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State dependent fiscal multipliers in a Small Open Economy*

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Abstract

We compute state dependent fiscal multipliers using an estimated small open economy medium scale DSGE model for a country that is a member of Eurozone, focusing specifically on the case of Ireland over the period 2000-2019. State dependency refers to the state of public finances, specifically we quantify fiscal multipliers across states of high/low public debt. Our open economy setup enable us to assess the impact of a fiscal stimulus on aggregate output but also its compositional effect in the small open economy with two-sectors, namely, tradable and non-tradable. We find a non-linear negative relationship between public debt and the fiscal multiplier. Additionally, government spending compared to other fiscal instruments, is more likely to simulate the economy in states of high public debt. The latter effect works mostly through the non-tradable sector.

Keywords: Fiscal multipliers,Small Open Economy, State dependent
JEL Classification: E30, E60, F41

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1 Introduction

The recent global economic crises, namely the Great Recession and the COVID-19 induced crisis, have prompted national governments to implement significant fiscal stimulus packages to mitigate the negative impact of these economic downturns. This has reignited the attention of academics and policymakers on the efficacy of fiscal policy.

The importance of national fiscal policy in Euro Area has grown even more significantly for several reasons. Specifically, EA countries have delegated their monetary policy to a supranational entity, the European Central Bank (ECB). As a result, national governments depend solely on fiscal policy to counteract the effects of the business cycle. However, several EA small open economies have accumulated historically unprecedented high public and external debts vis-à-vis the rest of the world. As a result, in the aftermath of these crises, especially during the European Debt Crisis, several EA small open economies borrow from international financial markets only with a sovereign premium.

Ireland is one of the EA small open economies which has encountered these challenges as Figure 1 illustrates. The upper panel presents public debt as a share of an aggregate economic indicator, either GDP or total modified domestic demand.[1] The lower panel illustrates the borrowing cost of the Irish national government, i.e., the 10-year nominal interest rate on Irish government bonds. As clearly illustrated in Figure 1, Ireland faced with a severe fiscal stress in the aftermath of the Global Financial Crisis, which was reflected in its international borrowing cost.

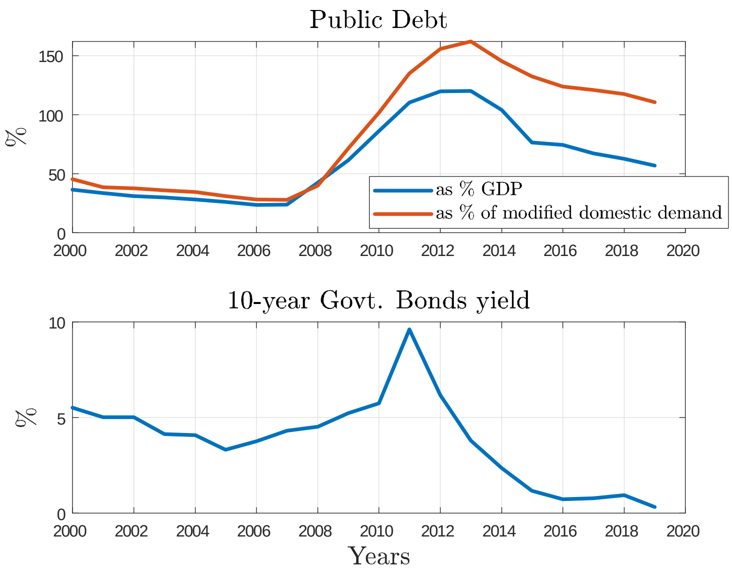
The concept of fiscal multipliers summarizes the impact of fiscal policy, and thus in this economic environment, the size of fiscal multipliers has attracted more attention. The latter heavily depends on the structural characteristics of each economy as well as the phase of the business cycle. Therefore, from a quantitative point of view, it is important to understand how the multiplier varies across different states of the economy.

The aim of this paper is to compute state-dependent fiscal multipliers for the key tax-spending policy instruments in a small open economy model of a country that participates in a monetary union mimicking the Eurozone regime. Our focus is on exploring the relationship between the fiscal multiplier and the state of a country's public finances, as indicated by a fiscal metric such as the ratio of public debt to output.

To do this, we estimate the model via Bayesian estimation methods using Irish data over 1999Q1 to 2020Q1. Ireland distinct economic structure makes it an interesting case study to quantify fiscal multipliers. Ireland is a small open economy participating in Eurozone. At the same time, it is highly integrated in the global economy with an exceptional degree of openness. The latter is translated to a relatively larger share of the tradable sector vis-à-vis the non-tradable sector. In addition, the tradable sector is highly export-oriented, at the same time, the non-tradable production is relatively more import-oriented than most EA economies. Ireland has been severely impacted during the recent European Debt Crisis, while its sovereign premium has been skyrocketed. In addition, the Irish economy is characterized by relatively low automatic stabilizers, e.g., the effective tax rates are particularly low especially for the capital tax rate.

[1] A comparison of the two indicators suggests that relying on GDP might overestimate the fiscal position of a very open economy in the globalized world, such as Ireland. For that reason, in what follows, we will mostly utilize total modified domestic demand as a relatively more accurate measure of aggregate economic activity. This choice is motivated by the well documented problem that Irish GDP has been distrorted by the operations of a limited number of multinational enterprises.

