Tales of Two Countries: Cross-Border Fiscal Spillovers and Global Asset Market Participation

Ayobami E. Ilori
Department of Economics
University of Sheffield
E-mail: aeilori1@sheffield.ac.uk

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Abstract

This paper examines the effects of cross-border fiscal spillovers and the role of countries' relative participation at the global asset market on its propagation. A two-country DSGE model is developed for the UK and Euro area and estimated using Bayesian technique. Two key findings are observed: first, fiscal spillovers from the EA have non-negligible effects on the UK economy, and these effects depend on specific choice of fiscal instrument. Second, changes in relative participation of the source country (EA) drives the volatility and amplification of fiscal spillovers in the response country (UK). Given the implications of this result, we conclude that fiscal spillovers can be a major source of macroeconomic fluctuation, especially when the spillover is from a major trading partner. Thus, fiscal authorities should incorporate the reaction functions of countries with close links in their policy model.

Key words: Fiscal Spillovers; Asset Market Participation; DSGE Model; Bayesian Estimation

JEL classification: E62, F41, F42.

1 Introduction

The Great Recession of 2008-2010 has rekindled debates and policy discussions among academics and policymakers on the domestic effects of fiscal policy and its cross-border implications (Blanchard et al., 2016; Alesina et al., 2015; Coenen et al., 2013; Cwik and Wieland, 2011). This paper aims to contribute to this stream of literature by analysing the spillover effects of fiscal consolidation in the Euro area on UK economic activity. It also analytically examine how liquidity conditions of the global asset market, due to changes in countries' relative participation, influence the propagation of fiscal spillovers. To achieve these objectives, we develop a two-country Dynamic Stochastic General Equilibrium (DSGE) model in the spirit of Justiniano and Preston (2010), featuring incomplete asset market which implies limited international risk-sharing across borders à la Kollmann (2010), exclusion of a fraction of households from asset markets as in Galí et al. (2007) and Bilbiie (2008) which captures financial constraints among households, and a robust fiscal sector in which government services directly affect households' preferences as in Coenen et al. (2013). These features are particularly of interest to this study as we intend taking the model to the data.

This paper makes three contributions to the literature: first, since households are typically heterogeneous in nature, we enrich the model to reflect different responses of different types of households to fiscal changes.[1] This helps to track agent-specific responses to policy shocks which are quite different from aggregate responses as Aiyagari (1994) noted. Second, in the spirit of Kliem and Kriwoluzky (2014), Corsetti et al. (2012) and Leeper et al. (2010), we propose a new set of fiscal rules, which are implementable for each country/region. Third, we derive and show analytically that relative participation at the global asset market is a key driver of countries' net foreign asset position and, by extension, cross-country spillovers. We estimated the model on quarterly data of the UK and EA using Bayesian technique and obtain the impulse responses. 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 policy have negligible effects on the EA economy, which we argue may be due to the relatively small size of the UK economy, or possibly due to relatively large proportion of trade with EA to total UK trade. The magnitude of these spillover effects strongly depend on the choice of fiscal instrument employed. By extending the simulation to involve different proportions of asset holders in the EA, the result shows that changes in relative participation of the source country (EA) significantly drives macroeconomic volatility and amplification of fiscal spillovers in the response country (UK).

As Beetsma et al. (2006) have argued, analysis of fiscal spillovers, such as this one, can help policymakers to understand the degree of interdependence between national fiscal policies and highlights the interest that fiscal authorities might have in each others' policy stance, especially in a trade or currency union where policy spillovers tends to be regular phenomena. The rest of this paper is arranged as follows: section 2 discusses the motivation for the study and reviews related literature; section 3 describes the model of interest for the analysis; section 4 describes the Bayesian estimation technique and results of the model; section 5 presents the impulse responses of the estimated model; and section 6 summarises the findings of the paper and conclusion.

[1] We allow different types of households to have different weights of public goods in their actual (effective) consumption bundle.

Figure 1: Ratio of UK trade (goods only) with the Euro area as a percentage of total UK trade (goods only). Source: Office for National Statistics (https://www.ons.gov.uk/)

2 Motivation and Related Literature

Following the recent global financial crisis, governments around the world put in place various fiscal stimulus packages in order to stimulate the economy from the depressing effects of the crisis.[2] But this fiscal action was short-lived as increased public spending causes public debt level to rise, leading to sovereign debt crises especially in Europe. As a result, fiscal authorities are forced to implement painful consolidation policies in order to stabilise public debt (Reinhart and Rogoff, 2010, 2011, 2015). Meanwhile, this domestically implemented fiscal policy has been documented in the literature to have cross-border spillover effects on foreign economies with close links (Faccini et al., 2016; Gadatsch et al., 2016; Corsetti et al., 2010; Forni et al., 2010; Justiniano and Preston, 2010). More so, some economists have argued that the effects of fiscal spillover do not seem to depend on country characteristics but on the liquidity conditions of the global asset market, which in turn may interact with the degree of openness of the countries (see Blanchard et al. (2016)).[3]

With Ireland announcing its first auterity budget in 2008, many other Euro area member-countries have followed suit to implement various shades of consolidation policy (see Anderson et al. (2014) and OECD (2011)) which may have spillover effects on countries with close links, especially the United Kingdom. Figure 1 shows that UK trade with the EA accounts for about half of total UK trade; and according to received wisdom, trade is the primary channel of cross-border fiscal spillovers, hence it likely that EA debt-financing policy could have some implications for the UK economy. Also, as Cwik and Wieland (2011) noted, the share of financially constrained households is likely to have increased during the financial crisis as the share of households that desire to borrow declines due to less promising financial prospects during the recession. This, in turn, may affect the liquidity conditions of both domestic and international asset markets; since Europe is strongly integrated financially, changes in relative participation of these countries in Europe financial market may influence fiscal spillovers.

[2]For instance, the American Recovery and Reinvestment Act (ARRA) of 2009 and the European Economic Recovery Plan (EERP) of 2008

[3]Also see the panel discussion comment of Ashoka Mody in Corsetti and Müller (2006).

International fiscal spillover refers to the effect of domestic (source country) fiscal shocks on foreign (recipient country) real aggregates. There are two major channels of fiscal policy transmission identified and widely discussed in the literature. The first is the trade channel which traces how changes in the domestic fiscal policy transmit across border by affecting the demand for foreign goods and services via changes in income (demand effect), and influencing the country's relative terms of trade via changes in import and export flows (competitiveness effect). In this channel, a fiscal contraction is likely to reduce domestic demand for imports if real wage falls, force downward review in domestic prices and wages, and cause domestic currency to depreciate, thereby improving international competitiveness at the expense of competing foreign economies (Canova et al., 2013; D'Auria et al., 2014). The second channel, the financial or interest rate channel, traces the effect of domestic fiscal shocks on global interest rate parity via its effect on sovereign risk premium and financial market confidence. And since financial markets are integrated globally, this will affects movement of assets across countries. Thus, a fiscal consolidation, driven by government spending cuts, is likely to put a downward pressure on domestic interest rate relative to global rate, cause outflow of capital to foreign country with higher interest rate and stronger market confidence, which in turn lead to exchange rate depreciation.

A large body of literature has been devoted to investigate the cross-border effects of fiscal shocks. Foremost among all is the standard Keynesian theory based on the Mundell-Fleming-Dornbusch framework. This theory suggests that fiscal innovations which deteriorates the government's budget position also worsens the external balance of the economy (Arin and 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 complexity of factors considered and assumptions made about the economy being modelled, such as the initial level of public debt, exchange rate regime, the degree of openness, country size, level of development, market frictions and so on.

