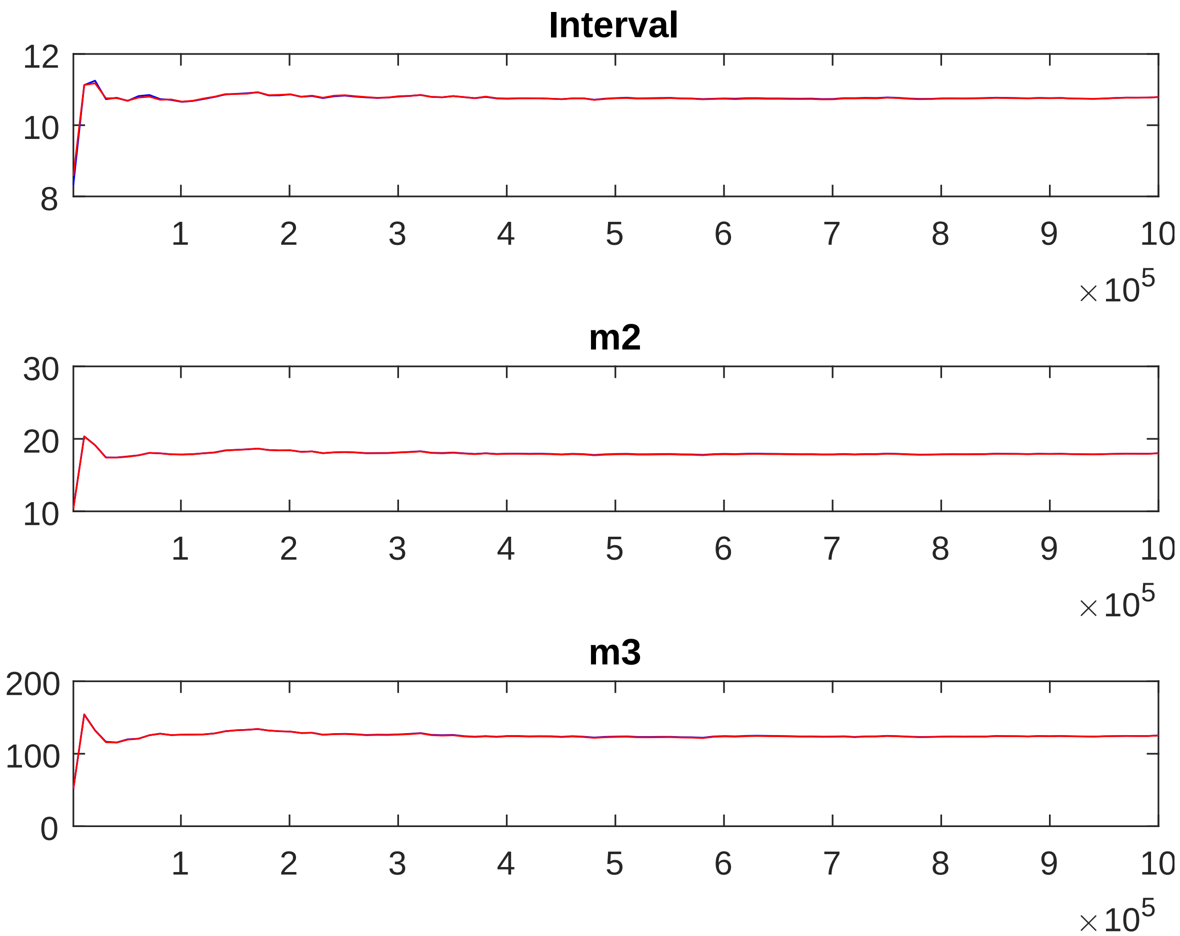


Figure 2.12: **Multivariate Convergence Diagnostics**

Notes: This figure reports the multivariate version of Brooks & Gelman (1998)'s convergence diagnostics, which is based on the posterior likelihood function for all parameters rather than individual univariate diagnostics originally proposed by Brooks & Gelman (1998). The top panel shows the convergence diagnostics for the 80% of the posterior distribution. The blue line depicts the 80th quantile range based on the pooled draws from all sequences, while the red line depicts the mean interval range. Convergence is achieved when the two lines are close to each other and stabilised across the horizon. The second and third panels portray the second and third moments of the same statistic respectively. Given the result of the convergence diagnostic reported here, we can conclude that the Monte Carlo Markov Chains (MCMC) converge to unique posterior value.

V: Prior and Posterior Distributions

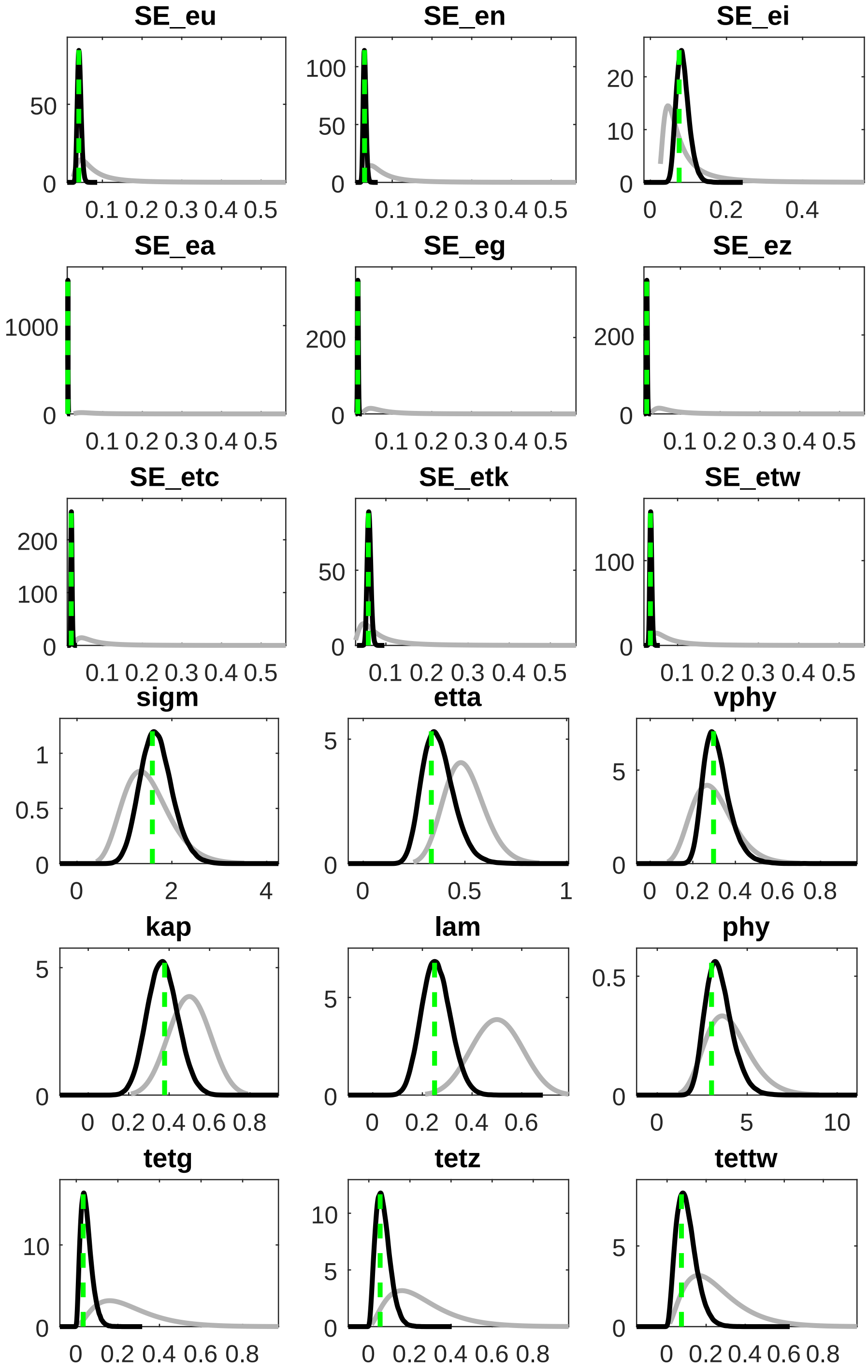


Figure 2.13: **Prior and Posterior Distributions I**

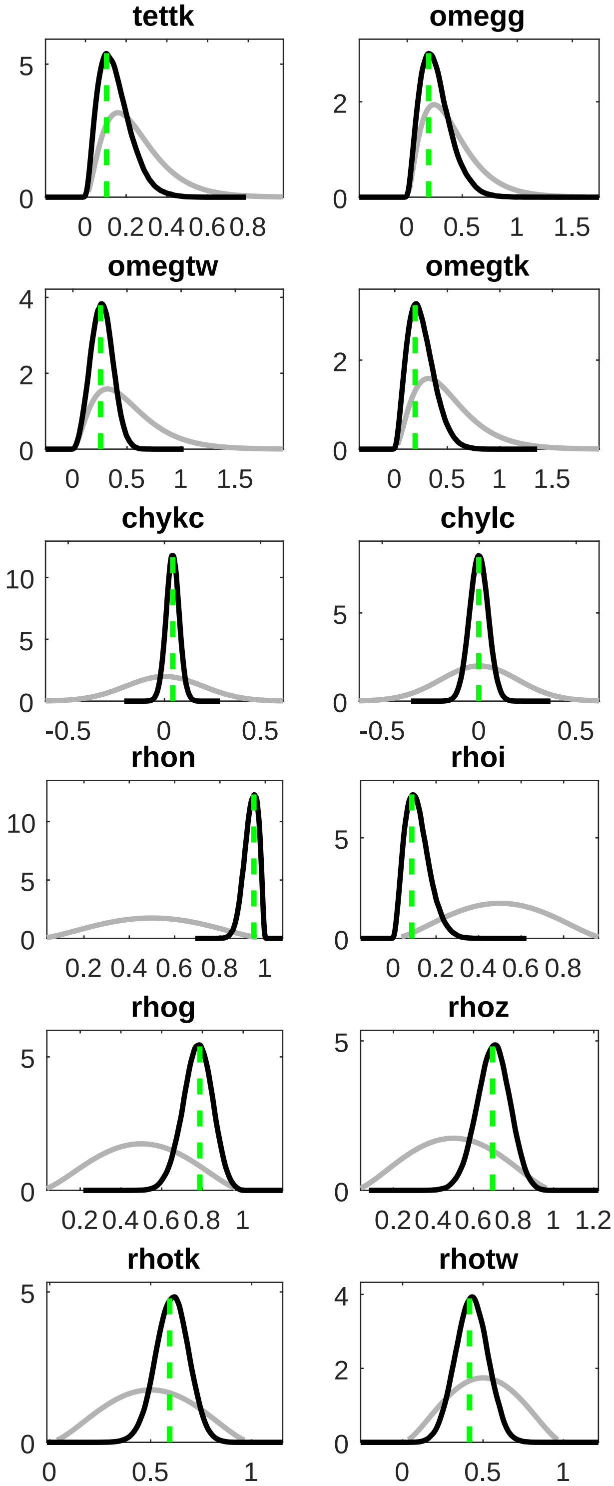


Figure 2.14: **Prior and Posterior Distributions II**

Notes: This figure (see also 2.13) plots the prior and posterior distributions of the estimated parameters. The grey line shows the prior density, the black line depicts the density of the posterior distribution, while the green vertical line indicates the posterior mode. The plots show that the posterior estimates are clearly identified.

Chapter 3

International Fiscal Spillovers and Asset Market Participation

3.1 Introduction

The recent global financial crisis and the subsequent Great Recession of 2008–2010 have rekindled policy debate on the relative importance of discretionary fiscal measures as effective macroeconomic stabilisation tools. A new literature on the transmission of fiscal policy and the relative importance of different fiscal measures in different regimes has emerged (Alesina et al. 2018, Ramey & Zubairy 2018, Leeper et al. 2017, Auerbach & Gorodnichenko 2016, Alesina, Barbiero, Favero, Giavazzi & Paradisi 2015). Even so, a new number of studies have shown that domestic fiscal policy have substantial international implications for countries with strong links (Blanchard et al. 2016, Corsetti & Müller 2014), and the international multipliers vary across the state of the business cycle (Auerbach & Gorodnichenko 2013).

In this paper, we examine the cross-border transmission of fiscal policy between the United Kingdom and the Euro Area. Evidence from the UK trade statistics shows that nearly half of total UK trade between 1999 and 2015 is with the EA (see Figure 3.1). And given that trade is the primary channel of international transmission of fiscal policy, it is likely that EA fiscal policy could have some implications for the UK economy. The paper also investigates the role of household's credit-constraint in international transmission of fiscal policy. Although a significant number of studies have been devoted to the analysis of international transmission of fiscal policy, relatively little is known about the implication of international exposure at the global asset market on cross-border fiscal spillovers. This is the focus of this paper. Specifically, we address the questions: What are the cross-border effects of fiscal policy? How do liquidity

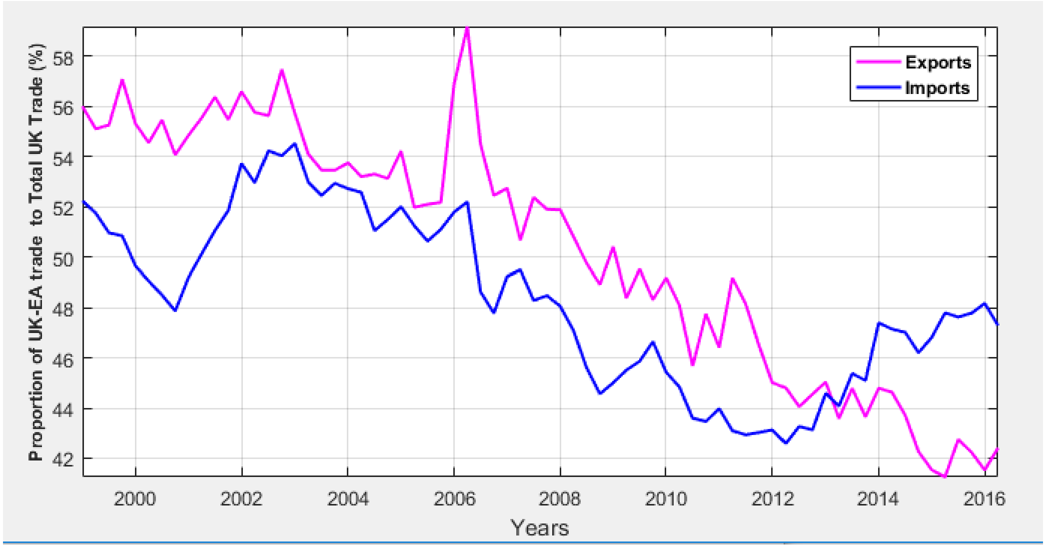


Figure 3.1: **Ratio of UK trade with the Euro area as a percentage of total UK trade (goods only). Source: Office for National Statistics.**

conditions at the global asset market influence the transmission and propagation of fiscal policy across borders?

To address these questions, we develop a two-country Dynamic Stochastic General Equilibrium (DSGE) model and estimate it on quarterly UK and EA data using Bayesian methods. Following Corsetti et al. (2010, 2012), we develop a model that features an incomplete asset market which implies limited international risk-sharing across borders, à la Kollmann (2010); an exclusion of a fraction of households from asset markets to captures household credit-contraints, as in Galí et al. (2007) and Bilbiie (2008); and a productive fiscal sector in which government services directly affect household preferences, as in Coenen et al. (2013). These features are of interest to this paper as we intend to take the model to the data.

We make three contributions. First, since households are heterogeneous in nature, we enrich the model to reflect the responses of different types of households to changes in fiscal policy. Specifically, we allow different types of households to have different weights of public goods in their effective consumption bundle. This helps to track agent-specific responses to fiscal policy shocks, which are quite different from aggregate responses (Aiyagari 1994). Secondly, in the spirit of Kliem & Kriwoluzky (2014), Corsetti et al. (2012) and Leeper, Plante & Traum (2010), we propose a new set of fiscal rules for both economies, which are close to the actual fiscal policy being implemented in these countries. The estimated parameters of the proposed fiscal rule are also uniquely identified with flexibility, compared to other fiscal rules found in the literature. Finally, we show through analytical derivations that relative participation at the global asset market is a key driver of cross-country spillovers via its effects on countries' net foreign asset position.

Simulation results based on the estimated model show that fiscal spillovers from the EA have significant effects on economic activities in the UK, while UK fiscal policy have negligible effects on the EA economy. This result is driven by the strong trade linkage between the EA and the UK, and the relatively small size of the UK economy. Also, the magnitude and sign of these spillover effects strongly depend on the choice of fiscal instrument employed. While spending-based fiscal spillovers tend to have strong pro-cyclical effects, tax-based fiscal spillover effects are relatively small and sometimes countercyclical. Given the insight derived from the analytical solution of the model, we extend the simulation exercise to involve varying degrees of household credit-constraints in the source country, in order to ascertain how relative participation at the global asset market influences international fiscal spillovers. The result shows that changes in the source country's relative participation at the global asset market drive the propagation and amplification effects of cross-border fiscal spillover; but the amplification mechanisms vary for different types of households. Holders of internationally-traded assets respond within the same year to this change as they are likely to receive the news much earlier, thereby adjusting their asset portfolios accordingly. Whereas, non-asset holders respond to the change mainly in the medium-run.

The remainder of this paper is organised as follows: In Section 3.2, we briefly review related literature, while in Section 3.3, we describe the model of interest for the analysis. In Section 3.4, we briefly describe the estimation procedure and the data. We also discuss the calibration of some model parameters not estimated, as well as the assigned prior and posterior estimates of the estimated parameters. Section 3.5 discusses the simulated impulse responses based on the estimated model and the sensitivity of the result to changes in relative participation at the global market. Section 3.6 summarises the findings of the paper and concludes.

3.2 Literature Review

According to received wisdom, trade is the primary channel of cross-border fiscal policy transmission. Changes in domestic fiscal policy transmit across borders by affecting the demand for foreign goods and services via changes in income (demand effect), as well as the country's relative terms of trade via changes in import and export flows (competitiveness effect). Alternatively, a fiscal shock could be transmitted across border via its effect on sovereign risk premium and financial market confidence. This is known as the financial or interest rate channel. The risk premium affects the global interest rate parity, and since financial markets are globally integrated, this affects the movement of assets across countries and influences the relative terms of trade (Canova et al. 2013, D'Auria et al. 2014).

The standard Keynesian theory, based on the Mundell-Fleming-Dornbusch framework, suggests that fiscal innovations which deteriorate the government's budget position also worsen the external balance of the economy (Arin & Koray 2009, Born et al. 2013) – hence, the name *twin-deficit* hypothesis. More recently, studies have developed more sophisticated models, such as the dynamic general equilibrium models, to analyse the transmission of fiscal innovations domestically and across borders. Analytical results based on these models differ considerably across studies due to a complexity of factors considered and assumptions made about the economy being modelled. Some of these factors and assumptions include: the choice of fiscal instruments (Erceg & Lindé 2013), exchange rate regime (Born et al. 2013), the degree of openness and size of the country (Sutherland 2005), market frictions among others (Blanchard et al. 2016, Corsetti et al. 2012, 2013, Corsetti & Müller 2014).

Corsetti et al. (2010, 2012) analyse fiscal spillovers with spending reversal within a two-country New Keynesian model while allowing for some country-specific characteristics such as trade elasticities, country size, degree of openness and imperfections in financial markets. They find that anticipated fiscal expansions with spending reversal have positive cross-border spillover effects mainly through the interest-rate channel. This result is further confirmed by Forni et al. (2010) who find that fiscal spillovers from Germany and Belgium have expansionary effects on the rest of the Euro area in a calibrated two-country model. In contrast, Gadatsch et al. (2016) find that German fiscal stimulus during the financial crisis has small or negative spillover effects on the rest of the Euro area in an estimated three-country DSGE model of Germany, the Euro area and the rest of the world.

Arce et al. (2016), Blanchard et al. (2016) and Bénassy-Quéré (2006) examine the transmission of fiscal spillovers within a monetary union (core versus peripheral entities) and observe that its net effects (domestic plus cross-border spillovers) strongly depend on the extent of monetary responsiveness and accommodativeness. Using a New Keynesian model of a currency union, Blanchard et al. (2016) show that when there is no liquidity trap, the spillover effects of expansion in core government spending on periphery output tend to be small or even negative, which is due to a rise in the common real interest rate which erodes the competitive gains from depreciation of the periphery's terms of trade. Whereas, when there is a liquidity trap, periphery output tends to rise in response to core fiscal expansion since the common interest rate is barely responsive, and the magnitude of this response is directly proportional to the expected duration of the liquidity trap and inversely to the degree of home-bias in core government spending bundles.

Another strand of the literature empirically examined the international spillover effects of domestic fiscal policy within an structural VAR framework. Carmignani (2015) estimate the effect of United States government spending on economic activities of other OECD countries and finds that, on average, US government expenditure has positive international multiplier effects, but the size of the spillover effects vary across trade links, proximity and time. Similarly, in a panel analysis of 14 EU countries, Beetsma & Giuliodori (2011) and Beetsma et al. (2006) find that fiscal expansions in large EU countries, such as Germany, France and the UK, have significant positive spillover effects on output and exports of the rest-of-EU countries. In contrast, Arin & Koray (2009) find that an expansion in the US government spending has a negative spillover effect on Canadian output. Arin et al. (2012) also find that a positive shock to Australian government spending crowds-out real activity in New Zealand, both in the short and medium runs.

Some empirical studies also analyse the international implications of fiscal policy for several European countries within a Global VAR (GVAR) framework. Hebous & Zimmermann (2013) estimate the effects of coordinated fiscal actions in the Euro Area and find that an area-wide fiscal shock (a weighted-average for member-countries) has a sizeable effect on output compared to a domestic shock. Caporale & Girardi (2013) analyse the effect of fiscal imbalance in specific Euro member state on borrowing costs of the rest of Euro countries and find that government yields denominated in euro have strong links with each other, but financial markets are able to discriminate among different users. Dragomirescu-Gaina & Philippas (2015) analyse the strategic interaction of fiscal policies of 12 EU member-states by modelling the interdependencies public and private sector's saving-investment balances. The result of their analysis show that cross-border private capital flows can the policy options available to the government and worsen the tradeoff between policy responses to domestic shocks relative to foreign shocks. Some other studies, such as Bettendorf & León-Ledesma (2018), Georgiadis (2015), Dees et al. (2007) and Hashem Pesaran et al. (2007), also apply the GVAR framework to analyse the international connectedness of monetary policy, financial markets, wages and trade among Euro countries.

Finally, in a study that employed Smooth Transition VAR to estimate the effects of cross-border output spillovers over the business cycle in a panel of OECD countries, Auerbach & Gorodnichenko (2013) find that fiscal spillovers are statistically and economically significant, and considerably vary over the business cycle. The spillover effects are observed to be substantially higher during recessions than in expansions, especially when both the source and recipient countries are in recession.

3.3 The Model

To analyse the domestic and cross-border spillover effects of fiscal consolidation, we consider a variant of the two-country DSGE model developed by Corsetti et al. (2010, 2012). For simplicity and tractability, we follow the path of Leeper, Plante & Traum (2010) and Leeper, Walker & Yang (2010) by abstrating from nominal rigidities. But, to bring the model a bit closer to reality, we incorporate some real frictions, including: exclusion of a fraction of households from financial markets to capture financial frictions in the asset markets, as in Galí et al. (2007) and Bilbiie (2008); debt-elastic interest rate premium which captures financial friction at the international asset market, as in Schmitt-Grohé & Uribe (2003); incomplete international financial markets which imply limited international risk-sharing, as in Kollmann (2012); investment adjustment costs to control for costly acquisition of capital goods, as in Christiano et al. (2005); and habit formation in consumption to control for the influence of permanent consumption. More so, we allow for variations in country characteristics such as relative country sizes and composition of final goods. Finally, we propose new set of fiscal policy rules for both countries which follow closely that of Corsetti et al. (2012) where fiscal spending adjusts to government debt with reversal, augmented with the tax rule proposed by Kliem & Kriwoluzky (2014) in which income taxes respond to the employment or investment component of the business cycle.