Arce et al. (2016), Blanchard et al. (2016) and Bénassy-Quéré (2006) observed that, in a monetary union, the net effect (domestic plus cross-border spillovers) of national fiscal policies strongly depends on the extent of monetary responsiveness and accommodativeness. In Blanchard et al. (2016), a New Keynesian model of a currency union was developed and simulated for cases with and without liquidity trap. Their analysis shows 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 common real interest rate which erodes the competitive gains from depreciation of periphery's terms of trade. On the other hand, when there is liquidity trap, since the common interest rate is barely responsive, periphery output tends to rise in response to core fiscal expansion, 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 bundle. Corsetti et al. (2010) analysed fiscal spillovers with spending reversal within a two-country New Keynesian model while allowing for some country characteristics such as trade elasticities, country size, degree of openness and imperfections in financial markets. They found that anticipated fiscal expansions with spending reversal have positive cross-border spillover effects mainly through interest-rate channel. This result is further confirmed by Forni et al. (2010) which found that fiscal spillovers from Germany (a core country) and Belgium (a peripheral country) have expansionary effects on the rest of the Euro area in a calibrated two-country model. In contrast, Gadatsch et al. (2016) found that German fiscal stimulus during the financial

crisis has small or negative spillover effects on the rest of Euro area in an estimated three-country DSGE model of Germany, the Euro area and the rest of the world.

Another strand of the literature empirical examined the international spillover effects of domestic fiscal policy within an econometric framework. Auerbach and Gorodnichenko (2013) estimated fiscal spillovers in a panel of OECD countries while allowing for variation in multipliers across states of the business cycle. They found that fiscal spillovers are statistically and economically significant, and considerably vary over the business cycle. The spillover effects are observed to be substantially high in recessions than in expansions, especially when both the source and recipient countries are in recession. Arin and Koray (2009) investigated the effects of the US fiscal spillovers on the Canadian economy using semi-structural VAR model. Their result suggests that expansion in the US government spending has a negative spillover effect on Canadian output. Using the same methodology, Arin et al. (2012) found a similar result between Australia and New Zealand. A positive shock to Australian government spending crowds-out real activity in New Zealand, both in the short- and medium-run. On the contrary, using a SVAR models, Beetsma and Giuliodori (2011) and Beetsma et al. (2006) found that fiscal expansions in large EU countries, such as German and France, have significant positive spillover effects on output and exports of other (major trading) members. Finally, Hebous and Zimmermann (2013) estimated the spillover effects of domestic and area-wide fiscal shocks on euro area members and found that an area-wide fiscal shock has a much sizeable effect on output compared to a domestic shock.

3 The Model

To analyse the domestic and cross-border spillover effects of fiscal consolidation, we consider a variant of two-country DSGE model developed by Corsetti et al. (2010) and Justiniano and Preston (2010). However, in order to abstract fiscal changes from monetary effects, we assumed that all prices are flexible. But to bring the model close to reality, as often observed in economic data, we introduce some real frictions, including: exclusion of a fraction of households from financial markets which captures financial frictions in both the domestic and international asset markets; debt elastic interest rate premium which tie down longrun value of foreign debt; incomplete international financial markets which implies limited international risk-sharing, capital adjustment costs, and habit in consumption. More so, we allow for variations in country characteristics such as country size and composition of final goods. Finally, we propose a new 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 fiscal policy rules proposed by Leeper et al. (2010) and Kliem and Kriwoluzky (2014) in which each income tax rule involves contemporaneous response to hours or investment rather than output.

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 national and international level. As a result, this class of households are 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 at all in financial markets nor own any physical asset. 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 and the disutility from labour effort. The effective consumption of household-i, $i = (r, h)$, is a non-separable CES aggregator of that household's private consumption and public goods:

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

where C_t^i and G_t are the household-specific private consumption and public goods respectively, $\varrho_i \in (0,1)$ is the share of government consumption in that household's bundle, and $\varphi \in (0,\infty)$ is the CES substitution elasticity between C_t^i and G_t. This specification is particularly of interest because the non-separability of government consumption in household utility implies that public consumption spending will have direct effect on private welfare. 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 income groups, since in reality, households considerably differ in their valuation of public goods and the weight they place on them.[4]

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

$$E_t \left\{ \sum_{t=0}^{\infty} \beta^{t+j} \left[\frac{(\tilde{C}_{t+j}^i - \kappa \tilde{C}_{t+j-1}^i)^{1-\theta}}{1-\theta} - \frac{N_{t+j}^{i\,1+\eta}}{1+\eta} \right] \right\} \tag{2}$$

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

3.1.1 Asset Holding Households

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

$$\begin{aligned}(1+\tau_t^c)C_t^r + I_t^r + \frac{P_{H,t}}{P_t} B_{H,t}^r + \frac{P_{F,t}}{P_t} D_{F,t}^r = (1-\tau_t^w) W_t N_t^r + [R_t^k U_t] K_{t-1}^r \\ + \frac{P_{H,t}}{P_t} R_{t-1} B_{H,t-1}^r + \frac{P_{F,t}}{P_t} R_{t-1}^* D_{F,t-1}^r \Phi_{t-1}^d + \Pi_t^r + Z_t^r\end{aligned} \tag{3}$$

The asset holders chooses consumption, C_t^r, and labour services, N_t^r, that maximises their utility. They also invest, I_t^r, in capital goods, K_t^r, which is rented to domestic 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 domestic and foreign gross real interest rates. $\frac{P_{H,t}}{P_t}$ and $\frac{P_{F,t}}{P_t}$ are the relative prices of home and foreign goods respectively,

[4] For instance, low-income households depend more on government resources such as education and healthcare services since they can not easily afford private provision of such basic needs

Π_t^r is profit accrued from ownership of intermediate-good firms, and Z_t^r is the government transfer receipt.

Following Schmitt-Grohé and Uribe (2003), Φ_t^d is defined as 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

$$\Phi_t^d = e^{-\phi_d(\frac{P_{F,t}}{P_t}D_{F,t}-D_F)/Y^*} \tag{4}$$

where ϕ_d is the premium's elasticity with respect to foreign bond 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 continue borrowing in perpetuity. The capital accumulation process follow closely that of Christiano et al. (2005) which assumed a costly adjustment to investment:

$$K_t^r = (1-\delta(U_t))K_{t-1}^r + \Phi^k\left(\frac{I_t^r}{I_{t-1}^r}\right)\varepsilon_t^I I_t^r \tag{5}$$

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. The non-negative depreciation function closely follows the one analysed in Greenwood et al. (1988):

$$\delta(U_t) = \delta U_t^{1+\xi} \tag{6}$$

which satisfies $\delta(.)$, 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 utilisation rate. 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.

3.1.2 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, augmented with social transfer, in each period. Therefore, the non-asset holding households maximise their utility preference subject to the following budget constraint

$$(1+\tau_t^c)C_t^h = (1-\tau_t^w)W_tN_t^h + Z_t^h \tag{7}$$

where C_t^h and N_t^h are the hand-to-mouth households consumption and labour services respectively. Since this type of households do not form rational expectation about the future, they simply choose their current consumption based on current income. τ_t^c and τ_t^w are taxes on consumption and income respectively, and Z_t^h is government transfer to the household. It is assumed that government do not discriminate among households in the allocation of social transfer, 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:

$$C_t = (1-\lambda)C_t^r + \lambda C_t^h \tag{8}$$
$$N_t = (1-\lambda)N_t^r + \lambda N_t^h \tag{9}$$
$$I_t = (1-\lambda)I_t^r \tag{10}$$
$$K_t = (1-\lambda)K_t^r \tag{11}$$
$$B_{H,t} = (1-\lambda)B_{H,t}^r \tag{12}$$
$$D_{F,t} = (1-\lambda)D_{F,t}^r \tag{13}$$
$$\Pi_t = (1-\lambda)\Pi_t^r \tag{14}$$

3.2 Firms

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

3.2.1 Final Good Firms

Final-good firms operate in perfectly competition and produce final goods which are for the domestic economy immediate use and not traded across borders. 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

$$X_t = \left[\nu^{\frac{1}{\sigma}} X_{H,t}^{\frac{\sigma-1}{\sigma}} + (1-\nu)^{\frac{1}{\sigma}} X_{F,t}^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{15}$$

which is maximised subject to a cost outlay given by

$$P_t X_t = P_{H,t} X_{H,t} + P_{F,t} X_{F,t} \tag{16}$$

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 good and $P_{F,t}$ is the price of a unit of foreign good. $\nu \in (0,1)$ 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

$$P_t = \left[\nu P_{H,t}^{1-\sigma} + (1-\nu)P_{F,t}^{1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{17}$$

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.

3.2.2 Intermediate Good Firms

Like the final-good firms, intermediate-good firms operate in a competitive market. They rent capital from the asset-holders and employ labour from the households at a universal wage, W_t, since they do not discriminate between labours 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

$$Y_t = \varepsilon_t^A (U_t K_{t-1})^{\alpha} N_t^{1-\alpha} \tag{18}$$

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:

$$\Pi_t = \frac{P_{H,t}}{P_t} Y_t - W_t N_t - R_t^k U_t K_{t-1} \tag{19}$$

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

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:

$$\frac{P_{H,t}}{P_t} B_t = \frac{P_{H,t}}{P_t} R_{t-1} B_{t-1} + [G_t + Z_t - \tau_t^c C_t - \tau_t^w W_t N_t] \tag{20}$$

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 international, $D_{F,t}^*$:

$$B_t^* = B_{F,t}^* + D_{F,t}^* \tag{21}$$

In this model, it is assumed that both countries follow similar fiscal rules. This is particularly of interest since both countries of interest in this analysis (the UK and the Euro area) are members of the European Union and the EU's Stability and Growth Pact (SGP) fiscal agreement is binding on both. For the purpose of this analysis, we propose a set of fiscal rules which closely follow that of Leeper et al. (2010), Corsetti et al. (2012) and Kliem and Kriwoluzky (2014). For spending rule, it is assumed that (stochastic)fiscal spending ratios (government consumption and transfer) responds to government debt ratio with feedback as in Corsetti et al. (2012):

$$\frac{G_t}{Y_t} = \left(\frac{B_{t-1}}{Y_t}\right)^{-\varsigma_g} \left(\frac{G_{t-1}}{Y_{t-1}}\right)^{\rho_g} \epsilon_t^g \tag{22}$$

$$\frac{Z_t}{Y_t} = \left(\frac{B_{t-1}}{Y_t}\right)^{-\varsigma_z} \left(\frac{Z_{t-1}}{Y_{t-1}}\right)^{\rho_z} \epsilon_t^z \tag{23}$$

For the tax rule, it is assumed that consumption and income taxes respond to level of debt and income tax further responds to contemporaneous investment as in Kliem and Kriwoluzky (2014):[5]

[5] Kliem and 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 hour and

$$\tau_t^c = B_{t-1}^{\varsigma_{\tau^c}} \varepsilon_t^{\tau^c} \left(\varepsilon_t^{\tau^w}\right)^{\zeta_{cn}}; \quad \varepsilon_t^{\tau^c} = \left(\varepsilon_{t-1}^{\tau^c}\right)^{\rho_{\tau^c}} e^{\epsilon_t^{\tau^c}} \tag{24}$$

$$\tau_t^w = B_{t-1}^{\varsigma_{\tau^w}} I_t^{\vartheta_{\tau^w}} \varepsilon_t^{\tau^w} \left(\varepsilon_t^{\tau^c}\right)^{\zeta_{cn}}; \quad \varepsilon_t^{\tau^w} = \left(\varepsilon_{t-1}^{\tau^w}\right)^{\rho_{\tau^w}} e^{\epsilon_t^{\tau^w}} \tag{25}$$

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 persitence parameter of tax shocks, while ζ_{cn} is the cross-correlation paratemer of contemporaneous shocks to consumption and income taxes as in Leeper et al. (2010), and $\epsilon_t^x \sim NIID(0, \sigma_x)$ are the unanticipated fiscal shocks.

The nested fiscal rule in this model tends to be better compare to those in the existing literature for two reasons: first, unlike Leeper et al. (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 a priori. 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 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.

3.4 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

$$Y_t = C_{H,t} + I_{H,t} + G_{H,t} + C_{H,t}^* + I_{H,t}^* + G_{H,t}^* \tag{26}$$

$$Y_t^* = C_{F,t} + I_{F,t} + G_{F,t} + C_{F,t}^* + I_{F,t}^* + G_{F,t}^* \tag{27}$$

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:

$$X_t^* = \left[\nu^{*\frac{1}{\sigma}} X_{H,t}^{*\frac{\sigma-1}{\sigma}} + (1-\nu^*)^{\frac{1}{\sigma}} X_{F,t}^{*\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{28}$$

$$P_t^* X_t^* = P_{H,t}^* X_{H,t}^* + P_{F,t}^* X_{F,t}^* \tag{29}$$

$$P_t^* = \left[\nu^* P_{H,t}^{*\,1-\sigma} + (1-\nu^*) P_{F,t}^{*\,1-\sigma}\right]^{\frac{1}{1-\sigma}} \tag{30}$$

where starred variables are foreign prices and quantities and ν^* is the share of home goods in foreign

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.

basket. From the perspective of the home country, the terms of trade can be expressed as:

$$T_t = \frac{P_{F,t}}{P^*_{H,t}} \tag{31}$$

but if the principle of purchasing power parity (PPP) holds,[6] such that $P_{H,t} = P^*_{H,t}$, then:

$$T_t = \frac{P_{F,t}}{P_{H,t}} \tag{32}$$

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

$$\frac{P_{H,t}}{P_t} = [\nu + (1-\nu)T_t^{1-\sigma}]^{-\frac{1}{1-\sigma}} \tag{33}$$

$$\frac{P_{F,t}}{P_t} = [\nu T_t^{-(1-\sigma)} + (1-\nu)]^{-\frac{1}{1-\sigma}} \tag{34}$$

$$\frac{P^*_{H,t}}{P^*_t} = [\nu^* + (1-\nu^*)T_t^{1-\sigma}]^{-\frac{1}{1-\sigma}} \tag{35}$$

$$\frac{P^*_{F,t}}{P^*_t} = [\nu^* T_t^{-(1-\sigma)} + (1-\nu^*)]^{-\frac{1}{1-\sigma}} \tag{36}$$

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:

$$RX = \frac{P^*_t}{P_t} = \left[\frac{\nu^* + (1-\nu^*)T_t^{1-\sigma}}{\nu + (1-\nu)T_t^{1-\sigma}}\right]^{\frac{1}{1-\sigma}} \tag{37}$$

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

$$\Pi^*_t = \frac{P^*_{F,t}}{P^*_t} Y^*_t - W^*_t N^*_t - R^{k*}_t K^*_{t-1} \tag{38}$$

$$Y^*_t = \varepsilon_t^{A^*} (U^*_t K^*_{t-1})^{\alpha^*} N_t^{*1-\alpha^*} \tag{39}$$