3.3.1 Households

In each country, there is a continuum of households, indexed with $i \in [0, 1]$, which comprises two groups. The first group, indexed with $r \in [\lambda, 1]$, owns the domestic intermediate-good firms and trades state-contingent securities at the national and international level. As a result, this type of household is capable of smoothing consumption across time – intertemporal optimisation. They are referred to as "asset-holders" or Ricardian households. The second group, indexed with $h \in [0, \lambda]$, does not participate in asset markets. Rather, these households simply consume their labour income in the current period – intratemporal optimisation. Hence, they are referred to as "non-asset holders" or rule-of-thumb consumers.

Households have separable preferences which depend on the utility derived from their effective consumption, $\tilde{C}_t^i$, and the disutility from labour effort, N_t^i. The effective consumption of household-i, $i = (r, h)$, is a non-separable CES aggregator of household-specific consumption,

C_t^i, and government services, G_t, given by:

$$\tilde{C}_t^i = \left[(1-\varrho_i)^{\frac{1}{\varphi}} C_t^{i\,\frac{\varphi-1}{\varphi}} + \varrho_i^{\frac{1}{\varphi}} G_t^{\,\frac{\varphi-1}{\varphi}} \right]^{\frac{\varphi}{\varphi-1}} \tag{3.1}$$

where $\varrho_i \in (0,1)$ is the share of government service in household-i's effective consumption bundle, and $\varphi \in (0,\infty)$ is the CES substitution elasticity between public and private consumption goods. This specification is particularly of interest because the non-separability of government consumption in household utility implies that public consumption spending directly affect household preferences. One way this paper differ from existing literature with similar specification, such as Coenen et al. (2013), is that it allows the share of public goods in households' effective consumption bundle, ϱ, to vary across households; since, in reality, households considerably differ in their valuation of public goods and the weight they place on them.[1]

The life-time utility of households in each country is given by the following expression:

$$E_t \left\{ \sum_{t=0}^{\infty} \beta^{t+j} \left[\frac{(\tilde{C}_{t+j}^i - \kappa \tilde{C}_{t+j-1}^i)^{1-\theta}}{1-\theta} - \frac{N_{t+j}^{i\;\,1+\eta}}{1+\eta} \right] \right\} \tag{3.2}$$

where $\beta \in (0,1)$ is the subjective discount factor, θ is the relative risk aversion rate which is the inverse of intertemporal substitution elasticity, η is the inverse Frisch elasticity of labour supply which measures the response of labour hours to changes in after-tax wage, and $\kappa \in (0,1)$ is the within-group habit parameter. This expression shows that households' utility preference positively depends on the difference between individual households' current consumption, $\tilde{C}_t^i$, and own-group past consumption level, $\tilde{C}_{t-1}^i$, and negatively on labour hours, N_t^i.

Asset Holding Households

The asset-holding (Ricardian) households maximise lifetime utility subject to the following budget constraint:

$$\begin{aligned} (1+\tau_t^c)C_t^r + I_t^r + \frac{P_{H,t}}{P_t} B_{H,t}^r + \frac{P_{F,t}}{P_t} D_{F,t}^r &= (1-\tau_t^w) W_t N_t^r + [R_t^k U_t] K_{t-1}^r \\ &+ \frac{P_{H,t}}{P_t} R_{t-1} B_{H,t-1}^r + \frac{P_{F,t}}{P_t} R_{t-1}^* D_{F,t-1}^r \Phi_{t-1}^d + \Pi_t^r + Z_t^r \end{aligned} \tag{3.3}$$

Asset holders choose consumption, C_t^r, and labour services, N_t^r, that maximises their utility. They supply their labour services to the intermediate-good firms for a real wage, W_t. They

[1]For instance, low-income households depend more on government resources, such as education and health-care services, compared to high-income households who can afford provision of such basic needs.

also invest, I_t^r, in capital goods, K_t^r, which is rented to intermediate-good firms at a real cost R_t^k, and hold one-period domestic and foreign government bonds, $B_{H,t}^r$ and $D_{F,t}^r$ respectively. It is assumed that, while asset-holders in home country trade both home and foreign government bonds, foreign asset-holders trade only foreign government bonds. R_t and R_t^* are the gross real return on domestic and foreign government bond, $\frac{P_{H,t}}{P_t}$ and $\frac{P_{F,t}}{P_t}$ are the relative prices of home and foreign goods respectively, Π_t^r is profit from ownership of intermediate-good firms, and Z_t^r is the government transfer receipt.

Following Schmitt-Grohé & Uribe (2003), Φ_t^d is the debt-elastic interest rate premium which ensures that foreign debt level is stationary in a log-linear approximation to the model, and it is given by:

$$\Phi_t^d = e^{-\phi_d(\frac{P_{F,t}}{P_t}D_{F,t}-D_F)/Y^*} \tag{3.4}$$

where ϕ_d is the premium's elasticity with respect to foreign bonds issued in units of foreign output, Y^*. One interesting feature about this specification of interest rate premium is that, at steady state, domestic interest rate converges to foreign interest rate. Hence, no country can continually borrow in perpetuity.

The capital accumulation process follow closely that of Christiano et al. (2005) which assumed a costly adjustment to investment:

$$K_t^r = (1-\delta(U_t))K_{t-1}^r + \Phi^k\left(\frac{I_t^r}{I_{t-1}^r}\right)\varepsilon_t^I I_t^r \tag{3.5}$$

where $\Phi^k\left(\frac{I_t^r}{I_{t-1}^r}\right) = 1-\frac{\phi_k}{2}\left(\frac{I_t^r}{I_{t-1}^r}-1\right)^2$ is the investment adjustment costs while ϕ_k is the adjustment costs parameter. ε_t^I is an investment-specific shock which follows an AR(1) process, such that $\hat{\varepsilon}_t^I = \rho_I\hat{\varepsilon}_{t-1}^I + \hat{\epsilon}_t^I$, where $\hat{\epsilon}_t^I \sim NIID(0,\sigma_I)$ is a pure random error to investment. The non-negative depreciation function closely follows the one analysed in Greenwood et al. (1988), and it is given by:

$$\delta(U_t) = \delta U_t^{1+\xi} \tag{3.6}$$

where $\delta(.)$ satisfies: $\delta(.) > 0$, $\delta'(.) > 0$ and $\delta''(.) > 0$, implying that higher capital utilization rates lead to faster capital stock depreciation. U_t is the capacity utilisation level, while $\xi = \frac{U\delta''(U)}{\delta'(U)}$ is the constant elasticity of utilisation rate and δ is the steady-state depreciation rate.

Non-asset Holding Households

As earlier discussed above, non-asset holding households in each country simply live from "hand to mouth" by consuming their current disposable income in each period, augmented with government transfers. Therefore, the non-asset holding households maximise a single-period utility subject to the following budget constraint:

$$(1+\tau_t^c)C_t^h = (1-\tau_t^w)W_t N_t^h + Z_t^h \tag{3.7}$$

where C_t^h and N_t^h are the consumption and labour services of non-asset holding households. Also, it is assumed that there is no discrimination in the labour market. Hence, all households are paid similar real wage. τ_t^c and τ_t^w are taxes on consumption and income respectively, and Z_t^h is the government transfer to the household. It is assumed that the government does not discriminate among households in the allocation of social transfers, hence $Z_t = Z_t^r = Z_t^h$. The aggregate private consumption, hours, investment, capital, domestic and foreign government bonds and profit are given as:

$$C_t = (1-\lambda)C_t^r + \lambda C_t^h \tag{3.8}$$

$$N_t = (1-\lambda)N_t^r + \lambda N_t^h \tag{3.9}$$

$$I_t = (1-\lambda)I_t^r \tag{3.10}$$

$$K_t = (1-\lambda)K_t^r \tag{3.11}$$

$$B_{H,t} = (1-\lambda)B_{H,t}^r \tag{3.12}$$

$$D_{F,t} = (1-\lambda)D_{F,t}^r \tag{3.13}$$

$$\Pi_t = (1-\lambda)\Pi_t^r \tag{3.14}$$

3.3.2 Firms

There are two types of firms in this economy: the final-goods producers and the intermediate goods producers.

Final Good Firms

Final-good firms operate in perfect competitive markets. They produce final goods for immediate consumption within the domestic economy. Final goods, $X_t = (C_t, I_t, G_t)$, are produced using a CES aggregator of domestically produced and imported intermediate goods given by:

$$X_t = \left[\nu^{\frac{1}{\sigma}} X_{H,t}^{\frac{\sigma-1}{\sigma}} + (1-\nu)^{\frac{1}{\sigma}} X_{F,t}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{3.15}$$

which is maximised subject to a cost outlay given by

$$P_t X_t = P_{H,t} X_{H,t} + P_{F,t} X_{F,t} \tag{3.16}$$

where $X_{H,t}$ are domestically produced *home* intermediate goods, $X_{F,t}$ are the imported *foreign* intermediate goods, $P_{H,t}$ is the price of a unit of home-produced goods and $P_{F,t}$ is the price of a unit of foreign goods. $\nu \in (0,1)$ is the share of home goods in the aggregate bundle which measures the degree of home bias, while $\sigma \in (0,\infty)$ is the CES elasticity of substitution between home and foreign goods. By substituting the optimal value of intermediate goods produced domestically and imported into the cost outlay, the equation for the aggregate price index can be obtained as

$$P_t = \left[\nu P_{H,t}^{1-\sigma} + (1-\nu) P_{F,t}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{3.17}$$

It is worth noting that, with this specification, the government is assumed to consume a combination of both home and foreign goods. We have used this CES specification for all agents so as to achieve aggregation.

Intermediate Good Firms

Like the final-good firms, intermediate-good firms operate in a competitive market. They rent capital from the asset-holders at a real cost, R_t^k, and employ labour from the households at a universal real wage, W_t, since they do not discriminate between labour services of households. Capital and labour are assumed to be immobile internationally but can be adjusted freely in each period within a country. Output, Y_t, is produced using a CES technology given by:

$$Y_t = \varepsilon_t^A (U_t K_{t-1})^{\alpha} N_t^{1-\alpha} \tag{3.18}$$

where $\alpha \in (0,1)$ is the share of capital, and ε_t^A is the technology shock in the home country. The firms maximise a profit function given by the expression:

$$\Pi_t = \frac{P_{H,t}}{P_t} Y_t - W_t N_t - R_t^k U_t K_{t-1} \tag{3.19}$$

subject to the CES production technology, where $\frac{P_{H,t}}{P_t}$ is the relative price of home goods.

3.3.3 Fiscal Authority

In each period, the government decides on a set of fiscal instruments that satisfy its current budget constraint which evolves according to the following law of motion:

$$\frac{P_{H,t}}{P_t}B_t = \frac{P_{H,t}}{P_t}R_{t-1}B_{t-1} + [G_t + Z_t - \tau_t^c C_t - \tau_t^w W_t N_t] \tag{3.20}$$

where B_t is the total amount of bond issued by the home government which is denominated in domestic currency. Since it is assumed that home government bond is held by only domestic households, $B_t = B_{H,t}$. On the other hand, the foreign government bond is held by both home and foreign asset holders. Hence, from the foreign government's perspective, the total amount of bonds issued,B_t^*, is equal to the amount held within the domestic economy, $B_{F,t}^*$ and the amount traded internationally, $D_{F,t}^*$:

$$B_t^* = B_{F,t}^* + D_{F,t}^* \tag{3.21}$$

In this model, it is assumed that both countries follow similar fiscal rules. For the purpose of this analysis, we propose a set of fiscal rules which closely follow that of Leeper, Plante & Traum (2010), Corsetti et al. (2012) and Kliem & Kriwoluzky (2014). For spending rules, it is assumed that (stochastic) fiscal spending ratios (government consumption and transfers) respond to government debt ratio with feedback, as in Corsetti et al. (2012):

$$\frac{G_t}{Y_t} = \left(\frac{B_{t-1}}{Y_t}\right)^{-\varsigma_g}\left(\frac{G_{t-1}}{Y_{t-1}}\right)^{\rho_g} e^{\epsilon_t^g} \tag{3.22}$$

$$\frac{Z_t}{Y_t} = \left(\frac{B_{t-1}}{Y_t}\right)^{-\varsigma_z}\left(\frac{Z_{t-1}}{Y_{t-1}}\right)^{\rho_z} e^{\epsilon_t^z} \tag{3.23}$$

For the tax rule, it is assumed that consumption and income taxes respond to the level of debt and income tax further responds to contemporaneous investment as in Kliem & Kriwoluzky (2014):[2]

[2] Kliem & Kriwoluzky (2014) observed that when the conventional debt feedback rule for income taxes, which is based on cyclical movements with contemporaneous output, are estimated, the feedback parameters are not statistically different from zero and/or may not be identified. But when income taxes are allowed to adjust to labour hours and capital, the feedback parameters are identified and statistically significantly different from zero. Hence, they proposed that the cyclical movements of labour and capital income tax rates should be described by a contemporaneous response to hours worked and/or investment.

$$\tau_t^c = B_{t-1}^{\varsigma_{\tau c}} \varepsilon_t^{\tau c} \left(\varepsilon_t^{\tau w}\right)^{\iota_\tau}; \quad \varepsilon_t^{\tau c} = \left(\varepsilon_{t-1}^{\tau c}\right)^{\rho_{\tau c}} e^{\epsilon_t^{\tau c}} \tag{3.24}$$

$$\tau_t^w = B_{t-1}^{\varsigma_{\tau w}} I_t^{\vartheta_{\tau w}} \varepsilon_t^{\tau w} \left(\varepsilon_t^{\tau c}\right)^{\iota_\tau}; \quad \varepsilon_t^{\tau w} = \left(\varepsilon_{t-1}^{\tau w}\right)^{\rho_{\tau w}} e^{\epsilon_t^{\tau w}} \tag{3.25}$$

where ς_x, for $x \in (g, z, \tau^c, \tau^w)$, are the fiscal adjustment parameters to government debt, ρ_g and ρ_z are the spending feedback parameters, ϑ_{τ^w} is the response of income tax to contemporaneous investment, ρ_{τ^c} and ρ_{τ^w} are the persistence parameters of tax shocks, while ι_τ is the cross-correlation parameter of contemporaneous shocks to consumption and income taxes as in Leeper, Plante & Traum (2010), and $\epsilon_t^x \sim NIID(0, \sigma_x)$ are the unanticipated fiscal shocks.

The nested fiscal rules in this model are relatively better compared to those in the existing literature for two reasons: first, unlike Leeper, Plante & Traum (2010) which allows fiscal instruments to adjust to contemporaneous output, our fiscal rule does not pre-empt the cyclical movement of output in response to estimated shock prior to estimation. Rather, within the spending rule, output response depends on a linear combination of the debt-adjustment and feedback parameters, while within the tax rule, it depends on the tax role within the model framework. Second, the specified spending rule is more flexible to work with, in the sense that it can be estimated with variables in ratio or level form with consistent and identified parameters.

3.3.4 Goods Market Equilibrium

The goods market clears when the aggregate supply equals absorption. The market clearing conditions for both home and foreign produced output are given by:

$$Y_t = C_{H,t} + I_{H,t} + G_{H,t} + C_{H,t}^* + I_{H,t}^* + G_{H,t}^* \tag{3.26}$$

$$Y_t^* = C_{F,t} + I_{F,t} + G_{F,t} + C_{F,t}^* + I_{F,t}^* + G_{F,t}^* \tag{3.27}$$

3.3.5 Foreign Country Block and International Linkages

The foreign country set-up is analogous to that of the home country, except that foreign households do not trade assets internationally. The foreign country's final-good aggregator, the cost of producing it and the resulting aggregate price index are given as follow:

$$X_t^* = \left[\nu^{*\frac{1}{\sigma}} X_{H,t}^{*\,\frac{\sigma-1}{\sigma}} + (1-\nu^*)^{\frac{1}{\sigma}} X_{F,t}^{*\,\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{3.28}$$

$$P_t^* X_t^* = P_{H,t}^* X_{H,t}^* + P_{F,t}^* X_{F,t}^* \tag{3.29}$$

$$P_t^* = \left[\nu^* {P_{H,t}^*}^{1-\sigma} + (1-\nu^*) {P_{F,t}^*}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{3.30}$$

where starred variables are foreign prices and quantities and ν^* is the share of home goods in the foreign basket. From the perspective of the home country, the terms of trade can be expressed as:

$$T_t = \frac{P_{F,t}}{P_{H,t}^*} \tag{3.31}$$

However, if the principle of purchasing power parity (PPP) holds,[3] such that $P_{H,t} = P_{H,t}^*$, then:

$$T_t = \frac{P_{F,t}}{P_{H,t}} \tag{3.32}$$

Therefore, we can express the relative prices of home- and foreign-produced goods as a function of the terms of trade:

$$\frac{P_{H,t}}{P_t} = [\nu + (1-\nu)T_t^{1-\sigma}]^{-\frac{1}{1-\sigma}} \tag{3.33}$$

$$\frac{P_{F,t}}{P_t} = [\nu T_t^{-(1-\sigma)} + (1-\nu)]^{-\frac{1}{1-\sigma}} \tag{3.34}$$

$$\frac{P_{H,t}^*}{P_t^*} = [\nu^* + (1-\nu^*)T_t^{1-\sigma}]^{-\frac{1}{1-\sigma}} \tag{3.35}$$

$$\frac{P_{F,t}^*}{P_t^*} = [\nu^* T_t^{-(1-\sigma)} + (1-\nu^*)]^{-\frac{1}{1-\sigma}} \tag{3.36}$$

while the real exchange rate, which is the ratio of foreign aggregate price to domestic aggregate price, can as well be expressed as a function of the terms of trade:

$$RX = \frac{P_t^*}{P_t} = \left[\frac{\nu^* + (1-\nu^*)T_t^{1-\sigma}}{\nu + (1-\nu)T_t^{1-\sigma}}\right]^{\frac{1}{1-\sigma}} \tag{3.37}$$

For the foreign country's intermediate-good firms, their analogous profit and production functions are given as:

$$\Pi_t^* = \frac{P_{F,t}^*}{P_t^*} Y_t^* - W_t^* N_t^* - R_t^{k*} K_{t-1}^* \tag{3.38}$$

$$Y_t^* = \varepsilon_t^{A^*} (U_t^* K_{t-1}^*)^{\alpha^*} {N_t^*}^{1-\alpha^*} \tag{3.39}$$

Following Baxter & Crucini (1993) and Baxter & Farr (2005), the exogenous process for productivity shocks, expressed in percentage deviation from steady state, is assumed to follow

[3] Otherwise known as the law of one price (LOOP).

a stationary process specified as a bivariate VAR(1):

$$\begin{bmatrix} \hat{\varepsilon}_t^A \\ \hat{\varepsilon}_t^{A*} \end{bmatrix} = \begin{bmatrix} \rho_a & \iota \\ \iota & \rho_a^* \end{bmatrix} \begin{bmatrix} \hat{\varepsilon}_{t-1}^A \\ \hat{\varepsilon}_{t-1}^{A*} \end{bmatrix} + \begin{bmatrix} \epsilon_t^a \\ \epsilon_t^{a*} \end{bmatrix} \tag{3.40}$$

The innovations to productivity process have zero mean, $E(\epsilon_t^a) = E(\epsilon_t^{a*}) = 0$, and a variance-covariance matrix given by:

$$E(\epsilon_t^a, \epsilon_t^{a*})(\epsilon_t^a, \epsilon_t^{a*})' = \begin{bmatrix} \sigma_a^2 & 0 \\ 0 & \sigma_{a*}^2 \end{bmatrix} \tag{3.41}$$

where ρ_a and ρ_a^* are the persistence parameters, ι is the diffusion parameter which captures how innovations to productivity are transmitted from one country to another, while σ_a^2 and σ_a^{*2} are the variances of technology shocks.

International Financial Markets

The internationally traded part of the foreign government bond has a zero net supply, such that:

$$\frac{P_{F,t}}{P_t} D_{F,t} + \frac{P_{F,t}^*}{P_t^*} D_{F,t}^* = 0 \tag{3.42}$$

Given that the law of one price holds, it can be shown that:

$$D_{F,t}^* = -\frac{P_t^*}{P_t} D_{F,t} \tag{3.43}$$

Substituting this identity into the expression for total foreign government bond, taking into account the aggregate definition for $D_{F,t}$ and an analogous aggregate definition for $B_{F,t}^* = (1-\lambda^*) B_{F,t}^{*r}$, we obtain:

$$B_t^* = (1-\lambda^*) B_{F,t}^{r*} - (1-\lambda) \frac{P_t^*}{P_t} D_{F,t}^r \tag{3.44}$$

where λ^* denotes the proportion of asset holders in the foreign economy. Applying the implicit theorem to this expression, it can be shown that:

$$\frac{dD_{F,t}^r}{dB_{F,t}^{r*}} = -\frac{\partial B_t^*}{\partial B_{F,t}^{r*}} / \frac{\partial B_t^*}{\partial D_{F,t}^r} = -\frac{1-\lambda^*}{-(1-\lambda)\frac{P_t^*}{P_t}} \tag{3.45}$$

Dividing the expression on the left hand size by the respective steady-state output gives:

$$\frac{dD^r_{F,t}}{Y}\left(\frac{Y}{Y^*}\right) \div \frac{dB^{r*}_{F,t}}{Y^*} = \left(\frac{1-\lambda^*}{1-\lambda}\right)\left(\frac{P^*_t}{P_t}\right)^{-1} \tag{3.46}$$

$$\therefore \frac{\hat{D}^r_{F,t}}{\hat{B}^{r*}_{F,t}} = \left(\frac{1-n}{n}\right)\left(\frac{1-\lambda^*}{1-\lambda}\right)\left(\frac{P^*_t}{P_t}\right)^{-1} \tag{3.47}$$

where, $\hat{D}^r_{F,t}$ and $\hat{B}^{r*}_{F,t}$ are the capital account balances of the home and foreign countries respectively, $\frac{P^*_t}{P_t}$ is the real exchange rate, and $n = \frac{Y}{Y+Y^*}$ is the relative size of the home country. This expression shows a number of factors influencing a country's relative net asset position at the global financial market. It simply states that the relative net asset position of an economy does not only depend on country characteristics – such as the relative country size and the exchange rate regime, but also driven by the relative degree of participation at the international asset market, as reflected in the relative size of the asset holders across economies. The implication of this derived result is that the degree of exposure at the global asset market could have important implications for cross-country policy spillovers.

Nesting all constraints by different agents and taking into consideration the first order optimization choices of both households and firms, the current account balance of the home country is obtained as

$$\frac{P_{F,t}}{P_t}(D_{F,t} - D_{F,t-1}) = \left[\frac{P_{H,t}}{P_t}Y_t - C_t - G_t - I_t\right] + \frac{P_{F,t}}{P_t}D_{F,t-1}(R^*_{t-1}\Phi^d_{t-1} - 1) \tag{3.48}$$

This equation simply states that the current account balance is equal to (national) savings less investment plus the net foreign asset income. Alternatively, the net foreign asset position can be expressed in terms of the trade balance by substituting the goods market equilibrium into the above equation to obtain:

$$\begin{aligned}(D_{F,t} - D_{F,t-1}) = &\left[\frac{1}{T_t}(C^*_{H,t} + I^*_{H,t} + G^*_{H,t}) - (C_{F,t} + I_{F,t} + G_{F,t})\right] \\ &+ (R^*_{t-1}\Phi^d_{t-1} - 1)D_{F,t-1}\end{aligned} \tag{3.49}$$

which simply states that the net foreign asset position of an economy is the sum of its trade balance (exports less imports, as shown in the first term on the RHS of the equation) and interest income on foreign asset.

3.4 Estimation

The procedure for the model evaluation involves three steps. First, we solve for optimal choices of households and firms. Then, we generate a system of equations by combining the agents' optimal choices with constraints and equilibrium conditions in the model. In the second step, we generate the steady-state conditions for the system of equations and log-linearise each equation relative to the steady-state conditions. This procedure allows variable responses to be interpreted as percentage deviations from steady-state. Finally, the third step involves the estimation of the model using Bayesian technique as described by An & Schorfheide (2007). This technique involves specifying prior distributions for the non-calibrated parameters of the model and obtaining the posterior distributions of the estimated parameters based on the state-space representation of the log-linearised approximation of the model using Kalman filter.

Let the prior distribution of the parameter vector $\theta \in \Theta$ for some model $m \in M$ be $P(\theta|m)$, and let the likelihood function of the observed data $X_T = \{x_t\}_{t=1}^{T}$ be defined as $L(X_T|\theta, m)$, which is conditional on the parameter vector θ and the model m. The computation of the likelihood starts from the solution to the log-linear state-space representation of the model using Kalman filter. The computed likelihood function for the data can then be combined with the prior distribution to obtain the posterior distribution of the estimated parameters, given as:

$$P(\theta|X_T, m) \propto L(X_T|\theta, m)P(\theta|m) \tag{3.50}$$

The posterior mode can be obtained by numerically maximizing $P(\theta|X_T, m)$. To obtain the posterior distribution, the Metropolis-Hasting (MH) algorithm is then initiated based on some Monte Carlo Markov Chain (MCMC) draws, with some draws discarded in the burn-in phase.

The model estimation is carried out in Matlab using Dynare interface. The rest of this section describes the observed data, parameter calibration, prior and posterior distributions of estimated parameters.

3.4.1 Data

In order to estimate the model described above, we use a set of 6 variables each for the United Kingdom and the aggregate Euro area respectively over the sample period 1999:Q1-2015:Q4 (68 observations): private consumption, investment, total labour hours, government consumption spending, consumption tax revenue and government debt. We have used 12 variables here since

Figure 3.2: **The observed variables (1999Q1-2015Q4).**
Notes: This figure shows the one-sided HP-filtered time series used in the estimation of the model.

there are 12 structural shocks (6 for each country) in the model. The choice of these selected variables is informed by the identification of key structural shocks and deep parameters of interest in the model. For instance, while the observed series on government consumption spending is targeted at identifying government spending shocks in the fiscal rule, government debt is aimed at identifying the share of asset holders in each country, and the net surplus/deficit of private and public demands between the two countries is to help identify the trade elasticity between home and foreign goods.

The data series are obtained from the Eurostat online database. The aggregate Euro area data employed for this analysis is the composite of the 19 members of the monetary union as of 2015. In comparison, Gadatsch et al. (2016) used aggregates of the 8 largest members of the union only, which is just a subset of the initial EMU-11 countries. All the variables are converted to real values using their respective constant price deflators, and further converted to per capita values using the respective population of the country/region.[4] The data series are detrended using the one-sided HP-filter, and the filtered series are further demeaned as suggested by Pfeifer (2018).

Figure 3.2 plots the stochastically de-trended time series of the observed variables used in the estimation of the benchmark model. From this plot, it can be observed that, while government

[4]Most of the studies in the literature have used the active population as the per capita deflator, but we have used the total population here as we could not have access to the aggregate Euro area active population. However, our approach is still much better than using the variables in levels as noted in Pfeifer (2018).

Table 3.1: **Calibration of selected parameters and key steady state ratios**

Parameter/Target Variables		Value UK	Value EA	Comment
Preference				
Subjective discount factor	β, β^*	0.995	0.995	Annualised real interest rate of 2% in EA
Govt share in Ric cons. bundle	ϱ_r, ϱ_r^*	0.2112	0.2552	Computed as: $\varrho_r = \frac{G}{C^r+G}$
Govt share in ROT cons. bundle	ϱ_h, ϱ_h^*	0.2657	0.2917	Computed as: $\varrho_h = \frac{G}{C^h+G}$.
Technology				
Capital share	α, α^*	0.30	0.30	One-third of income (See Coenen et al. (2013))
Depreciation rate	δ, δ^*	0.015	0.015	6% at annualised rate Coenen et al. (2013)
International sector				
Foreign debt elasticity	ϕ_d	0.01		See Bouakez & Eyquem (2015)
Foreign debt	$\frac{D_F}{Y}$	0.00		
Target Steady state variables				
Government consumption ratio	$\frac{G}{Y}, \frac{G^*}{Y^*}$	0.1898	0.2069	Eurostat database
Government transfer ratio	$\frac{Z}{Y}, \frac{Z^*}{Y^*}$	0.1268	0.1639	Eurostat database
Government debt ratio	$\frac{B}{4Y}, \frac{B^*}{4Y^*}$	0.5433	0.7605	Eurostat database
Consumption tax	τ^c, τ^{c*}	0.1755	0.1981	Computed as ratio of cons. tax rev. to priv. cons.
Income tax	τ^w, τ^{w*}	0.3001	0.3743	Calibrated from the model
Relative size of home country	n, $1-n$	0.1430	0.857	Eurostat database. $n = \frac{Y}{Y+Y^*}$
Imports share in consumption	$(1-\nu), \nu^*$	0.2095	0.0408	Eurostat database.

Notes: This table presents the calibrated values of selected parameters and key steady state ratios of target variables for our country/region of interest. In cases where a value is recorded for a parameter only under the UK column, it implies that such parameter is an interlink parameter between the two countries but calibrated from the UK's perspective.

spending rose sharply during the crisis period in both countries, it fell sharply and has remained below the trend line since 2010, which corresponds to the beginning of the sovereign debt crisis when fiscal consolidations were initiated in these countries. The initial increase in government spending during the crisis period led to a surge in government debt; however, since 2011, government debt has levelled down around the trend, which corresponds to the period of fiscal consolidation. More so, during the consolidation period, private consumption growth tends to be lower compared to the pre-consolidation era, while labour hours tends to be higher.

3.4.2 Calibration

Table 3.1 presents the values assigned to calibrated parameters and steady state ratios of key target variables for both countries of interest. For the calibrated structural parameters, α is set to 0.30 as in Coenen et al. (2013), suggesting that capital income share in both countries is about one-third; while δ is set to 0.015 as in Gadatsch et al. (2016), suggesting a 6% annualised depreciation rate of capital; and the subjective discount factor β is set to 0.995 to hit an annualised real interest rate of 2% for the EA.[5] The elasticity of the risk premium (the bond holding cost), ψ_d, is set to 0.01 as in most literature on incomplete market with limited risk-sharing. Bouakez & Eyquem (2015) estimated ψ_d to be around 0.006 for the UK in a trade

[5]For the EA, Gadatsch et al. (2016) set β to be 0.9985 while Coenen et al. (2013) calibrated β to hit an annualised equilibrium real interest rate of 2.5%, that is, $\beta = 0.9938$

with the rest of the world.

Based on the assumptions made in the model, the share of public goods in households' consumption bundle is calibrated differently for each type of household. ϱ_r and ϱ_h are calibrated to 0.2112 and 0.2657 for UK asset and non-asset holding households respectively, while the figures are 0.2552 and 0.2917 respectively for their counterparts in the EA. These values show that, while non-asset holders depend considerably more on government resources in both countries, which is in line with our earlier argument, the share of government spending in total final expenditure in the UK economy is relatively smaller compared to the EA.

Regarding the steady state values of key target variables as computed from the individual statistics of each economy, government consumption spending as a ratio of nominal GDP is about 19% for the UK and 21% for the EA, while transfer-to-GDP ratio is about 13% and 16% respectively. This suggests that steady state aggregate government spending ratio in the EA is about 17% points higher compared to the UK. Similarly, steady state tax rates on consumption and income are relatively higher in the EA compared to the UK. τ^c and τ^w are calibrated to about 18% and 30% respectively for the UK, while for the EA, they are about 20% and 37% respectively. Meanwhile, steady state government debt ratio (quarterly average) is about 54% for the UK, compared to a much higher value of about 76% for the EA, while the foreign debt is assumed to be zero at steady state.

Finally, we calibrated some useful parameters relating both economies. The relative size of the UK economy is calibrated to about 14.3%, suggesting that the UK is relatively small compared to the aggregate EA economy. Also, the share of imports from EA in UK's aggregate consumption bundle is computed to be about 21%, which is quite reasonable.

3.4.3 Prior Distribution

Table 3.2 presents the prior distributions of the estimated parameters. The select priors conform with existing studies on the Euro area (see Gadatsch et al. (2016), Coenen et al. (2013), Forni et al. (2010)). As it's the norm in international business cycle studies, similar parameters in both the UK and EA are assigned equal priors. For the relative risk aversion, (θ, θ^*), and the inverse Frisch elasticity of labour supply, (η, η^*), we assume a Gamma distribution with the prior mean set at 1.5 and 2 respectively and standard deviation of 0.40, which are similar to the values set by Leeper, Plante & Traum (2010). The habit formation parameter, (κ, κ^*), is assumed to follow a Beta distribution with the mean set at 0.50 and a standard deviation of 0.10. The elasticity of substitution between private and public goods, (φ, φ^*), is assumed

Table 3.2: **Prior distributions and posterior estimates for baseline model**

Parameter		Prior			Posterior			
		Density	Mean	Std.	Mode	Mean	[5%,95%]	Std
United Kingdom								
Structural								
Risk aversion	θ	Gamma	1.50	0.40	1.978	2.022	[1.475, 2.563]	0.282
Inv Frisch elast.	η	Gamma	2.00	0.40	1.171	1.288	[0.876, 1.739]	0.213
Habit	κ	Beta	0.50	0.10	0.273	0.278	[0.159, 0.397]	0.063
Consump elast.	φ	Gamma	0.30	0.10	0.471	0.488	[0.320, 0.675]	0.086
Share of non-asset holders	λ	Beta	0.35	0.05	0.279	0.279	[0.215, 0.348]	0.034
Inv. adj. costs	ϕ_k	Normal	5.00	2.50	2.679	4.227	[1.353, 7.584]	1.414
Fiscal Rule								
G resp. to B	ς_g	Gamma	0.40	0.20	0.083	0.088	[0.030, 0.150]	0.031
Z resp. to B	ς_z	Gamma	0.40	0.20	0.139	0.182	[0.039, 0.348]	0.077
τ^c resp. to B	ς_{τ^c}	Gamma	0.40	0.20	0.167	0.185	[0.055, 0.325]	0.072
τ^w resp. to B	ς_{τ^w}	Gamma	0.40	0.20	0.528	0.551	[0.294, 0.808]	0.123
τ^w resp. to Inv.	ϑ_{τ^w}	Gamma	0.50	0.30	0.290	0.294	[0.105, 0.493]	0.100
Cross-corr of taxes	ι_τ	Normal	0.00	0.20	-0.131	-0.124	[-0.252, 0.006]	0.067
AR(1) Coefficients								
Technology shock	ρ_a	Beta	0.50	0.20	0.447	0.462	[0.209, 0.726]	0.137
Inv-Specific Tech. shock	ρ_i	Beta	0.50	0.20	0.136	0.161	[0.025, 0.313]	0.076
Govt spending feedback	ρ_g	Beta	0.50	0.20	0.823	0.804	[0.647, 0.952]	0.083
Transfer feedback	ρ_z	Beta	0.50	0.20	0.277	0.333	[0.081, 0.594]	0.145
Consumption tax shock	ρ_{τ^c}	Beta	0.50	0.20	0.622	0.623	[0.432, 0.815]	0.097
Income tax shock	ρ_{τ^w}	Beta	0.50	0.20	0.641	0.643	[0.455, 0.829]	0.097
Std. of Shocks								
Technology shock	σ_a	Inv. Gamma	0.10	2.00	0.015	0.016	[0.013, 0.019]	0.002
Inv-Specific Tech. shock	σ_i	Inv. Gamma	0.10	2.00	0.109	0.164	[0.059, 0.287]	0.052
Govt spending	σ_g	Inv. Gamma	0.10	2.00	0.018	0.019	[0.016, 0.023]	0.002
Transfer	σ_z	Inv. Gamma	0.10	2.00	0.096	0.100	[0.081, 0.121]	0.010
Consumption tax	σ_{τ^c}	Inv. Gamma	0.10	2.00	0.025	0.026	[0.021, 0.030]	0.002
Income tax	σ_{τ^w}	Inv. Gamma	0.10	2.00	0.027	0.029	[0.023, 0.036]	0.003
Euro Area								
Structural								
Risk aversion	θ^*	Gamma	1.5	0.40	2.281	2.315	[1.721, 2.902]	0.302
Inv Frisch	η^*	Gamma	2.0	0.40	1.549	1.571	[1.070, 2.096]	0.268
Habit	κ^*	Beta	0.50	0.10	0.276	0.284	[0.173, 0.398]	0.058
Consump elast.	φ^*	Gamma	0.30	0.10	0.394	0.413	[0.266, 0.572]	0.075
Share of non-asset holders	λ^*	Beta	0.35	0.05	0.295	0.295	[0.228, 0.364]	0.035
Inv. adj. costs	ϕ_k^*	Normal	5.00	2.50	5.075	6.091	[2.848, 9.587]	1.757
Fiscal Rule								
G^* resp. to B_F^*	ς_g^*	Gamma	0.40	0.20	0.107	0.119	[0.036, 0.207]	0.045
Z^* resp. to B_F^*	ς_z^*	Gamma	0.40	0.20	0.162	0.211	[0.040, 0.409]	0.090
τ^{c*} resp. to B_F^*	$\varsigma_{\tau^c}^*$	Gamma	0.40	0.20	0.153	0.188	[0.045, 0.352]	0.079
τ^{w*} resp. to B_F^*	$\varsigma_{\tau^w}^*$	Gamma	0.40	0.20	0.798	0.797	[0.418, 1.170]	0.191
τ^{w*} resp to Inv.	$\vartheta_{\tau^w}^*$	Gamma	0.50	0.30	0.218	0.253	[0.045, 0.473]	0.121
Cross-corr of taxes	ι_τ^*	Normal	0.00	0.20	-0.218	-0.205	[-0.374, -0.031]	0.090
AR(1) Coefficients								
Technology shock	ρ_a^*	Beta	0.50	0.20	0.777	0.764	[0.608, 0.910]	0.082
Inv-Specific Tech. shock	ρ_i^*	Beta	0.50	0.20	0.507	0.497	[0.272, 0.726]	0.117
Govt spending feedback	ρ_g^*	Beta	0.50	0.20	0.900	0.874	[0.755, 0.982]	0.061
Transfer feedback	ρ_z^*	Beta	0.50	0.20	0.646	0.631	[0.353, 0.891]	0.146
Consumption tax shock	$\rho_{\tau^c}^*$	Beta	0.50	0.20	0.803	0.793	[0.640, 0.939]	0.080
Income tax shock	$\rho_{\tau^w}^*$	Beta	0.50	0.20	0.738	0.739	[0.544, 0.924]	0.107
Std. of Shocks								
Technology shock	σ_a^*	Inv. Gamma	0.10	2.00	0.012	0.012	[0.012, 0.014]	0.001
Inv-Specific Tech. shock	σ_i^*	Inv. Gamma	0.10	2.00	0.063	0.076	[0.037, 0.121]	0.020
Govt spending	σ_g^*	Inv. Gamma	0.10	2.00	0.012	0.013	[0.012, 0.015]	0.001
Transfer	σ_z^*	Inv. Gamma	0.10	2.00	0.047	0.049	[0.040, 0.059]	0.005
Consumption tax	$\sigma_{\tau^c}^*$	Inv. Gamma	0.10	2.00	0.015	0.016	[0.013, 0.019]	0.001
Income tax	$\sigma_{\tau^w}^*$	Inv. Gamma	0.10	2.00	0.017	0.018	[0.014, 0.022]	0.002
External Block								
Trade elasticity	σ	Gamma	1.50	0.40	1.935	2.008	[1.436, 2.609]	0.289
Technology diffusion	ι	Normal	0.00	0.20	0.051	0.050	[-0.059, 0.157]	0.057

Notes: This table presents the prior distributions and posterior estimates of parameters in the benchmark model with an estimated share of non-asset holding households (ROT). The EA pameters are starred. Posterior Mean and percentiles are from two Monte Carlo Markov Chains with 1,000,000 draws generated using a Metropolis-Hasting random walk algorithm, where we discard 200,000 draws in the burn-in phase of each chain (i.e. 20%). The MH step-size is sufficiently tuned up such that it resulted to an acceptance rate of about 30% which is comfortably within the band specified in the literature (see Adjemian et al. (2011)). Finally, for convergence, we examine the Brooks & Gelman (1998) convergence plots to ensure that the MCMC chains converge to unique posterior value.

to follow a Gamma distribution with a mean of 0.30 and a standard deviation of 0.10. The share of non-asset holders, (λ, λ^*), is assumed to follow a Beta distribution with the mean set to 0.35 and a standard deviation of 0.05, which is consistent with the range of $(0, 0.50)$ often estimated in the literature (see Gadatsch et al. (2016), Coenen et al. (2013) and Corsetti et al. (2010)). The investment adjustment costs parameter, (ϕ_k, ϕ_k^*), is assumed to follow a Normal distribution with the mean set to 5 and a standard deviation of 2.5.

Regarding the fiscal adjustment parameters of government debt, $(\varsigma_x, \varsigma_x^*)$, since we have imposed sign restrictions on them within the model as in Leeper, Plante & Traum (2010), they are assumed to have a Gamma density with a prior mean of 0.40 and a standard deviation of 0.20. More so, we assumed that the contemporaneous response of income tax to investment, $(\vartheta_{\tau w}, \vartheta_{\tau w}^*)$, follows a Gamma distribution with a mean of 0.50 and a standard deviation of 0.30; while the contemporaneous cross-correlation of consumption and income tax shocks, $(\zeta_{cn}, \zeta_{cn}^*)$, is assumed to follow a Normal distribution with a zero mean and a standard deviation of 0.20.

Following Forni et al. (2010), we set the prior mean of trade elasticity between home and foreign goods, σ, to 1.5 with a standard deviation of 0.40 on the assumption that it has a Gamma density; whereas, the technology diffusion parameter, ι, is assumed to follow a Normal distribution with a zero mean and a standard deviation of 0.20. Finally, the prior distributions for the AR(1) coefficients and standard deviations of unanticipated shocks are pretty standard: (ρ_x, ρ_x^*) are assumed to follow a Beta distribution with a 0.50 mean and a standard deviation of 0.20, while (σ_x, σ_x^*) are assumed to follow an Inverse Gamma distribution with mean and standard deviation set to 0.10 and 2 respectively.

3.4.4 Posterior Estimates

The last four columns of Table 3.2 present the posterior distribution of the estimated parameters in the benchmark model with estimated share of non-asset holders. The table reports the posterior mode and mean with 5 and 95 percent confidence bounds, and the standard deviation. The posterior mode and standard deviation are obtained by maximizing the posterior kernel using the *fmincon* optimization routine in Dynare (option 1). The mean and the percentile distributions are obtained from two 1,000,000 MCMC draws, with 200,000 draws discarded in the burn-in phase of each chain (that is, 20%). The average acceptance ratio is between 29.46% and 29.55%, which is comfortably within the specified band in the literature (see Adjemian et al. (2011)). Furthermore, we carry out some diagnostic checks to ensure that the estimated parameters are uniquely identified and that the MCMC chains converge to unique posterior values (see the Appendix).

From the table, it can be observed that all parameters are estimated to be non-zero, except for the technology diffusion parameter and the comovement term of consumption and income taxes in the UK which both include zero. Comparing the domestic blocks, it can be observed that the size of non-policy structural parameters in both countries/regions are pretty similar, except for the investment adjustment costs (ϕ_k, ϕ_k^*) which is 4.23 for the UK and 6.09 for the Euro area. Both countries have a relatively sizeable amount of non-asset holders (λ, λ^*), roughly between one-quarter and one-third of the population (about 28% for the UK and 30% for the EA), which is consistent with most estimates in the literature for the economies (see Forni et al. (2009), Coenen & Straub (2005)). More so, elasticities of substitution between public and private goods, (φ, φ^*), are 0.49 and 0.41 at mean for the UK and EA respectively, suggesting that both goods are moderate complements, which is similar to the finding of Coenen et al. (2013). Furthermore, the result suggests that the parameter estimates of the AR(1) coefficients are relatively more persistent in the EA compared to the UK, while shocks to the UK economy are relatively more volatile compared to the EA.

Focusing on estimates of fiscal policy rules, it is observed that the response of fiscal instruments to domestic government debt innovations is relatively stronger in the EA compared to UK, especially for income taxes which have the highest response.[6] Also, the result shows that income taxes have sizeable procyclical movement with investment in both countries, suggesting that an increase in investment, hence output, could lead to a rise in income tax rate. Our fiscal adjustment estimates are comparable to studies on fiscal policy in Europe. For instance, Coenen et al. (2013) estimated government spending adjustment parameter to be -0.02, and -0.14 for transfer, which are a bit less than our estimates; while Forni et al. (2009) estimated labour income tax adjustment to be 0.28 at mean, and 0.50 for consumption tax adjustment.[7] Finally, the contemporaneous correlation between consumption and income taxes is estimated to be negative for both countries, suggesting that adjustments on one tax may affect the other, at least in the Euro area where the comovement term is statistically different from zero. Shocks to government transfers tend to be relatively more volatile compared to other fiscal shocks in both countries.

Regarding the parameters of international linkages, evidence from our result points to the

[6] It is worth noting that all fiscal adjustment parameters are estimated to be positive since we have already imposed sign restrictions on them in the model

[7] Note that the Forni et al. (2009) model also includes taxes on capital with the adjustment parameter estimated to be 0.57. This may account for the low estimate of labour income tax adjustment in their model compared to our model with zero capital tax.

fact that home and foreign goods are substitutes with the trade elasticity, $\sigma \in (1.44, 2.61)$, estimated to be significantly greater than one. This value is validly within the range of 0.66 to 3 suggested by Corsetti et al. (2010), and the range of 0.1 to 2 surveyed by Corsetti et al. (2008). However, this result is in contrast with the finding of Justiniano & Preston (2010) who estimated a median trade elasticity value of 0.86 for US trade with Canada, suggesting that home and foreign goods are weakly complementary. Also, Gadatsch et al. (2016) estimated a trade elasticity of 0.97 at mean for German trade with the rest of the Euro area, suggesting that final-goods firms have a near Cobb-Douglas technology. Finally, the technology diffusion parameter in the productivity transition matrix is estimated to be around 0.05 at mean, which is higher than a value of 0.025 estimated by Heathcote & Perri (2002) for the US trade with the rest of the world.

3.5 Impulse Responses

This section discusses the impulse responses of estimated fiscal shocks in the linearised benchmark model. The impulse responses are generated based on the posterior mean of the estimated parameters. Figures 3.3 – 3.6 plot the impulse responses to domestic fiscal shocks compared with international fiscal spillovers. The solid line denotes the response to UK fiscal consolidation shocks while the dotted-dashed line represents the response to consolidation shock in the Euro area. For convenience, the standard deviation of each shock is set to $100\hat{\sigma}_x$ such that the values on the vertical axis can be interpreted as percentage deviation from the steady state (the horizontal line), while the horizontal axis is the period in quarter.