Following Baxter and Crucini (1993) and Baxter and Farr (2005), the exogenous process for productivity shocks, expressed in percentage deviation from steady state, is assumed to follow a stationary Markov process specified as a bivariate VAR(1):

$$\begin{bmatrix} \hat{\varepsilon}^A_t \\ \hat{\varepsilon}^{A^*}_t \end{bmatrix} = \begin{bmatrix} \rho_a & \iota \\ \iota & \rho^*_a \end{bmatrix} \begin{bmatrix} \hat{\varepsilon}^A_{t-1} \\ \hat{\varepsilon}^{A^*}_{t-1} \end{bmatrix} + \begin{bmatrix} \epsilon^a_t \\ \epsilon^{a*}_t \end{bmatrix} \tag{40}$$

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

$$E(\epsilon^a_t, \epsilon^{a*}_t)(\epsilon^a_t, \epsilon^{a*}_t)' = \begin{bmatrix} \sigma^2_a & 0 \\ 0 & \sigma^2_{a*} \end{bmatrix} \tag{41}$$

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^2_a and σ^{*2}_a are the variances of technology shocks.

[6] Otherwise know as the law of one price (LOOP).

3.5.1 International Financial Markets

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

$$\frac{P_{F,t}}{P_t}D_{F,t} + \frac{P^*_{F,t}}{P^*_t}D^*_{F,t} = 0 \tag{42}$$

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

$$D^*_{F,t} = -\frac{P^*_t}{P_t}D_{F,t} \tag{43}$$

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 $B^*_{F,t} = (1-\lambda^*)B^{*r}_{F,t}$, to obtain:

$$B^*_t = (1-\lambda^*)B^{r*}_{F,t} - (1-\lambda)\frac{P^*_t}{P_t}D^r_{F,t} \tag{44}$$

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

$$\frac{dD^r_{F,t}}{dB^{r*}_{F,t}} = -\frac{\partial B^*_t}{\partial B^{r*}_{F,t}} \Big/ \frac{\partial B^*_t}{\partial D^r_{F,t}} = -\frac{1-\lambda^*}{-(1-\lambda)\frac{P^*_t}{P_t}} \tag{45}$$

Expressing the differential in terms of a small change gives

$$\frac{\Delta D^r_{F,t}}{\Delta B^{r*}_{F,t}} = \left(\frac{1-\lambda^*}{1-\lambda}\right)\left(\frac{P^*_t}{P_t}\right)^{-1} \tag{46}$$

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 the exchange rate regime, where $\frac{P^*_t}{P_t}$ is the real exchange rate), but also driven by the relative degree of participation at the international asset market as reflected in the relative size of asset holders.

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

$$\frac{P_{F,t}}{P_t}(D_{F,t} - D_{F,t-1}) = \left[\frac{P_{H,t}}{P_t}Y_t - C_t - G_t - I_t\right] + \frac{P_{F,t}}{P_t}D_{F,t-1}(R^*_{t-1}\Phi^d_{t-1} - 1) \tag{47}$$

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:

$$(D_{F,t} - D_{F,t-1}) = \left[\frac{1}{T_t}(C^*_{H,t} + I^*_{H,t} + G^*_{H,t}) - (C_{F,t} + I_{F,t} + G_{F,t})\right] + (R^*_{t-1}\Phi^d_{t-1} - 1)D_{F,t-1} \tag{48}$$

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.

Figure 2: The observables 1999Q1-2015Q4. This figure shows the one-sided HP-filtered time series used in the estimation of this model.

4 Bayesian Estimation

The model is estimated using the Bayesian technique as described in An and Schorfheide (2007). In this technique, a set of observed variables is directly mapped to the log-linearised equations of the model, with the data likelihood and parameter priors combined to maximise the log posterior function, followed by the initiation of the Metropolis-Hasting (MH) algorithm which samples from the posterior distribution using the Monte Carlo Markov Chain (MCMC) draws. This analysis is carried out in Dynare. The rest of this section describes the data, calibration choices, prior selections and the estimated posterior distributions.

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 1999Q1-2015Q4 (68 observations): private consumption, investment, total labour hours, government consumption spending, consumption tax revenue and government debt. We have used 12 variables here since there are 12 structural shocks (6 for each countries) 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 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 countries, 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

Table 1: Calibration of selected parameters and key steady state ratios

Parameter/Target Variables		Value		Comment
		UK	EA	
Preference				
Subjective discount factor	β, β^*	0.995	0.995	Calibrated to hit annualised real interest rate of 2% in EA
Technology				
Capital share	α, α^*	0.30	0.30	Set to about 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; Gadatsch et al., 2016)
International sector				
Foreign debt elasticity	ϕ_d	0.01		See the appendix in Bouakez and 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	0.1430		Eurostat database. Computed as $n = \frac{Y}{Y+Y^*}$
Imports share in consumption	$(1-\nu), \nu^*$	0.2095	0.0408	Eurostat database.

Note: 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 UK's perspective

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.[7] The data series are detrended using the one-sided HP-filter, and the filtered series are further demean as suggested by Pfeifer (2015).

Figure 2 plots the stochastically detrended time series of the observed variables used in the estimation of the benchmark model. From this plot, it can be observed that, while government 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 level down around the trend, which corresponds with the period of lower government spending and higher taxes. More so, during the consolidation period, private consumption tends to be lower compared to the pre-consolidation era, while labour hours tends to be higher.

4.2 Calibration

Table 1 presents the values of calibrated parameters and steady state for 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 EA annualise real interest rate of 2%.[8] The elasticity of the risk premium (the bond holding cost), ψ_d, is set to 0.01 as in most literature on incomplete

[7] 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 (2015)

[8] For the EA, Gadatsch et al. (2016) chose 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, $\beta = 0.9938$

market with limited risk-sharing. Bouakez and Eyquem (2015) estimated ψ_d to be around 0.006 for the UK in a trade with the rest of the world.

Based on the explicit assumptions made in the model, the share of public goods in households consumption bundle is calibrated differently for each types 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 counterpart in the EA. These values suggest that, while non-asset holders depend considerably more on government resources in both countries, which is in line with the earlier assertion of this paper, the UK economy is relatively less welfarist compared to the EA.

Regarding the steady state values of key target variables, from the individual statistics of each country/region, it was observed that government consumption spending as a ratio of output is about 19% for the UK and 21% for the EA, while transfer ratio is about 13% and 16% respectively, suggesting that steady state aggregate government spending ratio in the EA is about 17% points higher compared to the. 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 interlink parameters based on country statistics. 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; while the share of imports from EA in UK's aggregate consumption bundle is about 21%, which is quite reasonable.