3.5.1 International Transmission of Fiscal Shocks between the UK and EA

Figure 3.3 displays the responses of both the UK and EA to a consolidation shock induced by a cut in government consumption spending. On impact, private consumption and investment rises, while hours and real wage fall in the home country. The fall in labour supply causes domestic output to contract which, in turn, leads to less demand for foreign goods, and the depreciation of the bilateral terms of trade as domestic real interest rate falls below foreign real interest rate (negative differential), thereby causing domestic households to hold more foreign assets (capital outflow). These two forces (less import and terms of trade depreciation) reinforce each other to improve home country's trade balance. As a result, foreign output falls as well,

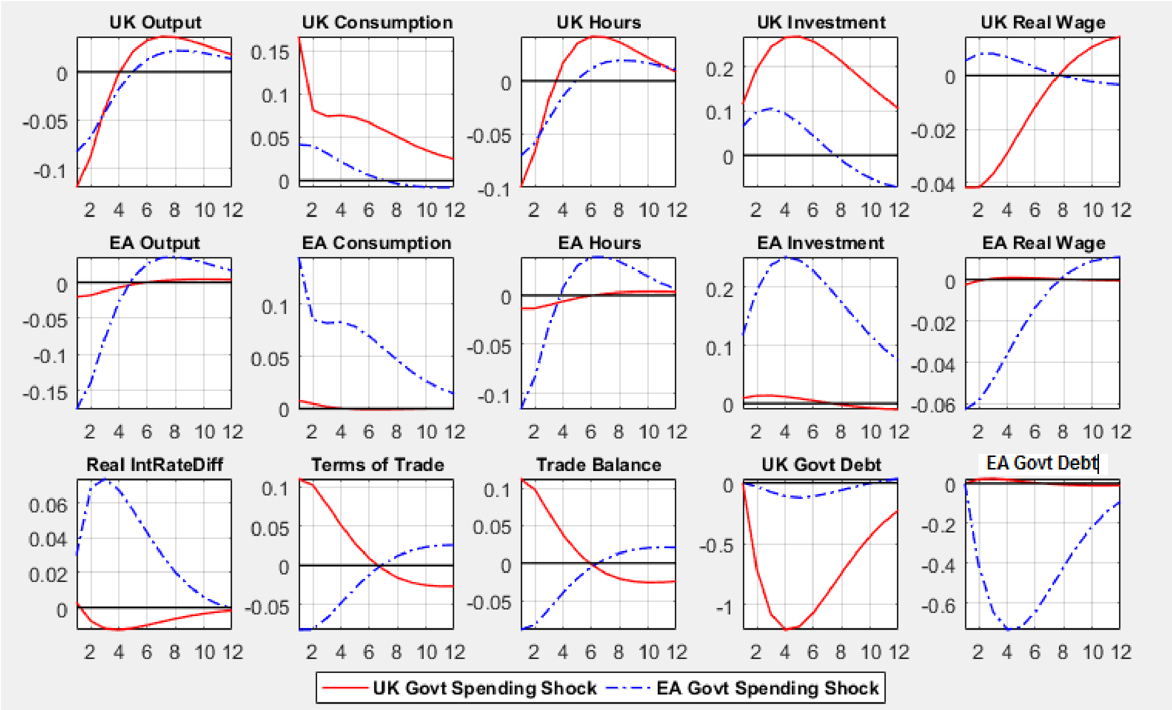


Figure 3.3: **Impulse responses to a one standard deviation decrease in government consumption spending.**

Notes: The figure shows the responses of both UK and EA to fiscal shocks from both countries. The impulse responses are computed based on the posterior mean of the estimated parameters. Solid lines denote responses to UK government spending shock while the dotted-dashed lines denote responses to EA government spending shock.

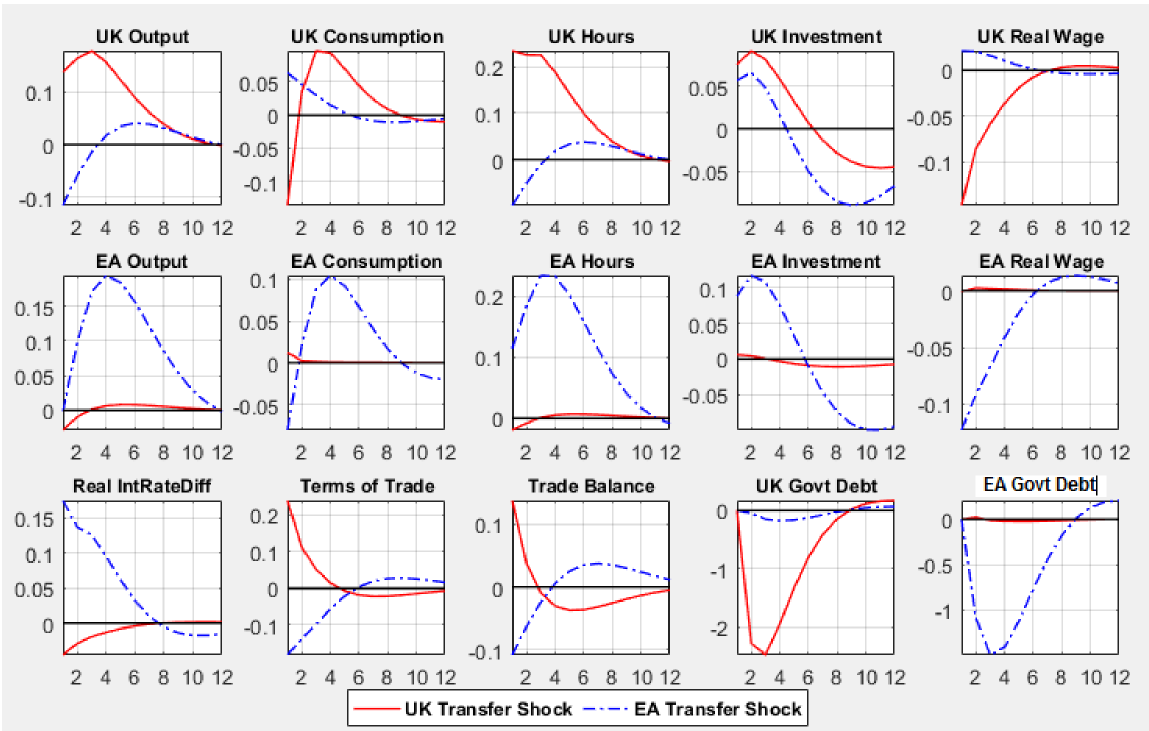


Figure 3.4: **Impulse responses to a one standard deviation decrease in government transfers.**

Notes: See Figure 3.3.

while foreign consumption rises.

In this model, foreign output falls in response to domestic government spending shock for two reasons: first, due to low demand for foreign goods by home agents (i.e. less export earnings for foreign country) and, second, due to the depreciation of the bilateral terms of trade which transfer competitiveness to the home country, thereby worsening the foreign country's trade balance. On the other hand, foreign consumption rises primarily because there are now more domestically produced good in the economy, and relatively cheaper imports. This result is consistent with the analysis of Corsetti et al. (2010) which finds that an increase in government spending leads to output expansion, both in the home and foreign economies, and a trade deficit in the home country. However, in contrast to our result, they found a positive comovement between private consumption and public spending which they argued is due to a fall in long run interest rate in their model. Also Gadatsch et al. (2016) observed that a positive shock to the German government purchases have negative spillover effects on output and consumption in the rest of the Euro area.

Figure 3.4 plots the impulse responses to government transfer cuts. Since transfer cuts imply lesser income to the households,[8] private consumption falls contemporaneously as households substitute leisure for more labour hours in order to achieve at least the pre-consolidation level of consumption. The rise in labour productivity improves the marginal productivity of capital, causing output to rise in the home country. As home household consumption falls, the demand for foreign goods decline and the terms of trade depreciates. This, in turn, leads to a fall in foreign output while foreign consumption rises.

Figures 3.5 and 3.6 plot the impulse responses to a positive shock to distortionary taxes on consumption and labour income respectively. As expected, an increase in consumption tax in the domestic economy leads to a fall in domestic consumption, while foreign consumption rises. As households postpone current consumption and substitute leisure for labour, investment rises, leading to an output expansion in the home country, while foreign output falls. On the other hand, a tax hike on labour income discourages labour effort, causing real wage to rise in the home country. The high labour costs leads to a fall in firms' investment spending, which in turn leads to a fall in output and consumption in the home country. As domestic income falls, households borrow from abroad, causing domestic interest rate to rise relative to foreign interest rate. As a result, the bilateral terms of trade appreciate in the home country which, in turn, worsen the trade balance condition. In response to this, foreign output rises as international competitiveness is transferred to the foreign economy, while foreign consumption falls because

[8] Transfer is an income received not earned.

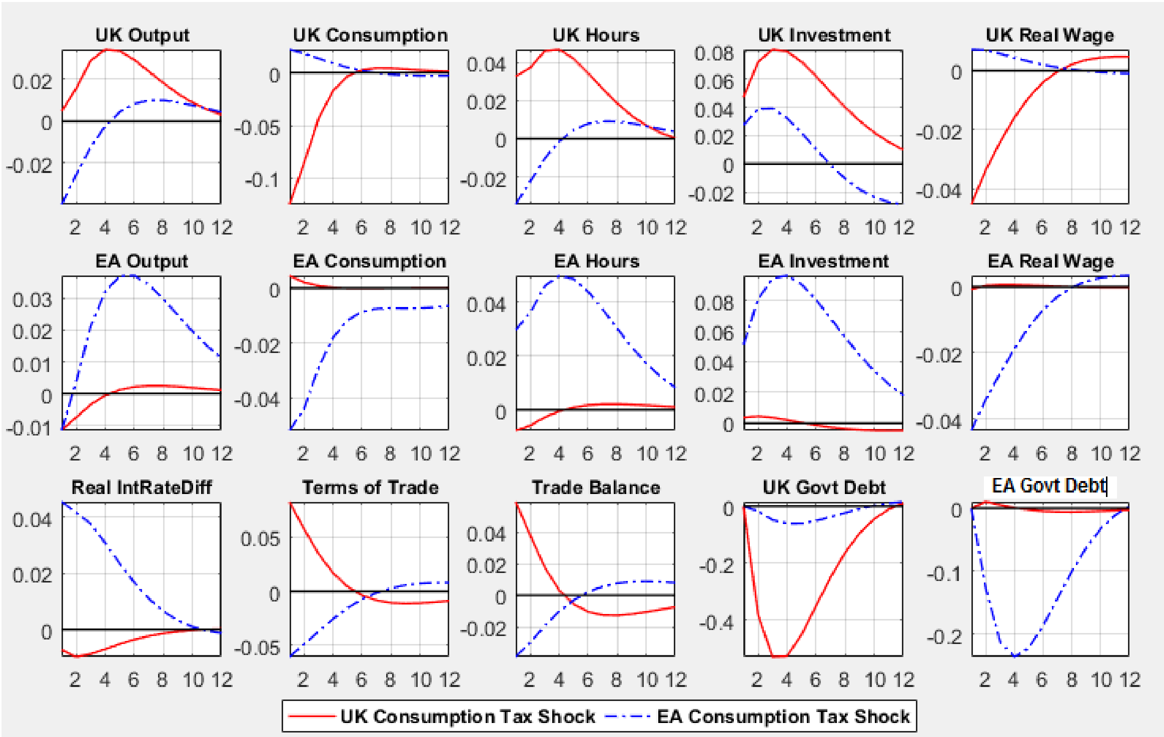


Figure 3.5: **Impulse responses to a one standard deviation increase in consumption tax rate.**
Notes: See Figure 3.3.

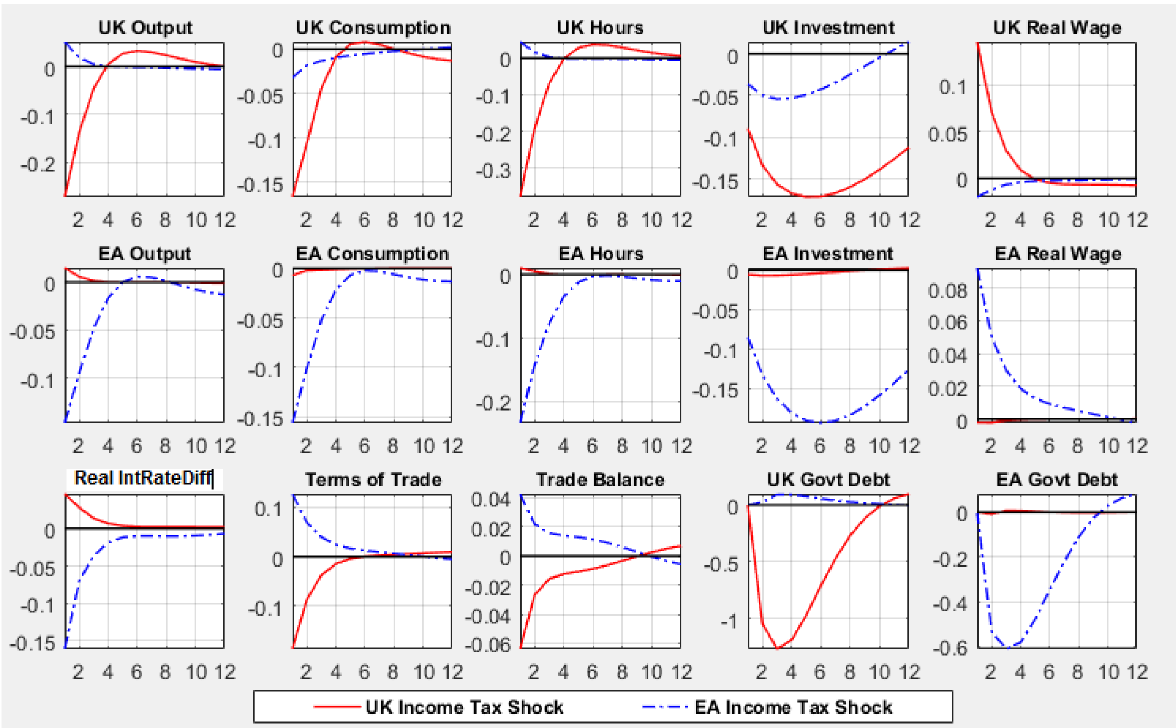


Figure 3.6: **Impulse responses to a one standard deviation increase in income tax rate.**
Notes: See Figure 3.3.

home goods have become relatively expensive. This result is partly in line with the findings of Gadatsch et al. (2016) which observed that a rise in German consumption tax causes output to contract and private consumption to increase in the rest of the Euro area, while German labour tax hike does not only crowd-out output and consumption in the home country but also in the rest of the Euro area.

Comparatively, evidence from the simulation results show that EA consolidation policies have significant spillover effects on the UK economy, while UK fiscal policies have relatively minimal effect on EA economic activities. For instance, while UK output response to EA government spending cut is nearly as high as its response to domestic spending cut, the UK government spending shock only accounts for about one-tenth of the magnitude of EA spending shock on EA output. This is partly due to the relatively small size of the UK economy compared to the aggregate Euro area economy,[9] and partly due to the trade effect, as trade between the two countries constitute nearly half of total UK trade. More so, this analysis shows that the effect of fiscal spillovers across borders depends on the type of fiscal instrument being considered. While the spending-based consolidation policies are transmitted across borders through partial crowding out/in of domestic demand, tax-based policies are transmitted through their effect on real wages and relative prices.

3.5.2 Fiscal Spillovers and International Asset Market Participation

In Section 3.3.5, we analytically derived that the relative participation of countries at the international asset market is a significant driving force for their net foreign asset holding which, in turn, influences cross-border policy responses. In this section, we demonstrate this key result in the estimated model. To do this, we plot the response of the UK economy to EA consolidation shocks and vary the share of non-asset holders in the EA (the source country) relative to the estimated value, while holding constant the estimated share of non-asset holders in the UK economy (the response country). The simulation results of this exercise are displayed in Figures 3.7 and 3.8.

Figures 3.7 and 3.8 plot the impulse responses of aggregate and agent-specific UK macroeconomic variables to EA fiscal consolidation shocks for varying degree of participation of the source country. For the agent-specific responses, we plot the effective consumption and labour hours of each type of household. Figure 3.7 shows that UK agents hold less assets in response to consolidation shocks in the Euro countries, except when the consolidation policy is income tax-based and the source country have at least the same level of participation with the response country. As UK agents adjust their foreign asset holding, current balance adjusts accordingly,

[9]UK GDP is roughly 17% of the size of Euro area GDP.

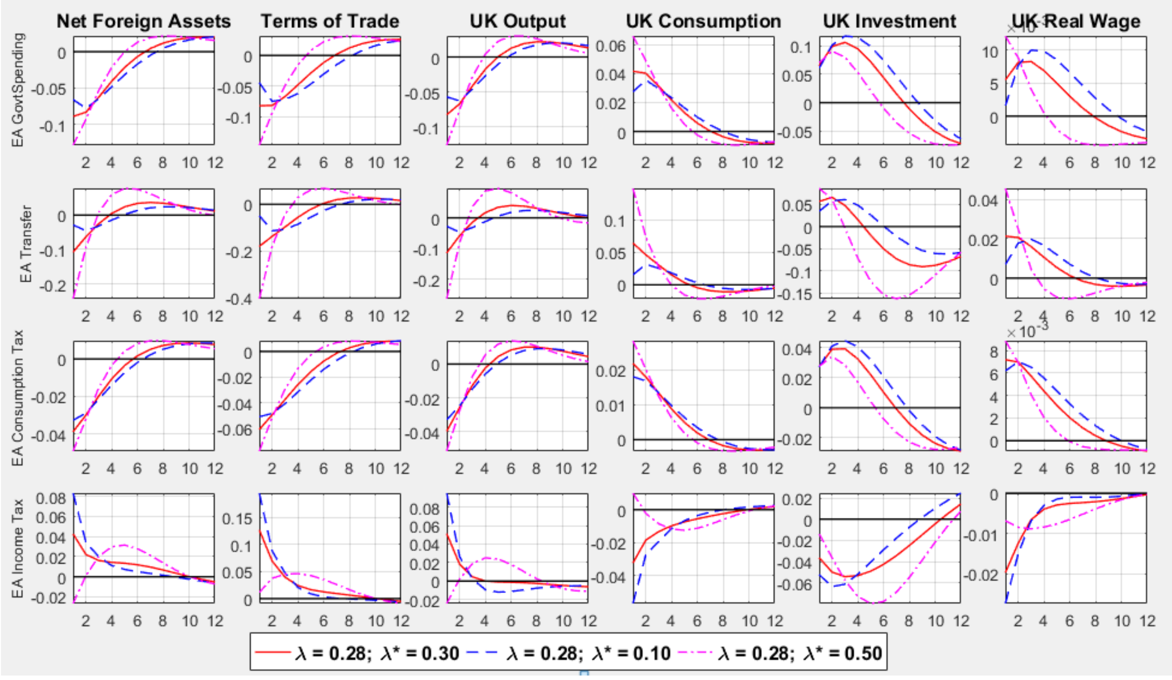


Figure 3.7: **Effect of changes in relative asset market participation on EA fiscal spillovers to the UK (aggregate variables).**
Notes: The solid lines denote the estimated baseline model with approximately equal asset market participation rate in both countries i.e. $(1-\lambda^*) \equiv (1-\lambda)$. The dash lines denote relatively more asset market participation in the EA compared to the UK, that is, $(1-\lambda^*) > (1-\lambda)$. The dotted-dash lines denote relatively less asset market participation in the EA compared to the UK, that is, $(1-\lambda^*) < (1-\lambda)$.

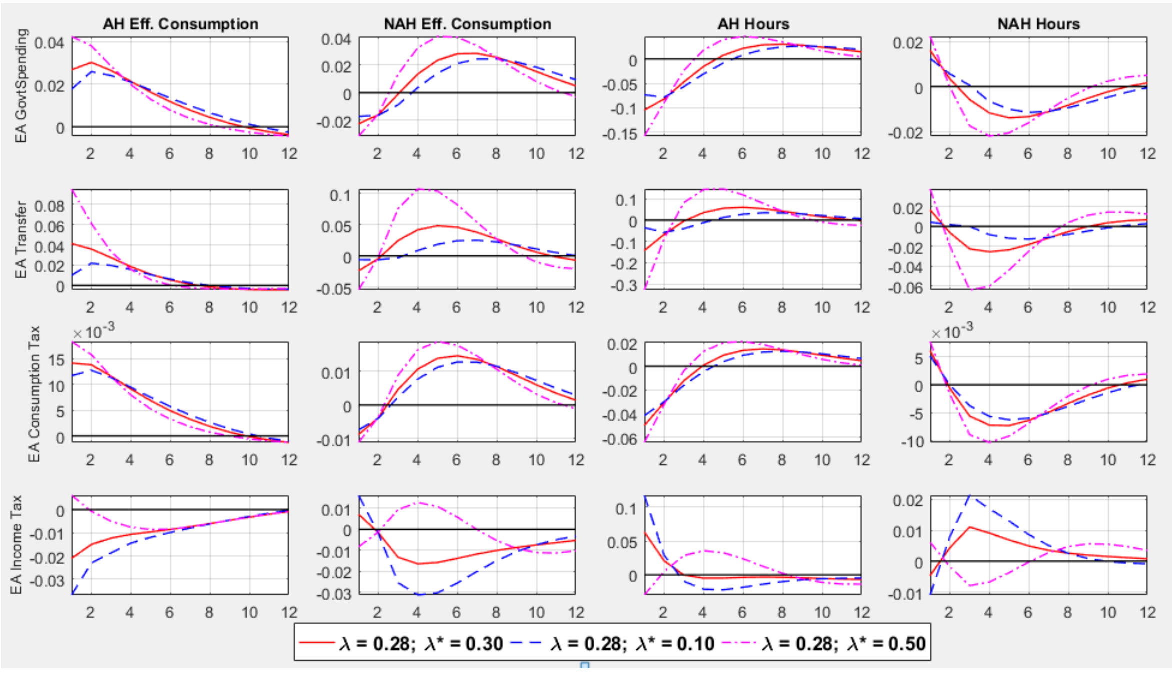


Figure 3.8: **Effect of changes in relative asset market participation on EA fiscal spillovers to the UK (agent-specific variables).**
Notes: See Figure 3.7. AH = Asset holders; NAH = Non-asset holders.

which directly translates into adjustments in GDP. Notice that, on impact, there is a one-for-one relationship between the current account balance and the domestic output. This result suggests that changes in net asset position, as a result of changes in source-country's relative participation, have a pro-cyclical effect on the response-country's output.

Regarding the effect of countries' relative participation at the global asset market, there are three key lessons observed from the simulation exercise. First, relative participation of the source country drives the propagation and amplification of fiscal spillovers in the response country. The higher the relative participation of the source country at the global asset market, the smaller the amplification effect of fiscal spillovers in the response country, except when the fiscal spillover is income tax-based. Secondly, in the medium run, relative participation of the source country have more pronounced effects on the dynamic response of investment and real wage in the response country. This may be due to the effect of fiscal spillovers on domestic prices, which in turn affects firms' investment decisions. Thirdly, from Figure 3.8, the relative participation of the source country mainly influences the asset holders' optimal choices (effective consumption and hours) in the response country in the short run, but this effect gradually disappear after 4-6 quarters; whereas, it mainly affects the optimal choices of the non-asset holders in the medium run. One plausible explanation for this could be the foresight ability of the households: since the domestic asset-holders participate in the global asset markets, thereby having first-hand information about global liquidity conditions, they quickly adjust their optimal bundles in response to any change in the portfolio of foreign asset-holders, and then smooth their choices afterwards. On the other hand, the non-asset holders suffers from information asymmetry, and only adjust their optimal choices in response to policy shock after some quarters.