4.3 Prior Distribution

Table 2 presents the prior distributions of parameter of interest. The select priors conforms with existing literature on the Euro area (see Gadatsch et al. (2016); Coenen et al. (2013); Forni et al. (2010)). For comparison's sake, we specified the same prior distribution for similar parameters of the UK and the EA. For the relative risk aversion, (θ, θ^*), and the inverse Frisch elasticity of labour supply, (η, η^*), we assume a Gamma distribution with mean set at 1.5 and 2 respectively and standard deviation of 0.40, which is similar to the values used in Leeper et al. (2010). The habit formation parameter, (κ, κ^*), is assumed to follow a Beta distribution with mean set at 0.50 and a standard deviation of 0.10, while the elasticity of substitution between private and public good, (φ, φ^*), is assumed 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 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 a 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 et al. (2010), they are assumed to have a Gamma density with a mean set at 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

Table 2: Prior distributions and posterior estimates for baseline model

Parameter		Prior			Posterior			
		Density	Mean	Std.	Mode	Mean	[5%,95%]	Std
United Kingdom (Domestic block)								
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	$\varsigma_{\tau c}$	Gamma	0.40	0.20	0.167	0.185	[0.055, 0.325]	0.072
τ^w resp. to B	$\varsigma_{\tau w}$	Gamma	0.40	0.20	0.528	0.551	[0.294, 0.808]	0.123
τ^w resp. to Inv.	$\vartheta_{\tau w}$	Gamma	0.50	0.30	0.290	0.294	[0.105, 0.493]	0.100
Cross-corr of taxes	$\zeta_{c,n}$	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	$\rho_{\tau c}$	Beta	0.50	0.20	0.622	0.623	[0.432, 0.815]	0.097
Income tax shock	$\rho_{\tau w}$	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	$\sigma_{\tau c}$	Inv. Gamma	0.10	2.00	0.025	0.026	[0.021, 0.030]	0.002
Income tax	$\sigma_{\tau w}$	Inv. Gamma	0.10	2.00	0.027	0.029	[0.023, 0.036]	0.003
Euro Area (Domestic block)								
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	$\zeta_{c,n}^*$	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

Note: This table presents the prior distributions and posterior estimates of parameters in the benchmark model with estimated shared of non-asset holding households (ROT). The starred parameters are for the euro area. 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 and Gelman (1998) convergence plots to ensure that the MCMC chains converge to unique posterior value.

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 its has 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.

4.4 Posterior Estimates

The last four columns of Table 2 presents the posterior distribution of the estimated parameters in the benchmark model with estimated share of non-asset holders. It reports the posterior mode, mean with 5 and 95 percent confidence interval, 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 distribution are obtained from two 1,000,000 MCMC draws, with 200,000 draws discarded in the burn-in phase of each chain (i.e. 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 unique identification of estimated parameters and convergence of the MCMC chains.

From this 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 for Europe (see Forni et al. (2009), Coenen and 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 AR(1) coefficients in EA are relatively more persistent 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 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.[9] Also, the result shows that income taxes have a 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 lesser than our estimates; while Forni et al. (2009) estimated labour income tax adjustment to be 0.28 at

[9]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

mean, and 0.50 for consumption tax adjustment.[10] Finally, the contemporaneous correlation between consumption and income taxes is estimated to be negative for both countries, suggesting that tax announcement on one may affect the other, at least in Euro area where the comovement term is statistically different from zero. Shocks to government transfer tend to be relatively more volatile compared to other fiscal shocks in both countries.

Regarding parameters relating to international linkage, evidence from our result pointed to the fact that home and foreign goods are substitutes with the elasticity of trade, $\sigma \in (1.44, 2.61)$, significantly greater than one. This value is validly within the range of (0.66,3) used in Corsetti et al. (2010), and the range of (0.1,2) surveyed in Corsetti et al. (2008). However this result is in contrast with the finding of Justiniano and Preston (2010) which estimated a trade elasticity value of 0.86 at median for trade between the United States and 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 0.05 at mean, which is higher than a value 0.025 estimated by Heathcote and Perri (2002) for US trade with the rest of the world.

5 Impulse Responses

This section discusses the impulse responses of estimated fiscal shocks in the benchmark model. Figures 3-6 plot the impulse responses to domestic fiscal shocks compared with international fiscal spillovers. The solid line denotes response to UK fiscal consolidation shocks while the dotted-dashed line represents response to consolidation shock in the Euro area. For convenience, the standard deviation of each shock is set to $100\sigma_x$ 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.

As figure 3 shows, in order to reduce government debt, a negative shock to domestic government consumption spending crowds-in private consumption, while hours fall; leading to fall in output on impact in the home country. Private investment also rises due to low labour costs. The fall in income, in turn, leads to less demand for foreign goods, and 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, 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 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 analytical simulation of Corsetti et al. (2010) which found that an increase in government spending leads to output expansion, both in home and foreign country, and trade deficit in home country. However, in contrast to our result, they found a

[10] Note that Forni et al. (2009) model also include 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.

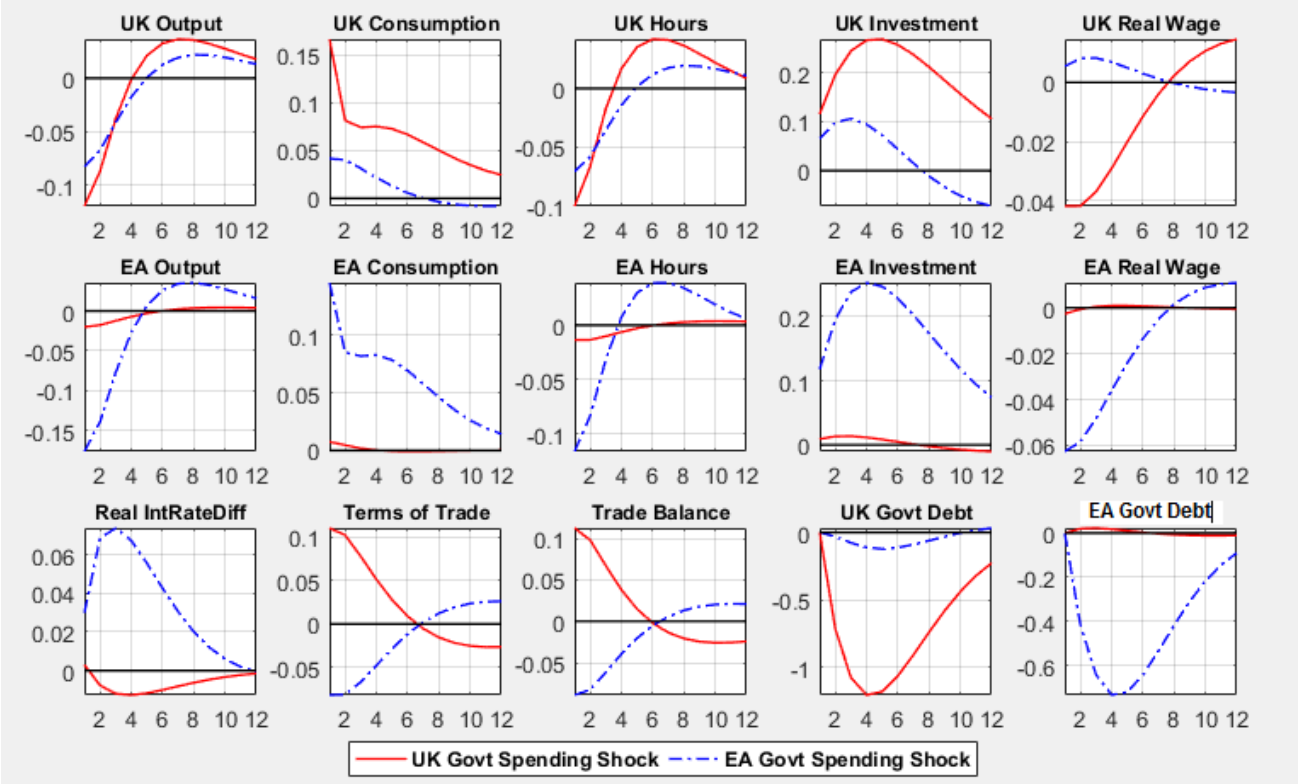

Figure 3: Impulse responses to a negative one percent innovation to government consumption spending. The solid line denotes response to UK government spending shock while the dotted-dashed line denotes response to EA government spending shock

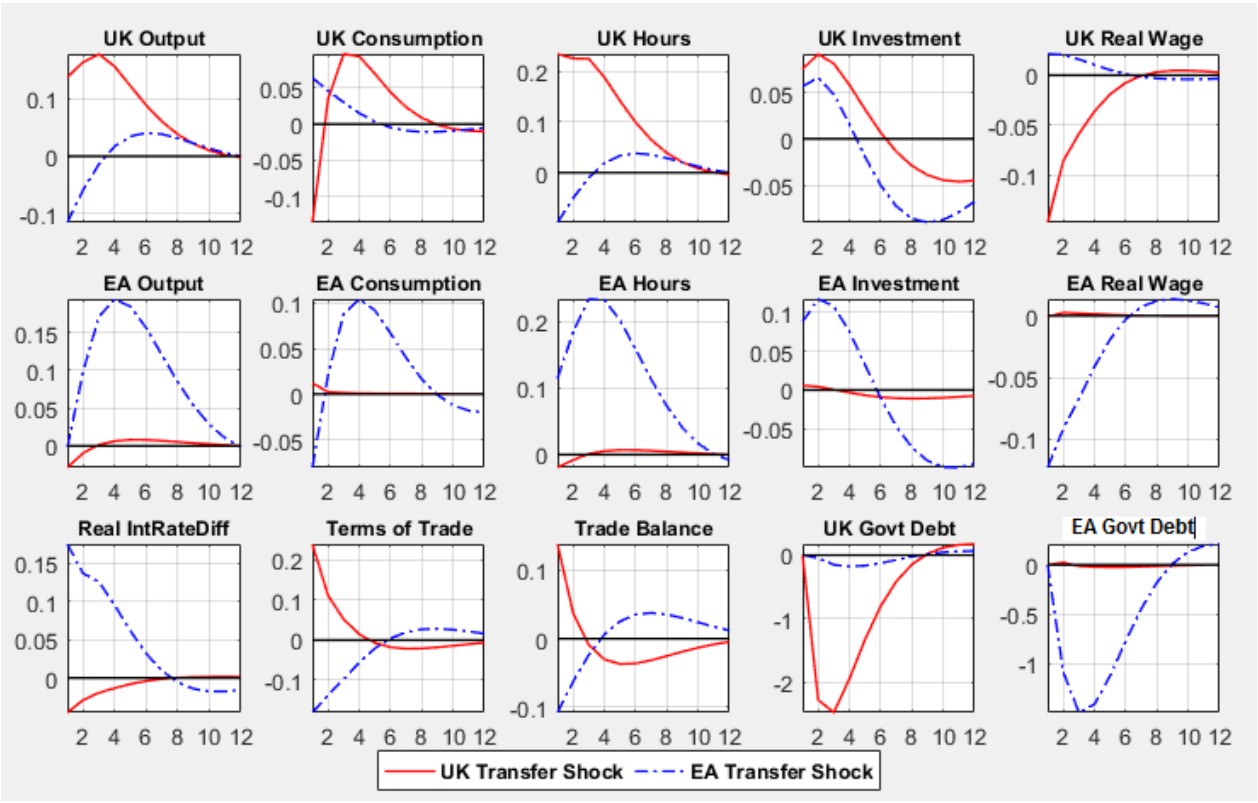

Figure 4: Impulse responses to a negative one percent innovation to government transfer. The solid line denotes response to UK government transfer shock while the dotted-dashed line denotes response to EA government transfer shock

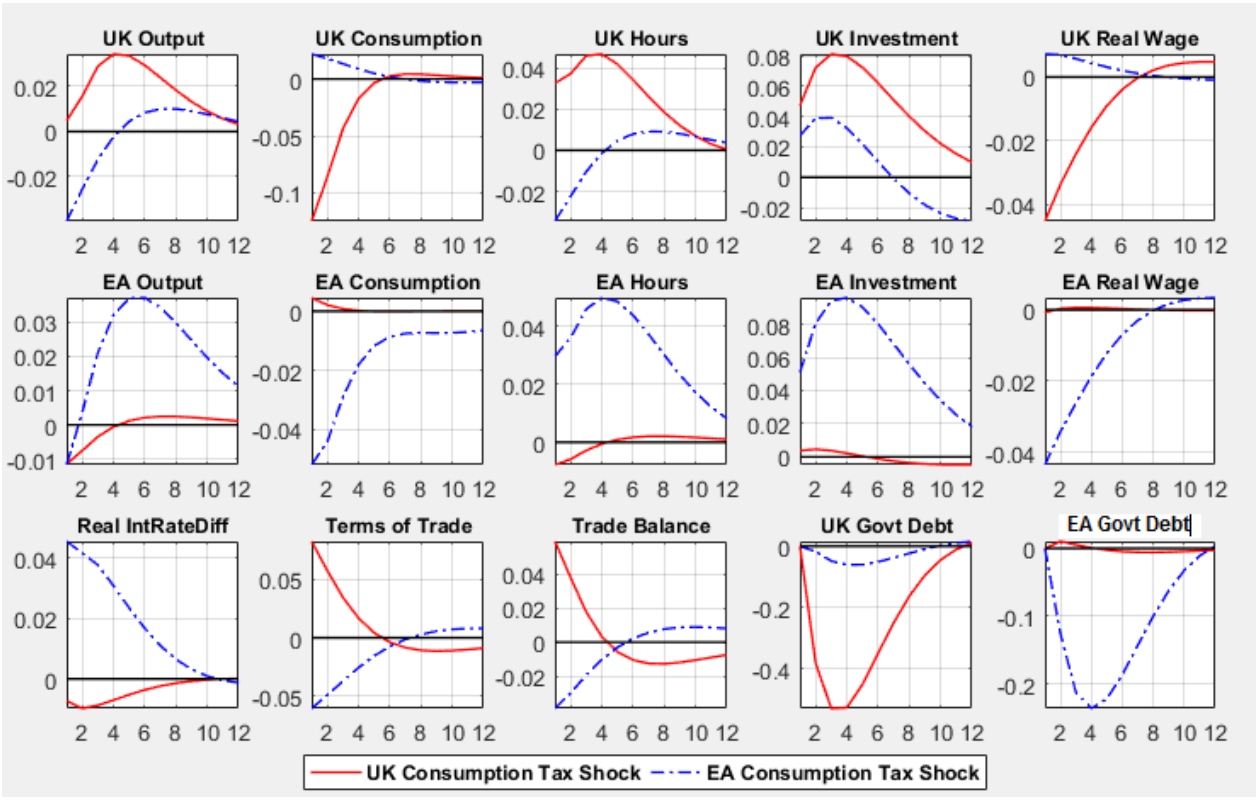

Figure 5: Impulse responses to a positive one percent innovation to distortionary tax on consumption. The solid line denotes response to UK consumption tax shock while the dotted-dashed line denotes response to EA consumption tax shock