3.6 Conclusion

Motivated by the recent implementation of various consolidation policies across many of the Euro area member-countries and the United Kingdom, and given that nearly half of the total UK trade is with the EA, this paper examines the effects of EA fiscal consolidation on UK economic activity. The paper also seeks to identify the drivers of cross-border fiscal spillover. To achieve this, we develop a two-country DSGE model in the spirit of Corsetti et al. (2010) and estimate it on data for the UK and Euro area, featuring incomplete market which implies limited risk-sharing across countries, exclusion of a fraction of households which exhibit rule-of-thumb behaviours, and productive government spending.

This paper makes three major contributions: first, different types of households are allowed to respond differently to fiscal changes; second, we propose a set of implementable fiscal rules for both economies which match the data; and, third, we analytically derive that, aside country-specific characteristics, relative asset market participation is a key driver of countries' net asset position and, by extension, cross-country spillovers. Simulation results based on the estimated model suggest that fiscal spillovers from the EA have significant effects on the UK economic activity, while UK fiscal policies have negligible effects on the EA economy, which we argue could be due to the relatively small size of the UK economy and the high proportion of total UK trade with the EA. The magnitude of these spillover effects strongly depend on the choice of fiscal instrument employed. Also, it is observed that changes in relative participation of the source country (EA) of the shock significantly drives the propagation and amplification of fiscal spillovers in the response country (UK).

Given the implications of our results, we conclude that fiscal spillover can be a major source of macroeconomic fluctuations in the domestic economy, especially when the spillover is from a major trading partner. Hence, fiscal authorities are encouraged to coordinate their policies in order to mitigate against uncertainties surrounding cross-border fiscal policy spillovers.

Appendix

I: Identification Check

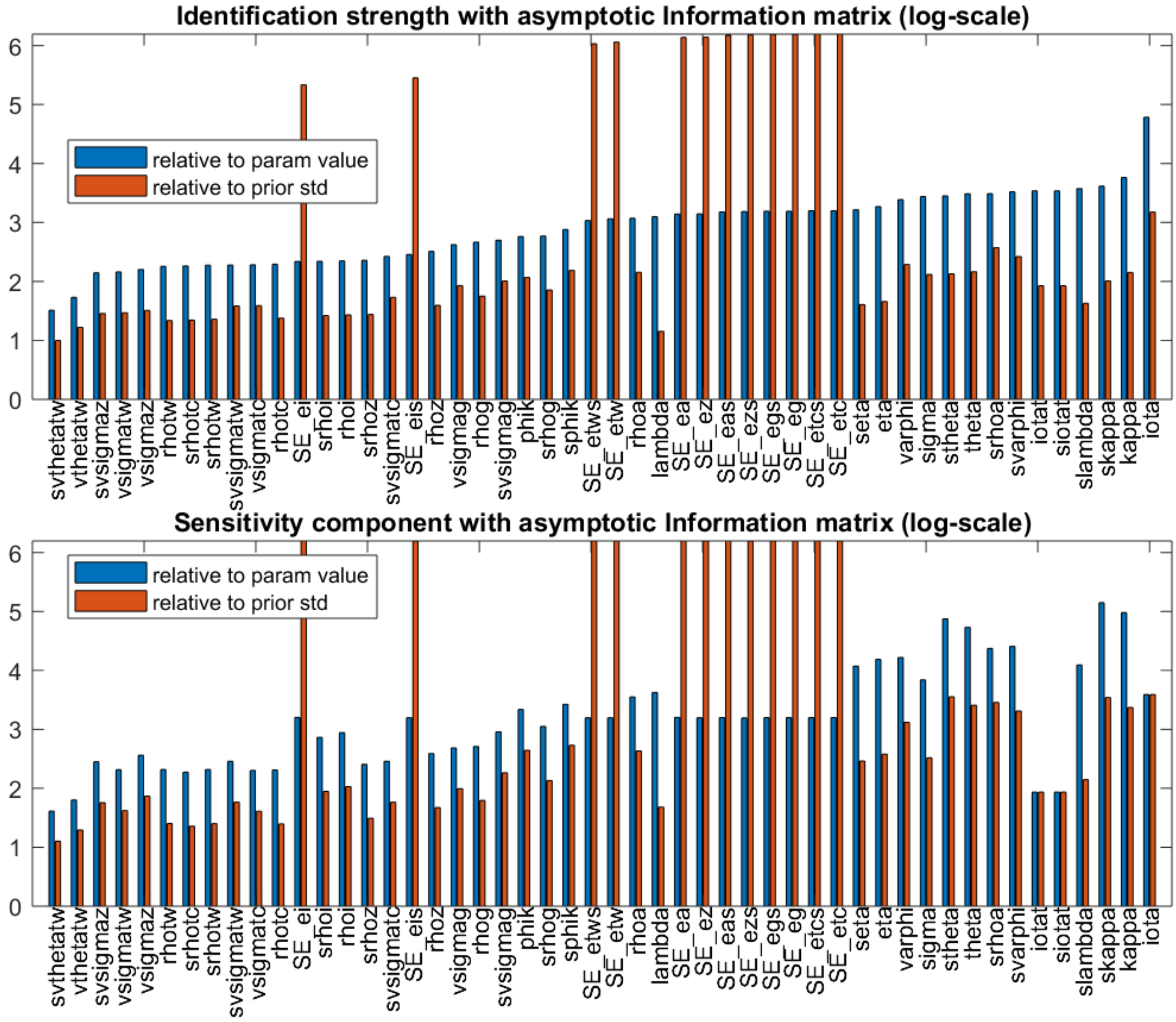


Figure 3.9: **Identification of Parameter Priors**

Notes: This figure shows the identification strength of the estimated parameters of the baseline model. The upper panel shows the identification strength of the parameters based on the Fischer information matrix normalized by either the parameter at the prior mean (blue bars) or by the standard deviation at the prior mean (red bars). The lower panel further decompose the relative sensitivity of the model behaviour to each parameter (Pfeifer 2017, Ratto & Iskrev 2011). Evidence from this identification check shows that the estimated parameters are uniquely identified – since their log-scale is significantly different from zero – and individually play distinctive roles in the dynamics of the model. Parameters with prefix ‘s’ are for the Euro Area.

II: Multivariate Convergence Diagnostics

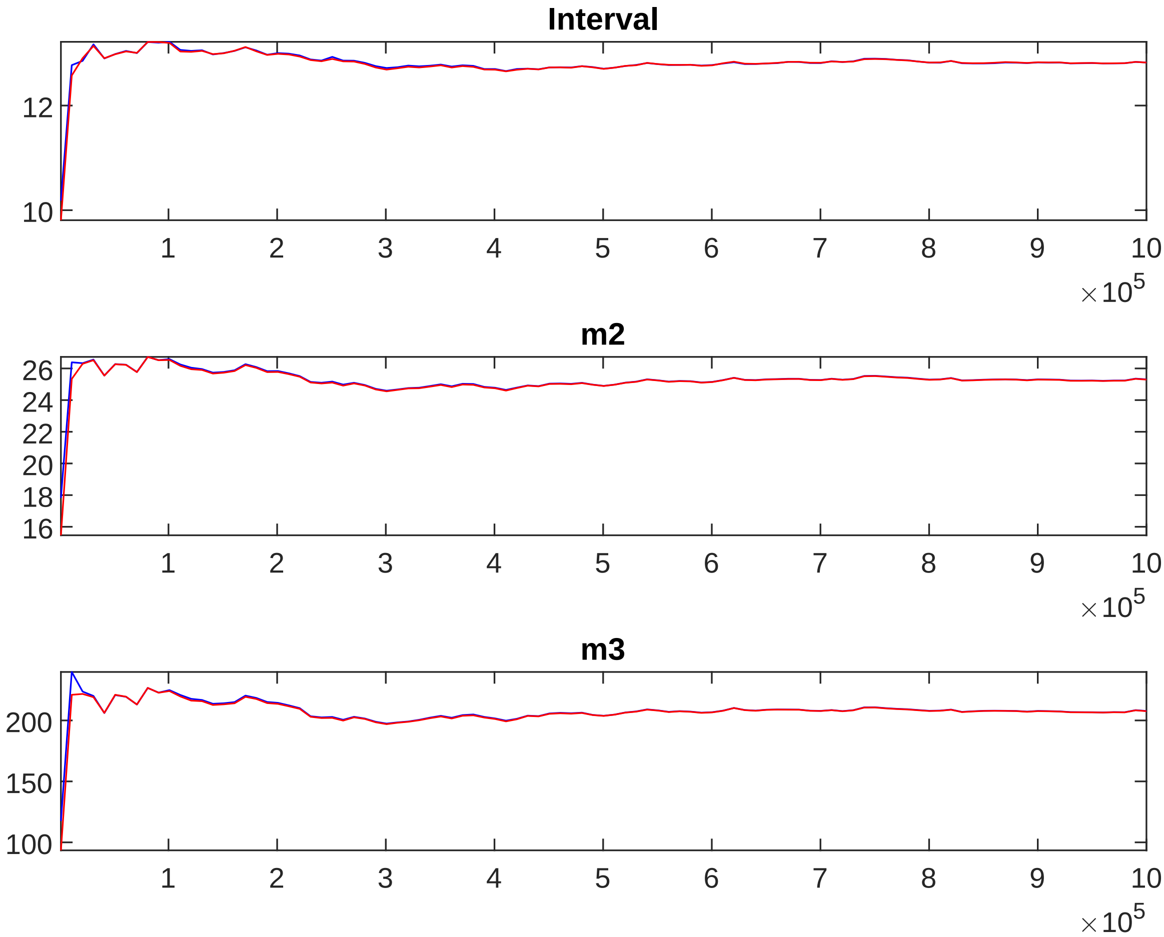


Figure 3.10: **Multivariate Convergence Diagnostics**

Notes: This figure reports the multivariate version of Brooks & Gelman (1998)'s convergence diagnostics, which is based on the posterior likelihood function for all parameters rather than individual univariate diagnostics originally proposed by Brooks & Gelman (1998). The top panel shows the convergence diagnostics for the 80% of the posterior distribution. The blue line depicts the 80th quantile range based on the pooled draws from all sequences, while the red line depicts the mean interval range. Convergence is achieved when the two lines are close to each other and stabilised across the horizon. The second and third panels portray the second and third moments of the same statistic respectively. Given the result of the convergence diagnostic reported here, we can conclude that the Monte Carlo Markov Chains (MCMC) converge to unique posterior value.

III: Prior and Posterior Distributions

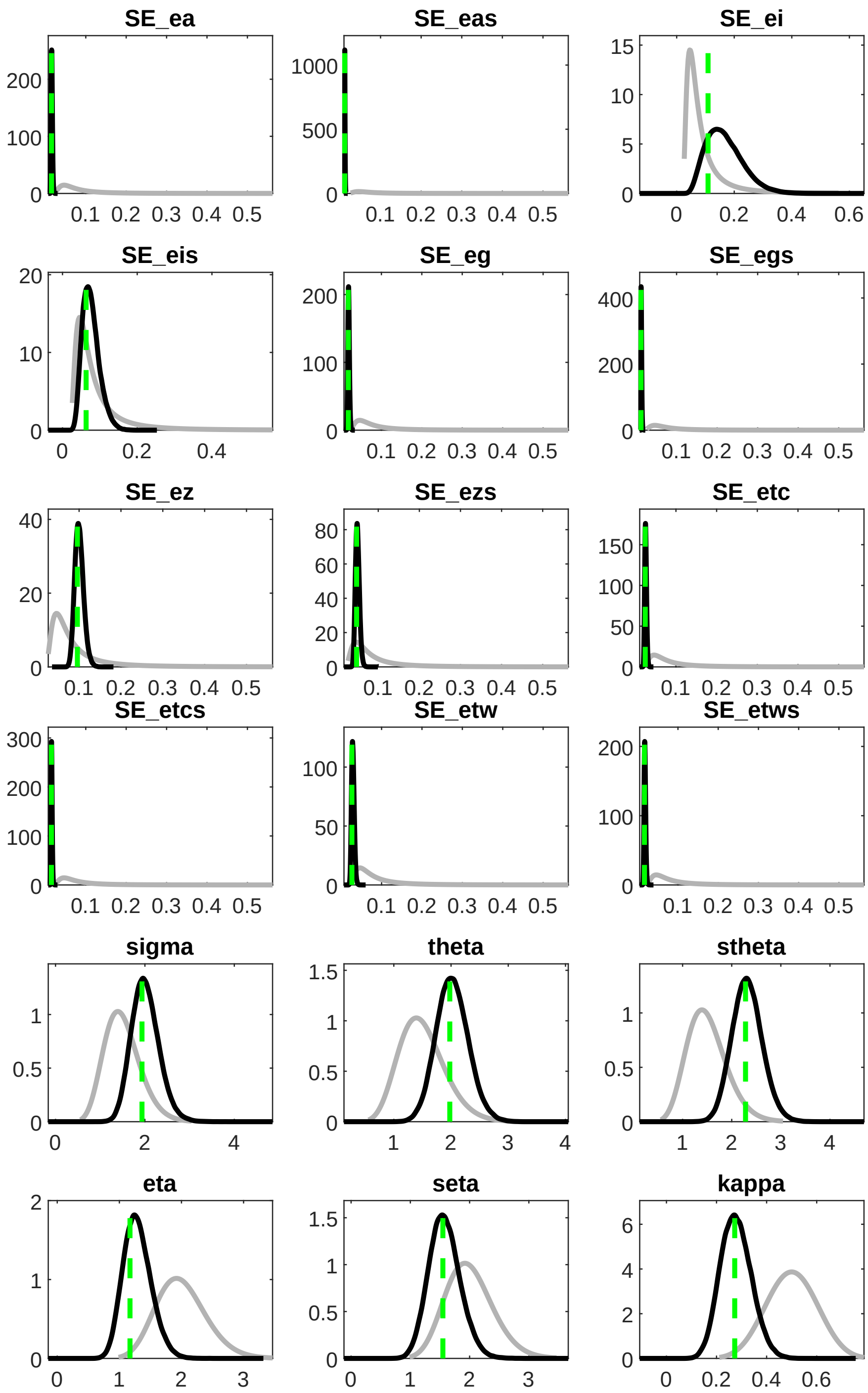


Figure 3.11: **Parameter Prior and Posterior Distributions I**

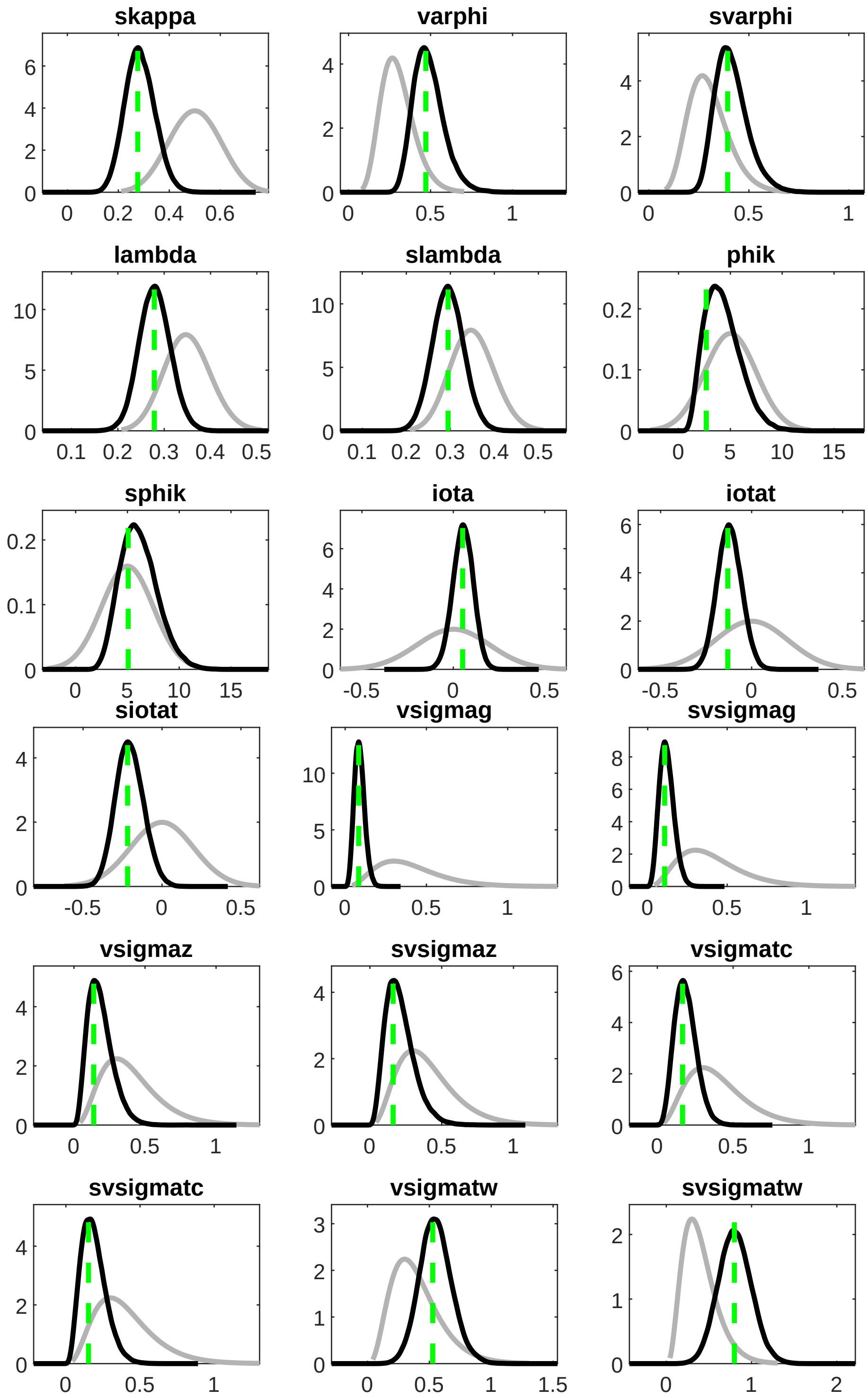


Figure 3.12: **Parameter Prior and Posterior Distributions II**

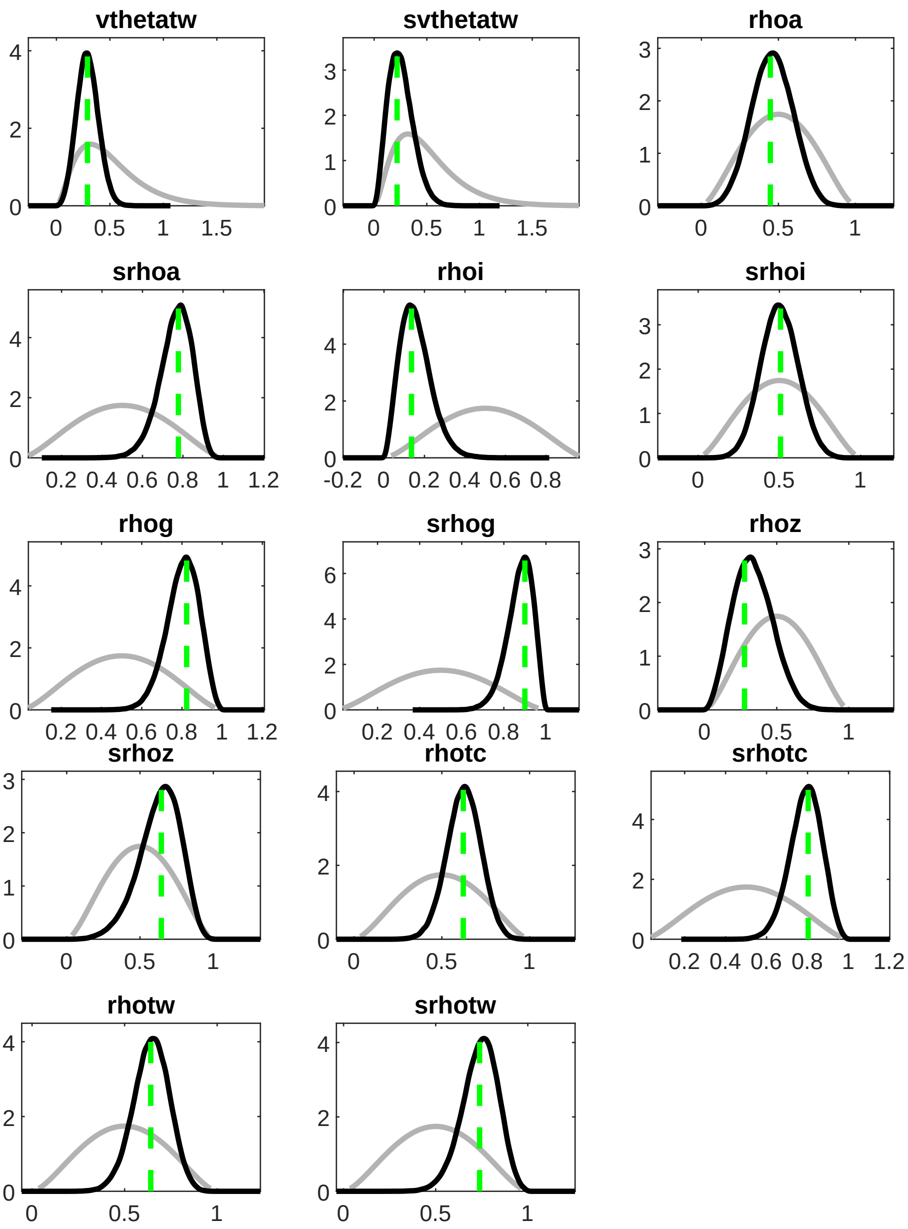


Figure 3.13: **Parameter Prior and Posterior Distributions III**

Notes: This figure (see also 3.11 and 3.12) plots the prior and posterior distributions of the estimated parameters. The grey line shows the prior density, the black line depicts the density of the posterior distribution, while the green vertical line indicates the posterior mode. The plots show that the posterior estimates are clearly identified.

Chapter 4

Fiscal Policy and Cross-Border Spillovers in Europe: New Evidence from an Agnostic Identification

4.1 Introduction

As the world economy recovers from the Great Recession, one major lesson stands out from the experience of the last decade: fiscal policy has regained policy relevance in macroeconomic discourse, as discretionary fiscal measures are widely adopted as stabilization tools in many developed and emerging economies. During the recent financial crisis, the United States and European Union enacted and implemented sizeable fiscal stimulus packages to stimulate economic recovery.[1] A new set of literature has shown that such fiscal measures have sizeable multiplier effects (Ramey 2011*a*, Leeper et al. 2017),[2] and that these effects vary across states of the economy (Auerbach & Gorodnichenko 2012, Candelon & Lieb 2013). There is also a growing literature on the international spillover effects of domestic fiscal policy with many of them observing sizeable international multipliers, which thereby motivates some policy mak-

[1]During the recent financial crisis, the United States government enacted and implemented a sizeable fiscal stimulus package, the American Recovery and Reinvestment Act (ARRA), to aid the recovery of the US economy. Similarly, the European Union commissioned the European Economic Recovery Plan (EERP) aimed at stimulating the recovery of European economies from the effects of the financial crisis. Several studies have attempted to quantify the effect of ARRA stimulus on output and employment. For instance, Romer & Bernstein (2009) estimate that, by 2010Q4, the ARRA should increase ouput by 3.7% while jobs should increase by 3,675,000. Wilson (2012) quantifies the job-multiplier effect of the ARRA stimulus to be about $125,000 per job, while Feyrer & Sacerdote (2011) estimate the per-job cost to be about $170,000 or $100,000 when education spending is excluded. Across the Atlantic, Coenen et al. (2013) estimate the multiplier effect if the EERP stimulus to be 0.52 and 0.57 in the first two years.