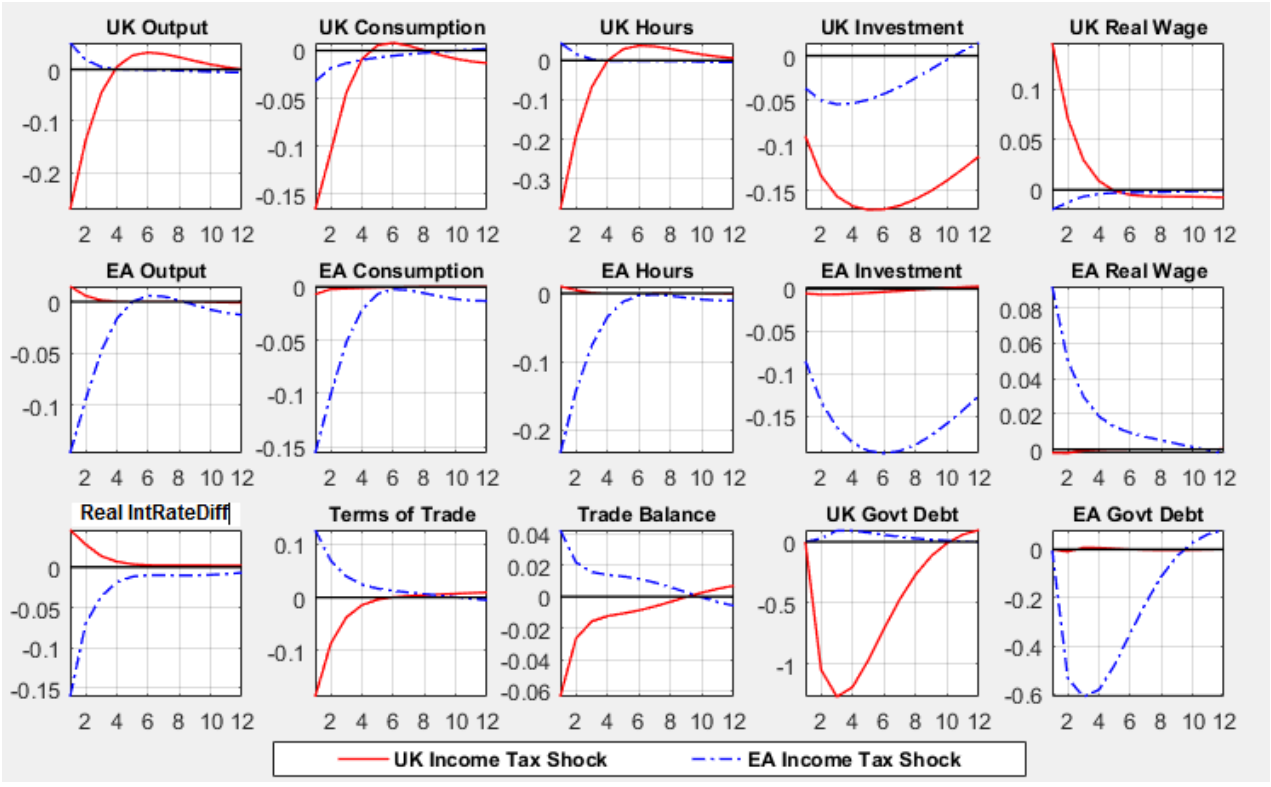

Figure 6: Impulse responses to a positive one percent innovation to distortionary tax on labour income. The solid line denotes response to UK income tax shock while the dotted-dashed line denotes response to EA income tax shock

positive comovement between private consumption and public spending which they argued is due to fall in longrun interest rate in their model. Also Gadatsch et al. (2016) observed that a positive shock to German government purchases have negative spillover effects on output and consumption in the rest of the Euro area.

Figure 4 plots impulse responses to government transfers cut. Since transfer cut implies lesser income to the households,[11] private consumption falls contemporaneously even as households substitute leisure for more labour hours in order to work their way back to the pre-consolidation welfare level. The rise in labour productivity improves the marginal productivity of capital, causing output to rise in the home country. As home household income has fallen, demand for foreign goods dips and terms of trade depreciates. This, in turn, leads to fall in foreign output while foreign consumption rises.

Figures 5 and 6 plot impulse responses to a positive shock to distortionary taxes on consumption and labour income respectively. As expected, an increase in domestic consumption tax leads to a fall in private consumption in the domestic economy, while foreign consumption rises. As households postpone current consumption and substitute leisure for labour, investment rises, leading to 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 fall in firm's investment spending, which in turn leads to fall in output and consumption in the home country. As domestic income has fallen, the 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 competitiveness is transferred to foreign country, while foreign consumption falls because home goods has become relatively expensive. This result is partly in tandem 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 this simulation results suggest that EA consolidation policies tend to have significant spillover effects on the UK economy, while UK fiscal policy have relatively minimal effect on EA economic activity. This is may be due to the relatively small size of the UK economy compared to the aggregate Euro area economy.[12] This might also be due to trade effect as trade between the two countries constitute a significant proportion of total UK trade. 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. More so, this analysis shows that the effect of fiscal spillovers across borders depend on the type of fiscal instrument being considered. While the spending-based consolidation policy are transmitted across borders through partial crowding out/in of domestic demand, tax-based policy are transmitted through their effect on real wages and relative prices.

5.1 Fiscal Spillovers and International Asset Market Participation

In section 3, we mathematically derived and conjectured that the relative participation of countries at the international asset market is a significant driving force for their net foreign asset holding, which in

[11] Transfer is an income received not earned.
[12] UK GDP is roughly 17% of the size of Euro area GDP.

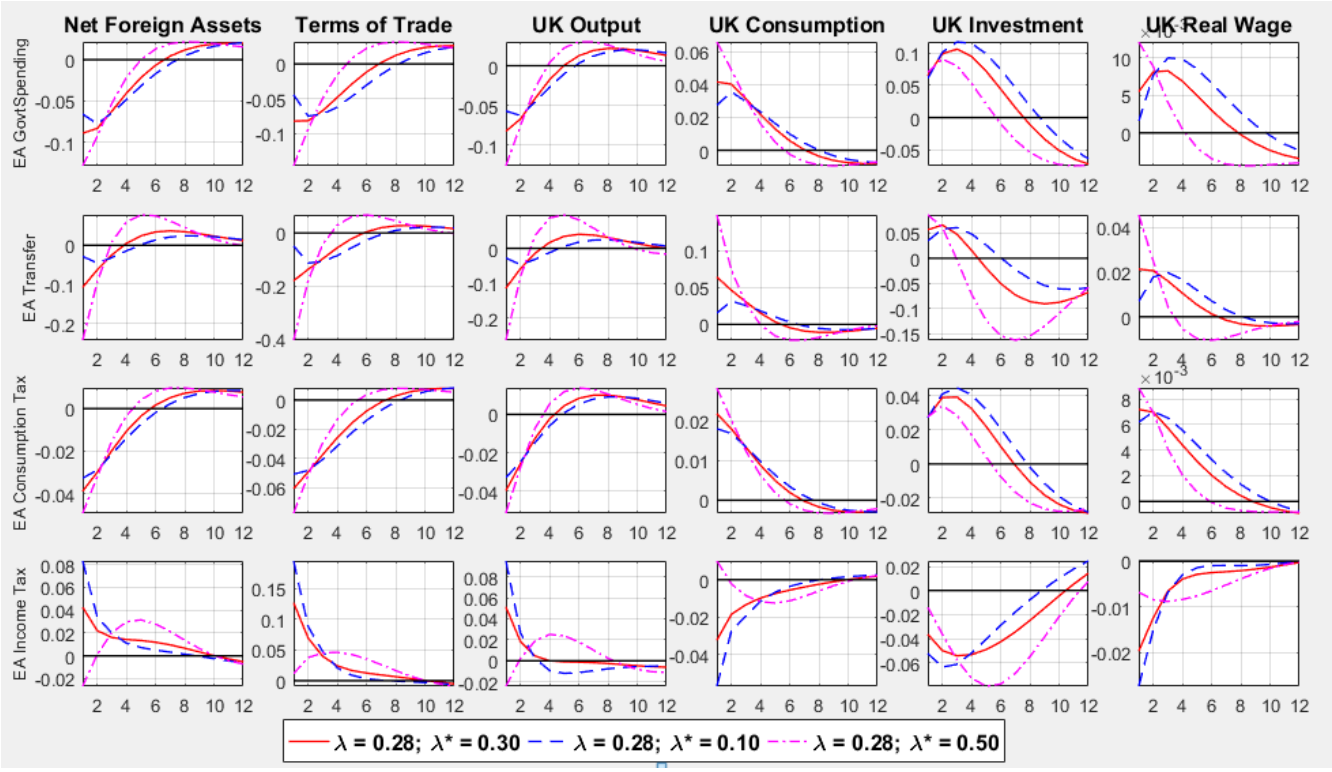

Figure 7: Impulse responses of UK aggregate macroeconomic variables to EA fiscal consolidation. The solid line denotes the estimated baseline model with approximately equal participation in the asset market. The dash line denotes relatively more participation of the EA, and the dotted-dash line denotes relatively less participation of the EA.

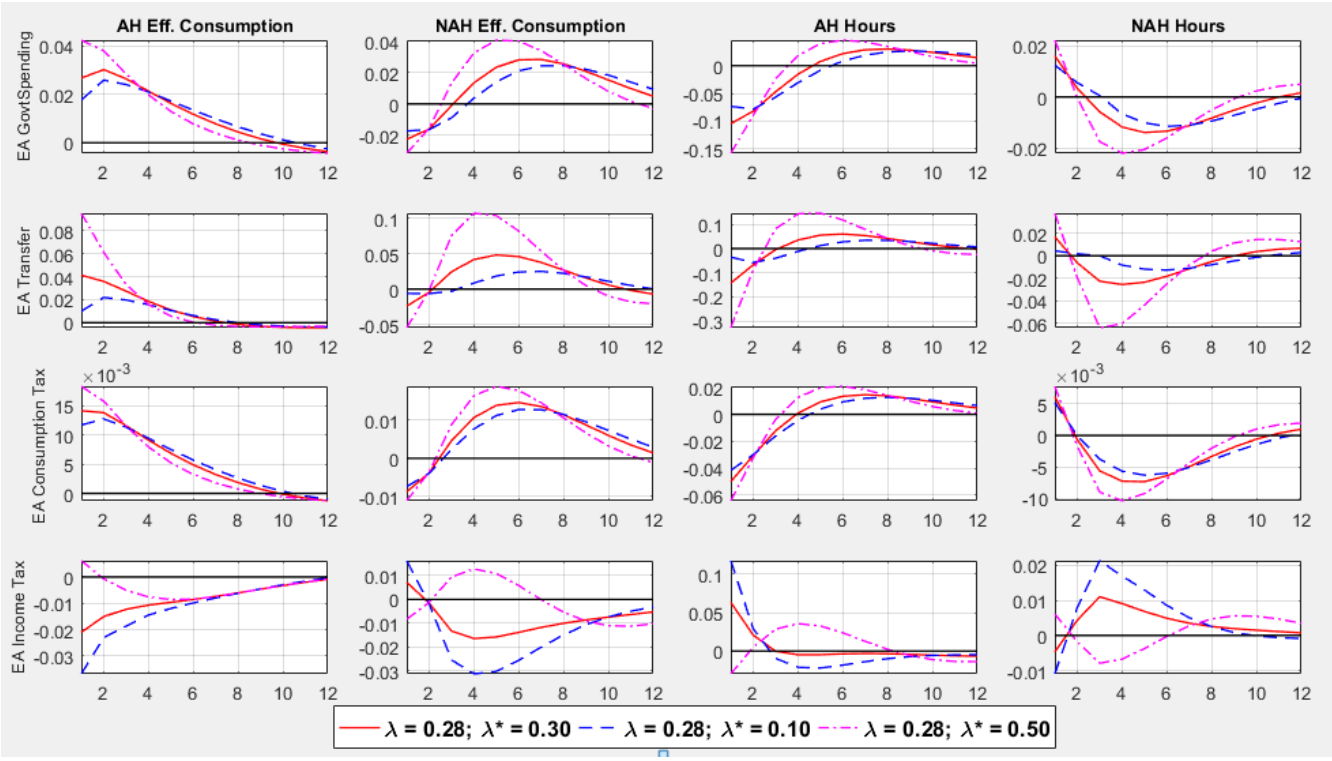

Figure 8: Impulse responses of UK agent-specific variables to EA fiscal consolidation. The solid line denotes the estimated baseline model with approximately equal participation in the asset market. The dash line denotes relatively more participation of the EA, and the dotted-dash line denotes relatively less participation of the EA. AH - Asset holders; NAH - Non-asset holders.

turn could influence cross-border policy responses. In this section, we try to demonstrate, analytically, how this relative participation at the global asset market influence international fiscal spillovers. To do this, we plot the response of 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).

Figures 7 and 8 plot the impulse responses of UK agent-specific and aggregate macroeconomic variables to EA fiscal consolidation shocks for varying degree of participation of the source country. For agent-specific responses, we plot the effective consumption and labour hours of each type of households. Figure 7 shows that UK agents hold less assets in response to consolidation shocks in the Euro area member-countries, except when the consolidation policy is income tax-based and the source country have at least same level of participation with the response country. As UK agents adjust their foreign asset holding, current balance adjusts accordingly, which directly translates into adjustments in GDP. Notice that, on impact, there is a one-to-one relationship between current account balance and 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 response-country's output.

Regarding the effect of countries relative participation at the asset market, there are three key lessons observed from the simulation exercise. First, relative participation of the source country is a key driver of macroeconomic volatility in the response country. The higher the relative participation of the source country at the global asset market, the lower the macroeconomic volatility in the response country in response to fiscal spillovers, except when the fiscal spillover is income tax-based. Second, in the medium-run, relative participation of the source country have more pronounced effect on the volatility 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 firm's investment decisions. Third, the relative participation of the source country tends to influence home country's asset holders optimal choices (effective consumption and hours) mainly in the short run and fizzle-out between 4-6 quarters, but it mainly affects optimal choices of non-asset holders in the medium run. One plausible explanation for this could be the foresight ability of the households: since asset-holders participate in the global asset markets, thereby having first-hand information, 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, non-asset holders suffers from information asymmetry, and will only significantly adjust their optimal choices in response to policy shock after some quarters.

6 Concluding Remarks

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 total UK trade is with the EA, this paper examines the effects of EA fiscal consolidation on UK economic activity. The paper also set out to unravel the role of countries' relative participation at the international financial market on the propagation of fiscal spillovers. To achieve this, we develop a two-country DSGE model in the spirit of Justiniano and Preston (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 departs from existing literature on international fiscal spillovers with three major

contributions: first, different types of households are allowed to respond differently to fiscal changes; second, we derive mathematically and show analytically 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 policy have negligible effects on the EA economy, which we argue may be due to the relatively small size of the UK economy and high proportion of total UK trade from 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 macroeconomic volatility and amplification of fiscal spillovers in the response country (UK).

Given the implications of our results, we conclude that fiscal spillover can become a major source of macroeconomic fluctuations in the domestic economy, especially when the spillover is from a major trading partner. Hence, it is advisable for policy makers to incorporate the reaction functions of countries with close links in their policy model.

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