[2]While many studies document sizeable fiscal multipliers, some other studies, such as Cogan et al. (2010), find much smaller multiplier effects.

ers to advocate for joint fiscal actions to forestall any future occurrence of global recession (Auerbach & Gorodnichenko 2013, Corsetti & Müller 2014).

In this paper, we investigate the effect of an expansion in German government spending on the domestic economy and the economies of other European economies. This is motivated by the recent calls by policy makers institutions, such as the International Monetary Fund and the European Union, for German government to increase its spending in order to boost economic activities in the rest of the Euro countries.[3] Their argument is based on the premise that a German fiscal expansion would boost domestic demand, thereby increasing the demand for foreign goods as well as stimulating income and inflation in the rest of Euro countries. In contrast, the German monetary authority argues that such fiscal expansion would have relatively small spillover effects on other European economies due to the low import content of German public expenditure.[4] We empirically evaluate this debate in the light of existing literature on fiscal policy transmission. Specifically, this paper addresses the following policy questions: What are the effects of expansionary German government spending on domestic demand for foreign goods? Does an increase in German government spending lead to an output expansion in other Euro countries? Is there heterogeneity in the responses of foreign economies to German spending shocks?

To answer these research questions, we proceed in two steps. First, we estimate an open-economy Bayesian vector autoregresive (BVAR) model for the German economy in order to quantify the effects of German fiscal expansion on domestic demand for foreign goods. This methodology involves taking a number of draws and identifying the shocks to each draw using Uhlig (2005)'s agnostic identification method which imposes sign restrictions on the impulse response functions. Specifically, we identify a debt-financed government spending shock which moves government spending, government debt and output in the same direction while we remain agnostic about the real exchange rate and net exports, which are the key variables of interest

[3]Following the announcement of a German fiscal surplus of €23.7 billion or 0.8 percent of GDP for the fiscal year 2016, which is the fifth year of budget surplus in a row and the highest recorded since reunification in 1991, some policy makers and institutions, such as the International Monetary Fund and the European Union, have called on Germany to increase public spending on investment, education, childcare and migration (International Monetary Fund 2017, EUobserver 2017, Financial Times 2017*a*,*b*). The call is driven by Germany's large and persistent current account surplus, which is second to none among G7 countries and in sharp contrast to the reality in the rest of the Euro Area (Jaumotte & Sodsriwiboon 2010). Some economists argue that Germany's huge current account surplus is harmful, creating "a deflationary bias for the euro area, as well as for the world economy" (U.S. Treasury 2013, Krugman 2013*b*). The German government refute this claim, arguing that the country's surplus is due to its economic competitiveness and world demand for its quality product (Spiegel 2013). But, as Krugman (2013*a*) notes, high-quality exports do not drive current account surpluses, rather its the balance of saving and investment.

[4]See the keynote speech of the president of the Deutsche Bundesbank presented at a recent joint IMF-Bundesbank conference (Weidmann 2018).

for examining the spillover effects of German fiscal policy. In the second stage, we quantify the specific net effect of German fiscal expansion on fifteen European economies by replacing the external sector variables with bilateral real exchange rates and foreign output.[5] In estimating the international spillover effects of German fiscal policy, we follow the idea of Corsetti & Müller (2014) by explicitly controlling for endogenous fiscal adjustments of foreign countries by including German government spending in relative terms; that is German spending relative to partner's spending.

This paper makes three contributions. First, our analysis is among the few studies to estimate country-by-country effects of cross-border fiscal policy shocks within a sign-restricted structural VAR model. This methodology allow us to analyse country-specific responses of other countries to German fiscal shock. Similar empirical studies by Canzoneri et al. (2003), Corsetti & Müller (2014) and Beetsma & Giuliodori (2011) all employed the recursive identification method or Blanchard & Perotti (2002) identification approach, which has been criticised for being too restrictive and may not contain sufficient information to recover the actual fiscal shock (see Ramey (2011*b*) and Forni & Gambetti (2014, 2016)). Whereas, the identification strategy employed in this paper does not impose any restriction on the impulse responses of the variables of interest, thereby allowing more precise estimation. Other similar studies, such as Caporale & Girardi (2013), Hebous & Zimmermann (2013) and Dragomirescu-Gaina & Philippas (2015), analyse the area-wide transmission of fiscal policy among several European (or Euro Area) economies within a Global VAR. But responses to cross-border fiscal shocks can not be analysed on a country-by-country basis using this methodology, which is the focus of this paper.

Second, this paper is one of the first to empirically investigate country-specific international transmission of fiscal shocks to a large number of countries within and outside the monetary union.[6] We analyse country-specific spillover effects of German fiscal expansion on 15 European economies, taking into consideration their exchange rate regimes, relative size and the degree of sovereign debt risks —GIIPS (Greece, Ireland, Italy, Portugal and Spain) and non-GIIPS.[7]

[5]Similar empirical methods have been employed in the literature to estimate cross-border effects of changes in government spending and taxes. See, for instance, Canzoneri et al. (2003) and more recently Corsetti & Müller (2014).

[6]While Canzoneri et al. (2003) analyse the effect of US fiscal policy on three European countries (France, Italy and the UK), Corsetti & Müller (2014) analyse US fiscal spillovers to aggregate Euro Area and the UK. Beetsma & Giuliodori (2011) analyse the effects of government spending of the 5 largest EU countries (Germany, United Kingdom, France, Italy and Spain) on the rest-of-EU in a panel of 14 countries. However, the impulse responses from this panel analysis are for the aggregate EU economy and not specific to each country.

[7]While the Euro countries have a common currency, the non-Euro countries operate flexible exchange rate regimes. In terms of relative sizes, France, Italy, Spain and United Kingdom are relatively large countries, while countries like Austria, Belgium, Denmark and Sweden are relatively small compared to Germany. More so, the

Third, the data for our analysis extends beyond the period of financial crisis by nearly a decade, which enables us to examine how the effects of fiscal policy have changed after the crisis period. In contrast, most of the empirical studies in the literature focused on the pre-crisis period when fiscal policy was relatively passive, compared to the post-crisis period when fiscal policy is relatively active.

Our results are as follows: a debt-financed expansion in German government spending leads to a depreciation of the real exchange rate and the terms of trade, and a deterioration of the trade balance. The real exchange rate and the terms of trade both respond with lags (four and two quarters respectively), but the terms of trade returns to its pre-shock level after two years while the real exchange rate depreciates persistently till the fifth year. The fall in trade balance is driven mainly by a sharp rise in import demand in the first two years after the shock. On the cross-border implications of German fiscal expansion, we find a significant degree of heterogeneity in the dynamic responses of foreign output and bilateral real exchange rates across sub-groups of the sample countries. The international output multiplier of German spending is sizeable but mild, ranging between 0.5 and -0.5, which is close to the values reported in the literature. In the very short-run, an increase in German government spending leads to output expansion in the non-GIIPS Euro countries and non-Euro countries with strong trade links with Germany, such as Denmark and Switzerland, but crowds-out output of GIIPS countries. German fiscal expansion has non-positive effect on output of all the countries in the medium run. Also, while bilateral real exchange rate appreciates in the short run and depreciates in the medium run in non-GIIPS countries, it however depreciates with lags (no initial appreciation) in most of the GIIPS countries. In non-Euro countries, response of the bilateral real exchange rate is mixed depending on the exchange rate regime they pursue. Various sensitivity analyses are conducted to check the robustness of the results to additional restrictions, variations in the sample period, and alternative assumptions of constant and trend terms in the VAR estimation. The results of these analyses show that our result are stable and robust.

The rest of this paper is organised as follows: in Section 4.2, we discuss the identification strategy employed for our VAR analysis. Section 4.3 presents the estimation results. Section 4.4 presents further results of various sensitivity and robustness checks, while Section 4.5 concludes.

GIIPS countries have relatively high sovereign debt risks compared to Germany; that is, their risk of default on sovereign debt in the event of a crisis is relatively high.

4.2 Identifying Government Spending Shock

There is an ongoing debate in contemporary fiscal policy literature on how fiscal shocks should be identified. Four major approaches have been used in the literature: (1) the recursive approach with Cholesky decomposition, (2) the structural fiscal VAR approach of Blanchard & Perotti (2002), (3) the Uhlig (2005)'s agnostic identification approach with sign restrictions and (4) the narrative or event-study approach of Ramey & Shapiro (1998), which was further developed recently by Ramey (2011*b*). While structural VARs based on zero restriction (the recursive or the Blanchard-Perotti approach) are rather atheoretical in the sense that the underlying DSGE model rarely imply zero restriction, this is not the case for the sign restrictions (Canova 2007, Ch. 4). Meanwhile, standard fiscal VAR models have been critiqued on the grounds that the government spending innovations are non-fundamental (or non-invertible) as the model does not contain sufficient information (such as market expectation) to recover the actual fiscal shocks. This has been argued to be the case mainly in high frequency (quarterly) series where agents act on news of future changes in fiscal policy at some quarters before the actual implementation of the policy.[8] Also, Benati & Surico (2009) argue that VAR models may give uninformative results when used to analyse policy stimulus during regime changes.

To account for the omitted variables in fiscal VAR, Ramey & Shapiro (1998) use natural experiment to construct US war-date series based on large military announcements in the press. Ramey (2011*b*) incorporates this war-date series, and the Survey of Professional Forecasters as an alternative, in a fiscal VAR model for the US economy and suggests that both series should be ordered first. The main criticism of this identification method is the subjective approach of constructing the war-date series, which is at the mercy of the researcher. Fisher & Peters (2010) also control for market expectation of US government spending by incorporating the excess stock returns of large (top 3) military contractors to the US government in their fiscal VAR model.

4.2.1 Sign Restriction VAR Identification

The identification of structural VAR models using sign restrictions can be described as follows. Consider a reduced-form VAR model of order p:

$$Y_t = \sum_{j=0}^{d} \mu_j t^j + \sum_{i=1}^{p} B_i Y_{t-i} + e_t, \quad \text{for} \quad t = 1, ...T \tag{4.1}$$

[8] See Beetsma & Giuliodori (2011) for review of literature.

where Y_t is a k-dimensional vector of endogenous variables, μ_0 is a constant, t is the trend term with a maximum polynomial order of d,[9] B_i are $k \times k$ coefficient matrices, and e_t is a k-dimensional vector of one-step ahead reduced-form innovations with variance-covariance matrix $\Sigma_e = E[e_t e_t']$.

The essence of VAR identification is to translate the reduced-form VAR innovations into economically meaningful and invertible structural shocks, ε_t, which are assumed to be orthonormal; that is, they are mutually orthogonal and have a normalized unit variance. Hence, $E[\varepsilon_t \varepsilon_t'] = I_m$. The theory of the structural VAR identification assumes that the structural shocks, ε_t, are related to the reduced-form predictor errors, e_t, through a matrix A such that:[10]

$$e_t = A\varepsilon_t, \quad \text{and} \tag{4.2}$$

$$\Sigma_e = E[e_t e_t'] = AE[\varepsilon_t \varepsilon_t']A' = AA'. \tag{4.3}$$

The nth column of matrix A represents the impulse vector or the immediate impact of a one standard error innovation to the nth structural shock. However, matrix A, in its current form, is not uniquely identified. Conventional identification methods impose $k(k-1)/2$ restrictions on matrix A or its inverse either via recursive assumption using Cholesky decomposition or short-run structural relationships or long-run structural relationships or a combination of both.

To identify the structural model, we adopt the agnostic identification method proposed by Uhlig (2005), and applied to monetary and fiscal policy analysis by Scholl & Uhlig (2008) and Mountford & Uhlig (2009). The method imposes sign restrictions on the impulse response functions of the endogenous variables for a specific number of periods after the shock. Unlike in other identification methods, an interesting feature of this method is that the number of structural shocks to be identified can be less than the number of endogenous variables; that is $m \leq k$. Thus, this method is more suitable for our analysis since we seek to identify just a single shock – the government spending shock.[11] Fry & Pagan (2011) identify some issues with sign-restriction identifications. They argue that sign restriction are set restriction and therefore a range of different model can satisfy the sign restriction. Therefore, selecting the median of

[9] When d is set to 0, the VAR model includes only a constant term; $d = 1$ implies a constant and a linear time trend, while $d = 2$ implies a constant and quadratic time trend. When the first term on the right hand side of equation (4.1) is excluded, then the VAR model is estimated with a no-constant no-trend assumption.

[10] Given our specification of the VAR model, matrix A is the inverse of the contemporaneous matrix.

[11] Several other papers have employed the sign-restriction method to identify a single shock. For instance, Uhlig (2005), Scholl & Uhlig (2008) and Vargas-Silva (2008) analyse only the effect of monetary policy shock on US output, exchange rates and US housing market respectively. Dedola & Neri (2007) estimate a structural VAR model with sign restrictions to identify only technology shock. Fujita (2011) identifies and analyzes only the effect of aggregate shock on US labour market, while Chen & Liu (2018) study the individual effect of government consumption and government investment spending on real exchange rate in China.

each impulse response function is wrong because the median of each impulse response function might have been generated by a different underlying DSGE model. They suggested minimising the distance of each draw from the median.

The implementation of the sign restriction identification involves a number of stems. First, the reduced-form VAR model is estimated using Bayesian method and estimates of $\hat{B}$, $\hat{e}_t$ and $\hat{\Sigma}_e$ are obtained. Following Uhlig (2005), the Bayesian prior for estimating the VAR parameters (B, Σ_e) has a density that belongs to the Normal-Wishart distribution. By implication, the posterior density will also belong to the Normal-Wishart family. Next, a unique lower-triangular matrix P can be computed from the estimated variance-covariance matrix, $\hat{\Sigma}_e$, using some decompositions, e.g Cholesky decomposition, such that $PP' = \hat{\Sigma}_e$. Alternatively, $P' = \text{chol}(\hat{\Sigma}_e)$. Next, using the Bayesian method, n random samples of $\hat{B} = [\hat{B}_0 \quad \hat{B}_1 \quad \ldots \quad \hat{B}_k]$ and $\hat{\Sigma}_e$ are drawn from their posterior distributions. Then, random selections of a combination $(\hat{B}, \hat{\Sigma}_e)$ are drawn from the constructed n samples in the earlier step to construct an orthonormal matrix Q which satisfies $QQ' = I_k$.[12] Given the property of Q, the matrix $\hat{A}$ can be recovered from the Cholesky decomposition of $\hat{\Sigma}_e$ as follows:

$$\begin{aligned} PI_kP' &= \hat{\Sigma}_e \\ PQQ'P' &= \hat{\Sigma}_e = \hat{A}\hat{A}' \end{aligned} \tag{4.4}$$

where $\hat{A} = PQ$ is a candidate matrix of the structural model. If the implied impulse response functions satisfy the identifying restrictions, we retain Q; otherwise, Q is discard. The above steps are repeated for a large number of times, while recording each Q that satisfy the sign restrictions and saving the corresponding impulse functions.

Given this information, estimates of the structural shocks can be computed as:

$$\hat{e}_t = \hat{A}\hat{\varepsilon}_t \tag{4.5}$$

By construction, $\hat{\varepsilon}_t$ is serially uncorrelated. Fry & Pagan (2007, 2011) suggest that it is more efficient to work with shocks that have unit variance. This can be done by dividing each estimated structural shock, $\hat{\varepsilon}_t^{(k)}$, by its standard deviation. Let $\hat{S}$ be a diagonal matrix of the estimated standard deviations of the structural shocks. Thus, we can rewrite the estimated

[12] For step-by-step details of the QR decomposition for constructing Q, see Kilian & Murphy (2012). Note that, while Q is constructed from randomly selected combination of $\hat{B}$ and $\hat{\Sigma}_e$, it does not depend on the data (Kilian & Lütkepohl 2017, ch. 13).

version of equation (4.2) as:

$$\hat{e}_t = \hat{A}\hat{S}\hat{S}^{-1}\hat{\varepsilon}_t = \hat{T}\hat{\epsilon}_t \tag{4.6}$$

where $\hat{T} = \hat{A}\hat{S}$ is the rescaled version of the impact matrix, and $\hat{\epsilon}_t = \hat{S}^{-1}\hat{\varepsilon}_t$, which is the rescaled version of $\hat{\varepsilon}_t$, is the vector of normalised structural shocks with unit variance.

After the computation, summary statistics of the grid of impulse responses that satisfy the sign restrictions are reported, such as the median impulse response and its percentile bounds —say, 16th and 84th percentiles. As Fry & Pagan (2011) note, the percentile bounds in this case do not correspond to standard confidence intervals obtained from Bayesian estimations or bootstrapping which depict critical regions.

4.2.2 Data and Estimation Strategy

To conduct the estimation procedure for this empirical analysis, we rely on time series data at quarterly frequency for the period 1995:Q1 – 2016:Q4. Our choice of 1995 as the start date is partly motivated by the German unification date (1991) when reliable data become available for the German federation, and partly by the availability of reliable quarterly series for the response countries analysed in this paper. The sample countries are Germany (the source country of the fiscal shock), along with 10 other Euro Area countries (Austria, Belgium, Finland, France, Greece, Ireland, Italy, the Netherlands, Portugal and Spain) and five non-Euro countries (Denmark, Norway, Sweden, Switzerland and the United Kingdom). The choice of sample countries is motivated by existing studies in the literature (see Beetsma & Giuliodori (2011), Corsetti & Müller (2014), Canzoneri et al. (2003)). In addition to the 14 European Union (EU) countries included in the panel analysis of Beetsma et al. (2006, 2008) and Beetsma & Giuliodori (2011), our sample also includes Norway and Switzerland, which are non-EU countries. To the best of our knowledge, this paper is one of the first to analyse country-specific cross-border effects of fiscal policy for member and non-member countries of the European monetary union.

To address the questions raised in this paper, we estimate two variants of the baseline VAR estimation. First, we estimate the effects of exogenous shock to German government spending on the domestic economy. The German fiscal VAR model contains six time series: four main variables (log of real government spending, log of real GDP (output), consolidated government debt-to-GDP ratio and ex-post long-term real interest rate) and two external sector variables (we rotate, in turn, log of real effective exchange rate and log of the terms of trade, and also rotate exports-to-GDP ratio, imports-to-GDP ratio and trade balance ratio). The real variables are constructed using the GDP price deflator series. All the variables are multiplied by 100 such that their responses can be interpreted directly as percentage deviation from steady state or percentage point deviation for real interest rate and ratio variables.

In the second variant of the VAR model, we estimate the spillover effects of German spending shock on foreign output and real exchange rate. To do this, we replace the external sector variables in German fiscal VAR with foreign output and bilateral real exchange rate of the partner-countries. To correctly estimate the country-specific net effect of German fiscal spillover, we follow the idea of Corsetti & Müller (2014) by including German government spending in relative terms; that is German government spending relative to partner country-i's government spending. This transformation is necessary in order to control for the endogenous response of fiscal policy in foreign economies. When the endogenous fiscal adjustments in foreign country are not controlled for, the estimated spillover effects become rescaled versions of the effect in the source country (see, for instance, Canzoneri et al. (2003)).

The data for this analysis are collated from various sources. The series of GDP components are obtained from the Eurostat, the exchange rate series are collected from the database of Bank for International Settlements, while the interest rate data is obtained from OECD Main Economic Indicators database. The government debt data is collected from the World Bank's Quarterly Public Sector Debt database. The baseline VAR estimation include a constant and a quadratic time trend in order to adequately control for time effect and major area-wide and country-specific event episodes.[13]

4.2.3 Identifying Restrictions

Government spending shock can be defined in several ways. A surprise (unanticipated) shock to government spending have an impact effect on government spending and other macroeconomic variables. In contrast, a few studies have shown that fiscal actions are well anticipated by agents due to decision and implementation lags. As a result, fiscal announcements lead to changes in macroeconomic and financial variables before the actual time of impact of the policy. This is referred to as anticipated fiscal shock, or simply fiscal foresight (Forni & Gambetti 2016, Leeper et al. 2012, Ramey 2011*b*). Government spending shock can also be classified according to how it is financed. A tax-financed government spending shock moves government spending and taxes in the same direction with no change in deficit for a given period. On the other hand, a deficit-financed government spending shock moves government spending and deficit/debt in

[13]The major event episodes observed in the data which may affect the results of our analysis include the establishment of the common monetary system in the Euro Area in 1999, the global financial crisis of 2008-2009, the sovereign debt crisis of 2012-2013, and the peg of the Swiss franc ceiling again the Euro over the period 2011:Q3 – 2015:Q1.

Table 4.1: **Identifying Sign Restrictions for Government Spending Shock**

Response of	Sign	Motivation
German Variables		
Government spending	+	Canova & Pappa (2007), Mountford & Uhlig (2009)
Output	+	Pappa (2009), Galí et al. (2007)
Government debt	+	Canova & Pappa (2007), Mountford & Uhlig (2009)
Real Interest Rate	? (+)	Kim & Roubini (2008), Kim (2015)
Effective RER, TOT	?	Enders et al. (2011)
expy, impy, tby	?	Enders et al. (2011)
Foreign Economy Variables		
Foreign output	?	
Bilateral RER	?	

Notes: This table shows the sign restrictions on the impulse responses for the identified government spending shock. RER stands for real exchange rate, TOT stands for terms of trade, "expy" stands for exports-to-GDP ratio, "impy" stands for imports-to-GDP ratio while "tby" stands for net exports-to-GDP (trade balance) ratio. A '+' sign implies that the impulse response of the variable in question is restricted to be positive for four quarters following the shock, including the quarter of impact. A '?' implies that we are agnostic about the response of the variable in question; that is, no restrictions have been imposed.

the same direction for a given period with no change in taxes (Mountford & Uhlig 2009, Pappa 2009, Canova & Pappa 2007).

In this paper, we focus on a surprised debt-financed government spending shock. However, following Forni & Gambetti (2016) and Yang (2007), we control for bond market signals about anticipated changes in government spending by incorporating long-term real interest rate in our model. A summary of the set of identifying sign restrictions imposed on the impulse responses is provided in Table 4.1. We define a debt-financed government spending shock as a shock that moves government consumption spending, government debt and output in the same direction for four quarters following the shock, including the impact period. Following Mountford & Uhlig (2009), a tight restriction of four quarters is imposed in order to rule out highly transitory shock to government spending. For instance, a fall in government spending in one or two quarters after an initial increase. This restriction is also consistent with annual fiscal planning in many countries.

The identified sign restrictions on output is consistent with both standard real business cycle (RBC) models and even highly stylistic New-Keynesian dynamic stochastic general equilibrium (DSGE) models, such as that of Smets & Wouters (2003, 2007) and Christiano et al. (2005). In these models, an increase in government spending raises output mainly due to its additive effect on the economic resource constraint.[14] In more specialised models, such as Galí et al. (2007)'s model with rule-of-thumb consumers, or models in which government spending directly enters

[14]For a closed-economy model, the resource constraint is given as: $Y_t = C_t + I_t + G_t$.

household preferences as in Coenen et al. (2013), government spending raises output through its effect on household consumption. Also, empirical studies based on structural VAR models often produce positive fiscal multipliers. In a survey carried out by Ramey (2011*a*), estimate of government spending multiplier in the literature ranges between 0.6 to 1.8, though some other studies, such as Cogan et al. (2010), find much smaller fiscal multipliers. Pappa (2009) also restricted output to rise in response to government spending shock while remaining agnostic about employment and real wage.

Regarding the restriction on the impulse response of the real interest rate, we initially remain agnostic given the inconclusiveness of findings in the empirical literature. RBC models predict that real interest rate should rise in response to a government spending shock to reflect the cost of deficit-financing. Similar results are observed in New-Keynesian DSGE models where both nominal interest and inflation rise in response to spending shock,[15] but the rise in nominal interest relative to inflation depends on the monetary accommodativeness of the central bank. Empirical studies of Kim (2015) and Kim & Roubini (2008) find evidence in support of the theoretical model that real interest rate rises in response to government spending shock; whereas, Ramey (2011*b*), Corsetti et al. (2012) and Corsetti & Müller (2014) document a fall in real interest rate, suggesting monetary accommodativeness of fiscal policy. However, Ramey (2011*b*) notes that the fall in real interest rate may be due to the erratic behaviour of US inflation.

Following standard practice in the empirical literature, we remain agnostic about the responses of our variables of interest. Standard business cycle models predict that a positive shock to government spending raises the relative price of domestic goods, causing a real appreciation of the domestic currency and the terms of trade and a deterioration of the trade balance. However, in a New-Keynesian DSGE model, Corsetti et al. (2010, 2012) show that government spending increase could depreciate the real exchange rate if long-term real interest rate falls in anticipation of a medium-term consolidation to slowdown the path of government debt. The key factor here is the anticipated spending reversal. Corsetti et al. (2012) also document an empirical evidence in support of the spending reversal hypothesis along with a depreciation of the real exchange rate in an analysis for the US economy. In another empirical analysis for the US economy relative to an aggregate of industrialized economies comprising the Euro Area, Japan, Canada and the UK, Enders et al. (2011) derive robust sign restrictions for government spending shock within a New-Keynesian DSGE model but impose no restriction on real exchange rate, terms of trade and net exports. Their findings show that an expansion

[15] see for instance Enders et al. (2011).

in government spending depreciates both the real exchange rate and the terms of trade.

To the best of our knowledge, we are not aware of any existing empirical study that estimate country-specific international fiscal spillover in a sign-identified VAR model. Theoretical postulations from two-country DSGE models suggest that cross-border effect of home-country government spending shock on foreign output could be positive or negative depending on the calibration of the model. However, previous VAR estimations based on zero-restriction identification often produce positive spillover effects (see Canzoneri et al. (2003) and Corsetti & Müller (2014)). Based on these facts, we impose no restriction on the impulse responses of foreign output. But, to consistently estimate the spillover effects for each foreign economy, we impose sign restrictions on all German main variables in the VAR model, including real interest rate.[16]

4.3 Results

In this section, we report the results of our estimated sign-restricted VAR model. First, we estimate the VAR model described in Section 4.2.1 on time series data for the German economy, comprising government spending, government debt ratio, output, real interest rate and external sector variables. German exports, imports and net exports ratios are rotated in turn, likewise the real effective exchange rate and the terms of trade. In the second stage, we re-estimate the VAR model in order to quantify the net spillover effects of German spending increase by replacing German spending with German-to-partner's spending and replacing external sector variables with foreign output and bilateral real exchange rate.[17]

4.3.1 Domestic Effects of German Government Spending

Figure 4.1 displays the impulse responses computed from the estimated fiscal VAR model for the German economy. The debt-financed government spending shock is identified as a shock that moves government spending, government debt and output in the same direction for four quaters. The shock being analysed here is a normalised one standard deviation shock. For ease of interpretation, the impulse responses of all variables have also been rescaled by the

[16]In the spillover VAR estimation, we rely on the initial response of real interest rate in the baseline VAR model for Germany to identify the appropriate restriction for the variable. As discussed in the next section, German real interest rate rises in the first year, though with a lag. Hence, the modified identifying restrictions for the spillover VAR entail that German relative spending, output, government debt and real interest rate all rise in the first year after the shock, while no restriction is imposed on foreign variables.

[17]In estimating the VAR models reported in this section, this paper benefits greatly from the use of Ambrogio Cesa-Bianchi's VAR toolbox, which is available for download here: `https://sites.google.com/site/ambropo/MatlabCodes`

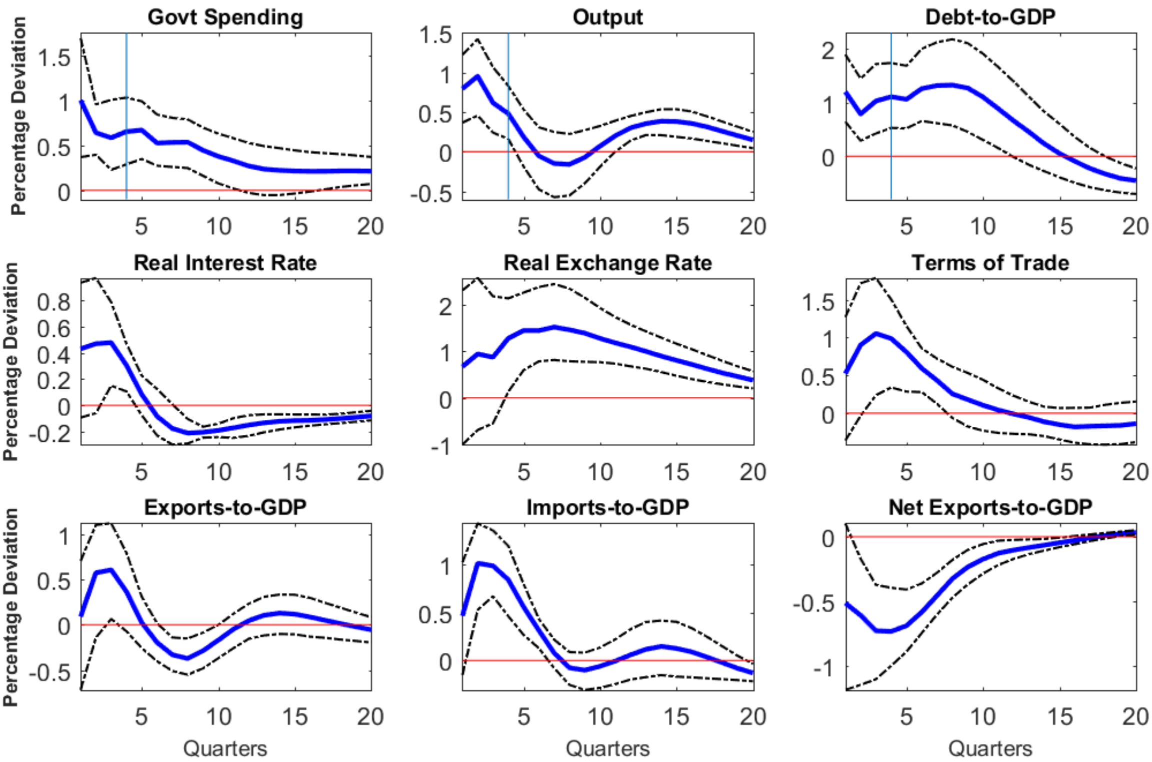


Figure 4.1: **Baseline Responses to a Normalised One-Standard Deviation German Government Spending Shock.**
Notes: Solid lines display the median impulse responses while the dotted-dashed lines show the 16th and 84th percentiles. Horizontal axes measure the quarters, while the vertical axes measure the percentage deviation from trend level or percentage points deviation from pre-shock level for real interest rate and ratio variables. For the real exchange rate and terms of trade, an increase implies a depreciation.

impact response of government spending. Hence, output response can be interpreted as impact effects (see Ramey (2016)). The solid lines denote the median impulse responses, while the dotted-dashed lines plot the 16th and 84th percentiles. Vertical lines indicate imposed sign-restrictions. The horizontal axes measure the quarters while the vertical axes measure the percentage deviation from trend level or percentage points deviation from pre-shock level for interest rate and ratio variables.

From the top left panel of Figure 4.1, government spending rises persistently and remains significantly above its trend level up to the third year. For a one percent increase in government spending, German output increases by nearly one percent on impact. However, the initial rise in output is limited to the period for which we imposed sign restrictions, slowing down up to the end of the third year and then rising again till the fifth year. Mountford & Uhlig (2009) and Enders et al. (2011) find similar weak response for output after a spending increase. In line with the evidence reported by Corsetti et al. (2012) and Corsetti & Müller (2014), debt-to-GDP ratio rises persistently until the fourth year and then fall below its trend level, implying higher taxes in the future and medium-run debt consolidation. Although the long-term real interest rate is left unrestricted, it initially rises by about 50 basis points after two quarters, but falls significantly below its preshock level after 6 quarters. The initial rise in real interest rate reflects the rising cost of government borrowing, while the subsequent fall is due to agents' anticipation of fiscal consolidation as reflected in the medium-term response of government debt. This result is consistent with the findings of Forni & Gambetti (2016) and Corsetti et al. (2012) that long-term interest rate falls after one year in response to a positive unanticipated government spending shock, though their empirical strategy is different from ours.

Turning to our variables of interest, the second and third columns of the middle panel of Figure 4.1 show the impulse responses of German real effective exchange rate and terms of trade to the government spending shock. In response to a debt-financed government spending shock, real exchange rate depreciates contemporaneously but significantly only after one year. Similarly, terms of trade worsens after two quarters, but returns to its preshock level after two years. In line with the findings of Corsetti et al. (2012), responses of real exchange rate and the terms of trade seem to be driven by the anticipated effect of future consolidation on real interest rate. In anticipation of a future debt-consolidation financed by increase in taxes, real interest rate falls which, in turn, leads to a depreciation of the real exchange rate and terms of trade. This result is also consistent with the empirical findings of Enders et al. (2011) and Kim & Roubini (2008) for the US, Monacelli & Perotti (2010) for the US, UK and Australia, and Kim (2015) for a panel of 18 advanced countries which show that a positive spending shock is followed by a real currency depreciation. Whereas, Born et al. (2013), Ilzetzki et al. (2013), Beetsma & Giuliodori (2011) and Beetsma et al. (2008) all document a real appreciation of the exchange rate, while Beetsma et al. (2006) find no significant response for real exchange rate after a government spending increase.

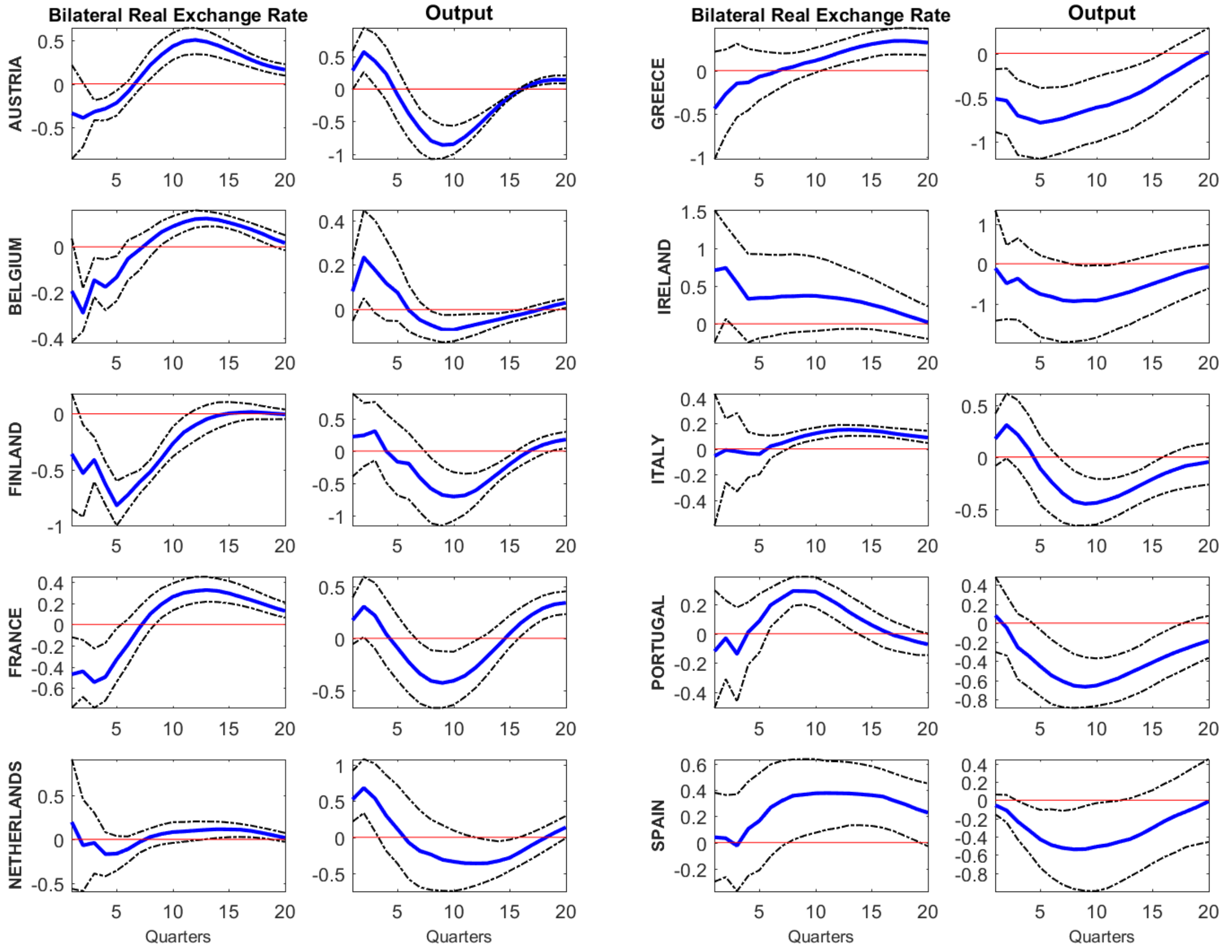
The last row of Figure 4.1 displays the impulse responses of external trade to government spending shock. A positive government spending shock deteriorates the trade balance up to the fourth year. This result seems to be driven mainly by an increase in domestic demand for foreign goods as imports-to-GDP rises on impact by about 0.5 percentage points, further rising to a peak effect of 1 percentage points after two quarters before returning to its preshock level after two years. On the other hand, German exports-to-GDP marginally deteriorates in the second year. This result is in line with the findings of Kollmann et al. (2015) which show that an expansion in German government consumption or investment spending raises German GDP and deteriorates the current account position. Meanwhile, empirical literature on the effect of fiscal policy on trade and current account balance is inconclusive. While Beetsma et al. (2008), Monacelli & Perotti (2010) and Born et al. (2013) find a deterioration of the trade balance after a fiscal expansion, Kim & Roubini (2008), Ilzetzki et al. (2013) and Kim (2015) find evidence in support of an improvement in the current account balance.

In summary, our analysis shows that a debt-financed increase in German government spending depreciates the real exchange rate and deteriorates the trade balance position. These results are well-documented by existing studies that used standard short run and long run restrictions. Evidence from our analysis suggests that the deterioration of the net exports is not necessarily driven by a decline in exports (which would have suggested an increase in domestic absorption of home-produced goods or imports substitution), but by an increase in domestic demand for imports. Given the degree of leakage in domestic income through imports, it is likely that an increase in German government spending may have some effects on foreign output, especially in countries with strong trade ties. This is the focus of the next section.

4.3.2 Spillover Effects of German Government Spending

In Figure 4.2 and 4.3, we turn to the analysis of cross-border spillover effects of German government spending shock on other European economies. As discussed above, we net off the domestic fiscal response of foreign government spending in order to ascertain the net effects of German government spending on foreign output. Hence, the fiscal instrument of interest here is the German government spending relative to country-i's spending. Like before, the shock analysed is a normalised one standard deviation shock. Hence, output response can be expressed as impact effects. The real exchange rate responses can be interpreted as percentage changes in bilateral real exchange rate resulting from one percent net increase in German government spending. An increase in the bilateral real exchange rate implies a real depreciation of partner-country's exchange rate relative to Germany. For comparison purpose, the Euro countries are classified into GIIPS (Greece, Ireland, Italy, Portugal and Spain) and non-GIIPS (Austria, Belgium, Finland, France and Netherlands) countries. The GIIPS countries are among the most affected countries in Europe during the financial crisis, with high public debt growth and high sovereign risk premia (Beetsma et al. 2013). Given that our study period covers nearly a decade after the financial crisis, it is likely that the response of foreign output and exchange rates in GIIPS and non-GIIPS countries may differ.

Figure 4.2a shows the computed impulse responses for the non-GIIPS countries. German government spending appears to have sizeable expansionary effect on output of non-GIIPS Euro countries. German spending shock crowds-in output on impact in most of the countries, but this effect is reversed after one year and then recovering again after 10 quarters. Since German



(a) Non-GIIPS Countries

(b) GIIPS Countries

Figure 4.2: **Spillover Effects of German Government Spending Shock on Euro Countries**

Notes: The shock being analysed is a one standard normalised deviation shock. The fiscal instrument here is the relative German-to-partner's government spending in logs. Solid lines display the median impulse responses while the dotted-dashed lines shows the 16th and 84th percentiles. For the bilateral real exchange rate, an increase implies a depreciation.

spending is relatively ineffective after this period, the latter recovery of foreign output may be associated with individual country's own-fiscal policy rather than German fiscal policy. The initial output responses are much stronger in Austria and Netherlands with strong trade ties with Germany, reaching a peak effect of about 0.5 percent. In Belgium and France, the initial output response is relatively mild and marginally significant with a peak effect of about 0.3 percent, while Finland's output response is insignificant in the first two years.

The effect of German government spending shock on bilateral real exchange rate is noticeable for almost all the non-GIIPS Euro countries, except for the Netherlands. German spending shock appreciate the bilateral real exchange rates of non-GIIPS countries in the first two to three years, and then depreciate afterwards. On average, the initial appreciation of the bilateral real exchange rate peaks at about 0.3 percent in Belgium to about 0.8 percent in Finland, while

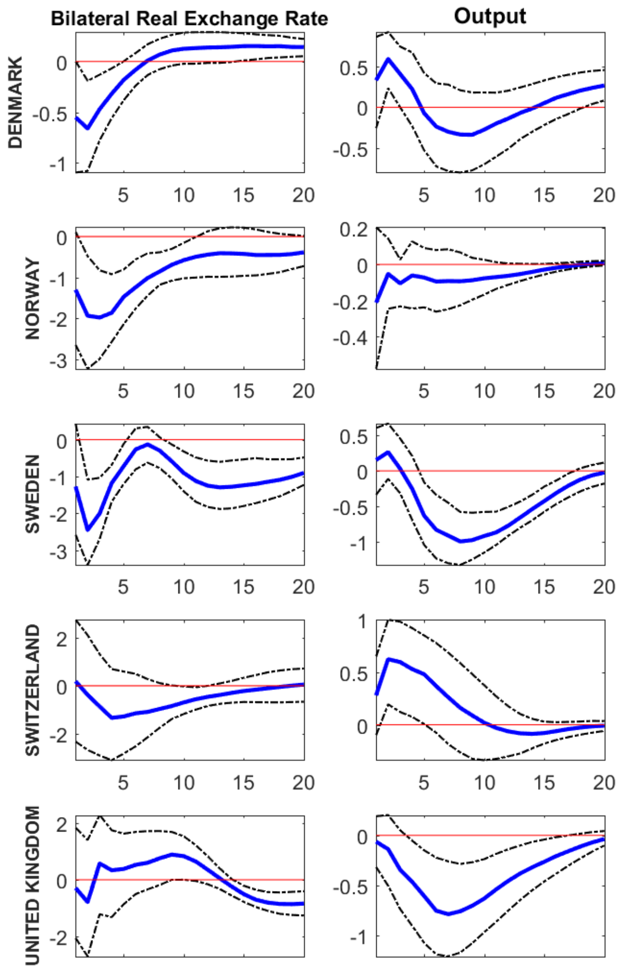


Figure 4.3: **Spillover Effects of German Government Spending Shock on Non-Euro Countries.**

Notes: The shock being analysed is a one standard normalised deviation shock. The fiscal instrument here is the relative German-to-partner's government spending in logs. Solid lines display the median impulse responses while the dotted-dashed lines shows the 16th and 84th percentiles. For the bilateral real exchange rate, an increase implies a depreciation.

the subsequent depreciation peaks at about 0.2 percent in Belgium to 0.5 percent in Austria. However, since these countries have a common currency with Germany, these effects simply reflect changes in relative prices in response to an increase in German demand for foreign goods.

In Figure 4.2b, we plot the impulse responses for output and bilateral real exchange rate of the GIIPS countries. German spending shock appears to have a non-positive effect on output of the GIIPS countries. An exception is the case of Italy where output marginally increases in the first two quarters with a peak effect of about 0.3 percent in the second quarter, but then slow down in the medium run. Greek output peaks at about -0.7 percent after six quarters while Spanish and Portuguese output peak at about -0.6 percent after two years. Changes in German government spending does not seem to have any significant effect on Irish output and bilateral real exchange rate. On average, an expansion in German government spending depreciates the bilateral real exchange rates of the GIIPS countries with a lag of 6–12 quarters. The medium run depreciation of the real exchange rate peaks at about 0.2 percent in Greece, Italy and Portugal and at 0.4 percent in Spain. Interestingly, the result shows a strong correlation in output and real exchange rate responses across the countries on the Iberian peninsula (Spain and Portugal). In both countries, German spending shock depreciates the bilateral real exchange rate and crowds-out output with 4–8 quarters lag.

The estimated impulse responses for the non-Euro countries are displayed in Figure 4.3. Compared to the Euro countries, output and real exchange rate responses in non-Euro countries exhibit significant heterogeneity. While German government spending crowds-in foreign output in Denmark and Switzerland with a peak effect of about 0.5 percent in the first year, it crowds-out Swedish and UK output in the medium run with a peak effect of about -1 percent by the end of the second year, while it has no significant effect on Norway's output. Similarly, while German spending shock significantly appreciates bilateral real exchange rates in the Scandinavian countries (Denmark, Norway and Sweden), it has no significant effect on Switzerland and UK's real exchange rates, at least in the short to medium run. However, the inflow of foreign exchange into the Scandinavian countries only translates to output expansion in Denmark, which maintains a pegged exchange rate to the euro even though it is not a member-country of the Euro Area. A possible explanation for this could be the strong appreciation of bilateral real exchange rates in Norway and Sweden which crowds-out the gains from trade. This also appears to be the case for Finland. Compared to Denmark with a peak appreciation of 0.5 percent, the peak effect of real exchange rate appreciation in Norway and Sweden is 4 times as much, and near twice as much in Finland.

Comparing the results of German fiscal spillovers for Euro and non-Euro countries, two empirical findings stands out. First, there is a significant degree of homogeneity in the dynamic responses of output and real exchange rate in Euro countries, compared to heterogeneous responses in non-Euro countries. A good explanation for this could be the strong economic integration among Euro countries with common currency and monetary policy. Although the European Monetary Union was established in 1999, many of the member-countries already maintained a fixed exchange rate with Germany as at the beginning of our study period in 1995. Second, percentage changes in bilateral real exchange rates are relatively larger in non-Euro countries compared to the Euro countries. Also, unlike in most Euro countries where real exchange rate depreciates in the medium run after an initial appreciation, real exchange rates in non-Euro countries do not depreciate in the medium. This result could be attributed to the exchange rate system maintained by the foreign countries. While a fixed nominal exchange rate is maintained in the entire Euro Area, non-Euro countries maintain floating nominal exchange rates against the euro. Denmark is an exception with a pegged exchange rate against the euro. Also, the upper limit of the Swiss franc was pegged against the euro between September 2011 and January 2015.

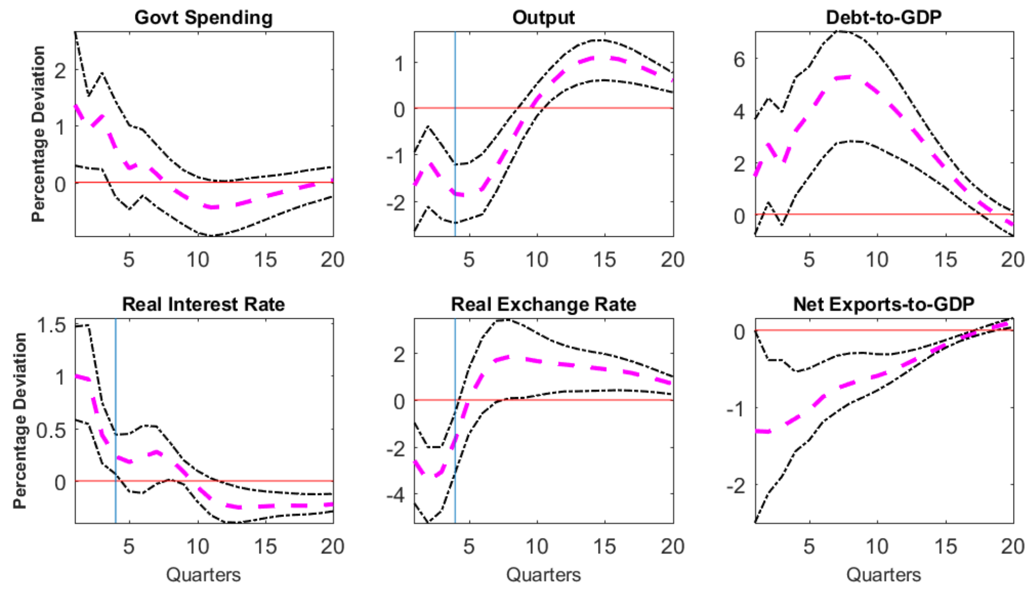
Overall, our results suggest that most of the increase in German domestic demand for foreign goods, due to a fiscal expansion, are channelled towards goods from non-GIIPS Euro countries and non-Euro countries with strong degree of integration with the German economy. These results are comparable to existing empirical findings documented in the literature. For instance, Beetsma & Giuliodori (2011) estimate a panel VAR model with zero-restriction for 14 EU countries for the period 1970-2004. They find that an increase in government spending of large EU countries (France, Germany, Italy, Spain or the UK) leads to an expansion in output of the rest of Europe with a peak effect of 0.35 percent after three years. In a similar study to ours, Corsetti & Müller (2014) estimate country-specific effects of US government spending on UK and Euro Area in a fiscal VAR model identified using both Blanchard & Perotti (2002) and Ramey (2011*b*) identification methods. They find that the results are similar under both identification methods with an exogenous expansion in US government spending raising UK and Euro Area output by 1 and 0.5 percent respectively. Regarding the dynamics of the exchange rate, Corsetti & Müller (2014) find that US bilateral real exchange rate relative to UK and Euro Area depreciates in response to US spending shock. In another similar study, Canzoneri et al. (2003) find that an exogenous shock to US government spending persistently increases output of Italy, UK and France with a peak effect of 38%, 70% and 75% of US GDP, and leads to a real depreciation of their real effective exchange rate, though France's real exchange rate initially appreciates.

4.4 Sensitivity Analysis

In order to check the robustness of the results presented in the previous section, we conduct several sensitivity analyses, including sensitivity to additional restrictions and shocks, the post-financial crisis events, and constant and trend terms in the model specification. First, following some concerns raised in the literature regarding the identification of a single-shock within sign-restricted structural VARs,[18] we check whether the results of our single-shock model are sensitive to additional identifying restrictions or shocks. To do this, we identify a new shock

[18] See detailed discussions by Fry & Pagan (2007, 2011).

(a) A: Monetary Policy Shock



(b) B: Fiscal Policy Shock

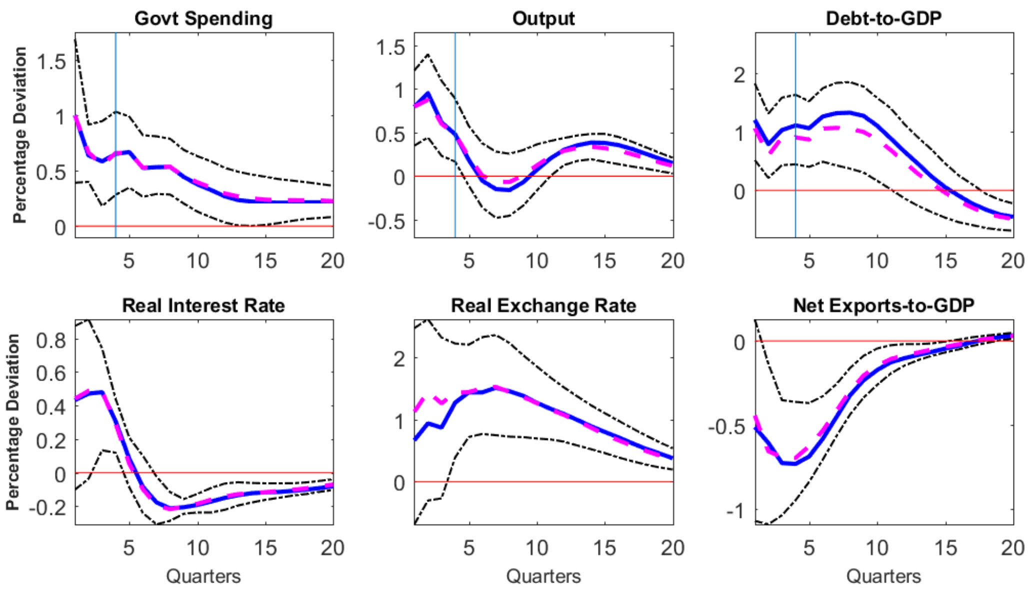


Figure 4.4: **Sensitivity Analysis I: Single-Shock vs. Multiple-Shock model.**
Notes: See Figure 4.1. The monetary policy shock is identify first and it is orthogonal to the fiscal policy shock. Solid lines denote baseline responses from the single-shock model, dashed lines denote multiple-shock model, while the dotted-dashed lines are the 16th and 84th percentiles for the multiple-shock models.

which raises the real interest rate, appreciates the real exchange rate and causes output to fall in the first four quarters. This shock can be interpreted as a monetary policy shock. Following Mountford & Uhlig (2009), the monetary policy shock is identified first and it is orthogonal to the fiscal policy shock.

Figure 4.4 displays the impulse responses computed from the multiple-shock model. Solid lines display baseline responses from the single-shock model while the dashed lines depicts

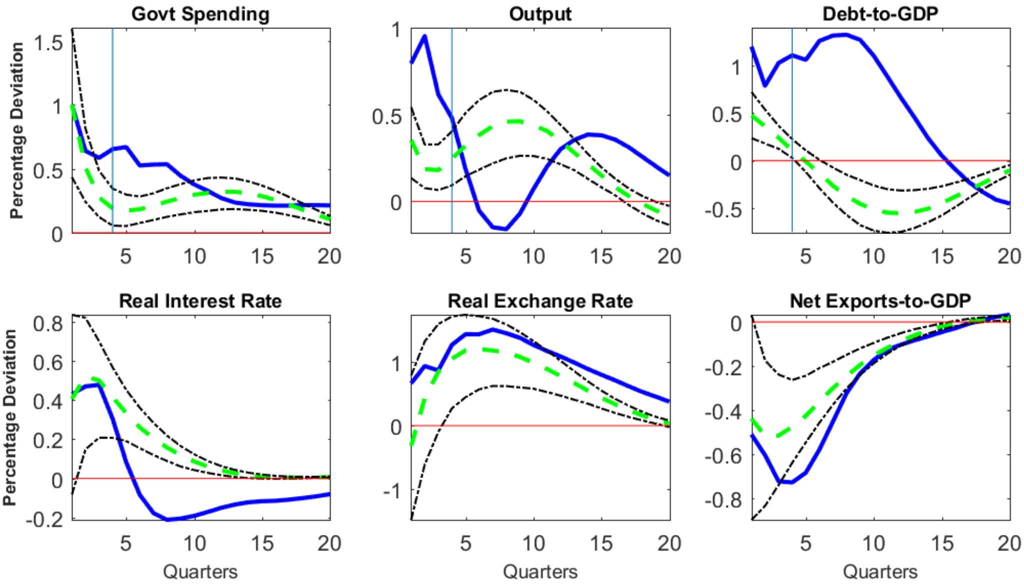


Figure 4.5: **Sensitivity Analysis II: Pre-Crisis vs. Full Sample Period**
Notes: See Figure 4.1. Solid lines depict baseline responses, dashed lines depict responses for the alternative pre-crisis model, while the dotted-dashed lines are the 16th and 84th percentiles for the alternative model.

impulse responses from the multiple-shock model. The dotted-dashed lines show the 16th and 84th percentiles. Figure 4.4b compares impulse responses for government spending shock under the single-shock and multiple-shock signed-VARs. The results show that there is no significant change in the impulse responses from both models as the median responses overlay each other in most cases. This shows that our estimated fiscal shock is robust to additional restrictions and is not biased by the identification of additional shocks.

From Figure 4.4a, in response to a monetary policy shock, real interest rate rises for the first four quarters for which the sign restriction is imposed and then fall afterwards. As a result, real exchange rate (falls) appreciates in the first four quarters and then depreciates as real interest rate falls. The initial appreciation of the real exchange rate transfers international competitiveness to foreign economy and leads to the deterioration of the trade balance. Output falls for an extended period in response to a monetary policy shock, but rises as real interest rate fall below its preshock level. Given the initial rise in the cost of borrowing, public debt quickly builds up, reaching a peak effect of about 6 percent after two years before gradually slowing down towards its preshock level. To dampen the effect of high real interest rate on output, government spending initially rises but quickly returns to its preshock level after three quarters.

Second, we check whether our result is sensitive to the events of the last decade following the financial crisis. This period is particularly characterised by low inflation, effective lower-bound on interest rate, and productivity stagnation in many European countries. And as existing studies have shown, these features could significantly affect the relative strength of fiscal policy and the dynamics of fiscal multipliers (see Correia et al. (2013) and Fernández-Villaverde et al. (2015)). To check this, we exclude the period after the financial crisis from our sample period; that is, data up to 2008:Q4. This left us with only 60 percent of our initial sample observation. Due to the small sample size, we include only one lag in this VAR estimation. Figure 4.5 shows the result of this estimation. Solid lines depict baseline responses, dashed lines depict impulse responses for the alternative pre-crisis model, and the dotted-dashed lines are the 16th and 84th percentiles for the alternative model. Focusing on our variables of interest, the responses of real exchange rate and net exports are directly comparable in both versions of the model. German spending depreciates the real exchange rate with a lag and causes deterioration of the trade balance. However, real exchange rate in the baseline model lies outside the 84th percentile of the alternative model after three years, while baseline net exports response marginally lies outside the 84th percentile of the alternative model between the third and eighth quarter. This result shows that our agnostic identification of German fiscal shock produces relatively stable results across the time period.

Finally, we check the robustness of our results to the inclusion of constant and trend terms in the baseline model. There is no consensus in the literature regarding the appropriate assumption for constant and trend to be included in the estimation of fiscal VARs. For instance, Mountford & Uhlig (2009) assume no constant or time trend, Enders et al. (2011) include only a constant, Corsetti & Müller (2014) include a constant and a linear time trend, while Ramey (2016) considers a constant and a quadratic time trend. For this reason, we compare our baseline model, with a constant and a quadratic time trend, to models with no constant or trend term, with constant only and with both a constant and a time trend. Figure 4.6 plots the result of this exercise. The response of government spending is highly persistent and does not show any sign of returning to its steady state after 5 years in all the alternative specifications. This is also the case for output response under the specifications with no trend. The specifications with time trend generate identical median responses for most variables except for government spending, suggesting the relative importance of including time trend that matches data moment in VAR. Focusing on our variables of interests, the median responses of real exchange rate and net exports are directly comparable under all specifications, but statistically insignificant under specifications with no trend term. When the VAR model is estimated under the no-constant no-trend assumptions, real exchange rate lies outside the 84th percentile of the baseline model, while the response of net exports under the no-trend assumption lies outside the 84th percentile of the baseline model. Overall, this analysis shows that our baseline model is relatively stable

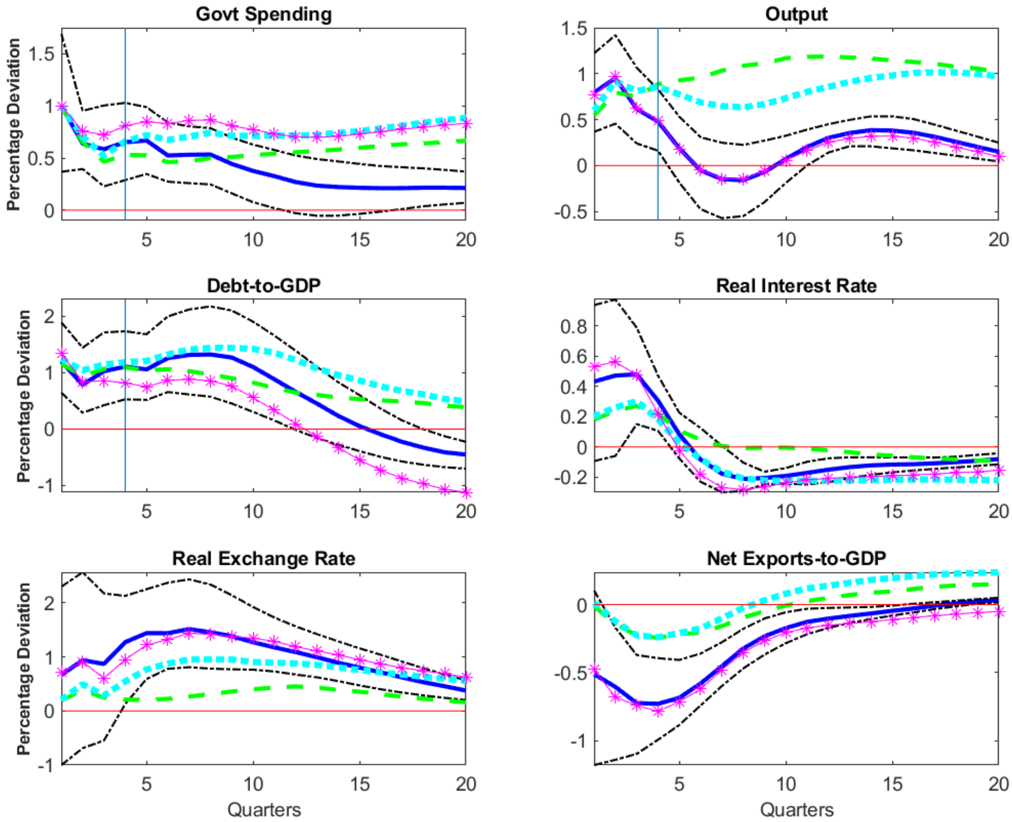


Figure 4.6: **Sensitivity Analysis III: Alternative Model Specifications**
Notes: See Figure 4.1. Solid lines depict baseline specification with a constant and a quadratic time trend, starred lines display the specification with a constant and a linear time trend, dotted lines plot the specification with only a constant, while dashed lines show the specification with no constant or time trend. The dotted-dashed lines are the 16th and 84th percentiles for the baseline specification.

compared to other specifications and can generate reasonable impulse responses.

4.5 Conclusion

Motivated by the recent calls on the German government to increase its spending in order to boost economic activities in the rest of the Euro countries, this paper examines the effect of such fiscal expansion on German domestic demand for foreign goods and on foreign output. Using Bayesian approach, we estimate a structural VAR model identified with Uhlig (2005)'s agnostic identification method which imposes sign restrictions on the impulse response functions. The imposed sign restrictions are derived from the predictions of standard business cycle models. The model is estimated on quarterly time series data for Germany and 15 other European countries (10 Euro and 5 non-Euro countries), including all the 14 EU countries analysed by Beetsma & Giuliodori (2011).

The VAR estimation is carried out in two steps. First, we estimate an open-economy fiscal VAR model on six German variables (government spending, output, government debt, real interest rate, real exchange rate, net exports) in order to estimate the effect of government spending shock on demand for foreign goods. We identify a debt-financed government spending shock which is defined as a shock that causes government spending, output and government debt to move in the same direction in the first four quarters, including the impact period. Evidence from this analysis shows that German government spending depreciates the domestic real exchange rate and the terms of trade and deteriorates the trade balance. The deterioration of the trade balance is driven by a sharp increase in the demand for imports, which rises much faster than exports, suggesting some degrees of output spillover.

In the second step, we estimate the country-specific net effect of German spending spillovers on European trading partners. To do this, we replace the external sector variables in the baseline VAR model with foreign output and bilateral real exchange rate of each country. Following Corsetti & Müller (2014), we control for the endogenous fiscal adjustments in foreign economies by expressing German government spending in relative terms to partner's spending. Our results for this analysis show that an increase in German government spending leads to output expansion on impact in non-GIIPS Euro countries, but have a non-positive impact effect on output of GIIPS countries. Also, in non-GIIPS Euro countries, bilateral real exchange rates initially appreciate in the short run to reflect the inflows of foreign exchange and then depreciates in the medium run; whereas, in GIIPS countries, bilateral real exchange rates mostly depreciate with about a year lag. The results for non-Euro countries are mixed and significantly different across countries.

Given the policy implication of our analysis, expansion in German government spending can improve economic activity in other Euro countries. However, the degree of integration with the German economy, the extent of trade intensity and the internal dynamics (such as the responsiveness of domestic prices or high sovereign debt risks as in the case of the GIIPS countries) of foreign economies could influence the extent of gains from trade.

Chapter 5

Conclusion

Motivated by the events of the last decade and recent debates in academic and policy circles on the effectiveness of discretionary fiscal measures as macroeconomic stabilisation tools, this thesis examines the domestic and international transmission of fiscal policy in Europe; taking into consideration the degree of financial constraints among households in the economy, the degree of country's exposure to foreign fiscal shocks through the global asset market, and the relative interdependence of fiscal policy in closely linked countries. The thesis comprises three different but related papers.

The first paper examines the heterogeneous effects of UK fiscal policy on households given the degree of financial constraints they face. The study finds that different types of households respond distinctively to fiscal consolidation shocks, depending on the degree of financial constraints they face. The tightness of household's financial constraints dampens the degree of responsiveness of fiscal instruments to government debt, thereby prolonging the actualisation of consolidation targets. The second paper investigates the international transmission of fiscal policy shocks between the UK and the Euro area. The study finds that EA fiscal shocks have sizeable effects on the UK economy, while UK fiscal shocks have negligible effects on the EA economy, which we argue is partly driven by the relatively large size of UK trade with the EA, and partly by the small size of the UK economy. Through analytical derivation and theoretical simulation, the study further shows that the relative participation of countries at the global asset market is a key driver of international fiscal spillovers. The third paper estimates the country-specific spillover effects of an expansion in German government spending on output and bilateral exchange rates of other European economies within a sign-restricted structural VAR model. The results show that an expansion in German government spending has sizeable but short-lived effects on foreign output. Responses of the Euro countries to German spending shock are homogeneous across subgroups of GIIPS and non-GIIPS countries, while non-Euro countries exhibit substantial heterogeneity.

Given the policy implications of the analyses, fiscal authorities are encouraged to be cautious in implementing consolidation plans in order to reduce the associated costs in terms of output loss. One feasible suggestion is to selectively implement fiscal consolidation measures by targeting specific sectors and consumer groups that are relatively indifferent to that measure —for instance, cutting transfers to the Ricardian household. Regarding the international policy spillovers, fiscal authorities are encouraged to coordinate their policies in order to mitigate against risks associated with cross-border transmission of fiscal policies. One of such risks is evident in the analysis of German fiscal spillovers. The output spillover effects in the GIIPS countries turn out to be negative, which is likely due to the high risk of default on sovereign debts in those countries.

As in many other studies, the theoretical and empirical analyses reported in this thesis are subject to several limitations and challenges that deserve to be mentioned. For instance, the results of the theoretical models are silent on the impact of fiscal policy on nominal prices and wages because nominal rigidities in goods or labour market are not incorporated in the models. Also, in the analysis of the international fiscal spillovers between the UK and the EA, trade with the rest of the world is not included. Whereas, the US and China are the single largest trading partners of the EA and the UK, and extending the analysis to incorporate such large trading partners may have substantial influence on the result of the model. Finally, the model estimations are severely affected by the availability of quality data. In most cases, we are not able to get quality data that matches the variables of interest at the appropriate frequency. In cases where the data are available, they are either short —as evident in the short time series used in the model estimation in the second and third papers— or have missing values.

The main chapters of this thesis can be extended or improved on in several ways. First, the analysis reported in chapters 2 and 3 can be improved on by incorporating nominal rigidities in goods and labour market. Future research may also consider incorporating monetary policy and the financial sector in the theoretical model of fiscal policy. Specifically, studies have shown that monetary policy can affect liquidity creation and therefore liquidity constraints. This, in turn, could influence the effect of fiscal policy in both closed and open economies (for instance, see Blanchard et al. (2016)). Also, incorporating the financial sector could help to account for the impact of financial flows.

Future research may also want to re-evaluate the implication of household heterogeneity for consolidation policy within a Heterogeneous Agents New Keynesian (HANK) model, as in Kaplan et al. (2018). The HANK model features may also be combined with different regimes in the state of the business cycle while analysing the effect of fiscal consolidation. It also possible that different types of households have different utility preference.[1] For instance, this might be the case even among Ricardian families which smooth their consumption not only based on expected income but also based on the uncertainty of their future income (that is, certainty equivalence does not hold). Hence, future study may want to explore the implication of heterogeneity in utility preferences on household response to fiscal consolidation.[2] Another suggestion is to consider heterogeneity in household labour supply or heterogeneity in employment, where low-skilled workers are employed by the informal sector while high-skilled workers are employed in the formal sector. One could also consider incorporating search and matching frictions in the labour market.

For chapter 4, the estimation of the country-specific fiscal spillovers could be improved with the availability of long quarterly series on German government revenue, average marginal tax or deficit-to-GDP ratio, since the new data series would provide valuable information about the revenue side of the government budget. Incorporating data on sovereign debt risks or any other proxy variable that could help to explain the heterogeneity in responses of GIIPS and non-GIIPS countries to German spending shock would improve the paper to a great extent. Also, as an alternative to the estimation strategy employed in this chapter, future research may estimate the spillover effects of German government spending in a Global VAR with sign restrictions, as in Eickmeier & Ng (2015), Feldkircher & Huber (2016) and Bettendorf & León-Ledesma (2018).

[1]For instance, Vissing-Jørgensen (2002) show that the elasticity of substitution for asset holders and non-asset holders differ considerably, irrespective of the measure of asset —stocks or bonds.

[2]In an earlier version of chapter 2, we model heterogeneity in household's utility preference by allowing differences in the risk aversion, Frisch labour elasticity and elasticity of substitution between public and group-specific private consumption for Ricardian and rule-of-thumb households. However, we are forced to abandon this feature due to non-availability to uniquely estimate each of the parameters. See here: https://www.birmingham.ac.uk/Documents/college-social-sciences/business/events/mmf-workshop/plenary/ILORI-Ayobami-Financial-Constraint.pdf

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