Figure 1: public debt of the Irish government and bond yields



Notes: Data on public debt, GDP and total modified domestic demand are taken from Central Statistics Office; data on 10-year government bonds are taken from OECD, Interest Rates: Long-Term Government Bond Yields: 10-Year: Main (Including Benchmark) for Ireland [IRLTLT01IEM156N], retrieved from FRED, Federal Reserve Bank of St. Louis;

We develop a medium scale small open economy DSGE model that incorporates a detailed fiscal block and several empirically relevant features such as nominal price and wage rigidities, Ricardian and non-Ricardian households, capital utilization and sources of real inertia. The model intentionally follows the tradition of New Keynesian medium scale DSGE models (e.g., Smets and Wouters (2003, 2007) and Christiano et al. (2005)) which has been widely used by policy institutions in Euro Area countries for quantifying fiscal multipliers.

Related Literature. There is a vast and constantly evolving literature that uses general equilibrium models to quantify the size of fiscal multipliers. A non-exhaustive list includes papers that use frictionless closed economy real business cycle models, see e.g., Aiyagari et al. (1992), Baxter and King (1993), Ramey and Shapiro (1998), Burnside et al. (2004) and Ramey (2011). Another strand emerged employing the New Keynesian paradigm see e.g., Gali et al. (2007), Monacelli and Perotti (2008), Christiano et al. (2011).[2] These papers mostly used stylized calibrated models to quantify the size of fiscal multipliers. More recently, Zubairy (2014),

[2] Also, there are papers that focus on a subset of fiscal policy toolkit, e.g., Leeper et al (2010), Bouakez et al. (2017, 2020) Malley and Philippopoulos (2023) study the public investment multiplier.

Drautzburg and Uhlig (2015) and Leeper et al. (2017) and Chang et al. (2021) utilize medium scale DSGE closed economy models enriched with empirically relevant frictions to compute fiscal multipliers. Moreover, Cacciatore and Traum (2022) compute fiscal multipliers in a two country model.

Our work is closely related to the literature on state-dependent multipliers.[3] Sims and Wolff (2018a) and (2018b) employed an estimated medium scale closed economy DSGE model to compute state dependent spending and tax multipliers. Our paper builds upon their work along several dimensions. First, we expand their approach in a two-sector open economy, incorporating tradable and non-tradable sectors. This framework enables us to compute not only an aggregate output multiplier, but also to decompose the effect on its sectoral constituents. Second, while we also examine state dependency, our primary focus centers on the state of public finances, specifically, as it is indicated by a fiscal metric such as the public debt to output ratio. In our setup, increasing public debt incurs costs beyond the direct effect on government budget constraint. Specifically, higher public debt implies that the small open economy will borrow from the international financial markets with a sovereign premium. Third, regarding macroeconomic policy, we consider the scenario of a small open economy that is a member of a currency union, foregoing monetary policy independence. Also, Canzoneri et al. (2015) compute state-dependent fiscal multipliers in a perfect foresight model with costly financial intermediation. Shen and Yang (2018) find business cycle-dependent government spending multiplier in a model with involuntary unemployment and downward nominal wage rigidity. Finally, Liu (2022) compute state-dependent government spending multiplier in a small open economy model with a collateral constraint on international borrowing.

Main Findings. Our analysis confirms that spending multipliers are higher than tax multipliers across states. Specifically, the posterior mean of government consumption multiplier is equal to 1.28 followed by the public wage at 0.87; while tax multipliers are lower with capital tax equal to 0.45, labour tax equal to 0.38 and consumption tax equal to 0.34. More importantly, fiscal stimulus predominantly benefits the non-tradable sector of an open economy compared to the tradable sector. Specifically, the government spending multiplier (i.e., government consumption) is consistently higher in the non-tradable sector vis-à-vis the tradable sector. The resulting posterior mean in the non-tradable sector is equal to 0.57, while the respective mean in the tradable sector is equal to 0.33. This also holds, albeit to a lesser extent, for tax multipliers. In the non-tradable sector of capital, labour and consumption tax multipliers are equal to 0.2, 0.17 and 0.15, respectively, compared to 0.16, 0.1 and 0.09 in the tradable sector. Although, fiscal stimulus has an aggregate output effect, our analysis enables to sheds light on the compositional effect. The underlying mechanism behind these results is driven by the open economy structure of our model. That is, in an open economy, fiscal stimulus is more likely to crowd out the tradable sector, while crowding in the non-tradable sector by affecting its international competitiveness.

Perhaps more interestingly, our model implies a steady non-linear negative relation between public debt and the fiscal multiplier. This negative relation is steeper for tax compared to spending instruments. The latter implies that spending instruments are more effective tool to mitigate the effects of an economic downturn during an era of fiscal stress. This works mostly through the stimulating effects on the non-tradable compared to the tradable sector. That is, spending stimulus not only has larger impact on the non-tradable but also it is more resilient in states of high public debt. Finally, we compute a useful fiscal metric that can be used in this class of models (widely used for fiscal policy analysis). This fiscal metric measures the probability of a fiscal stimulus to be effective conditional on public debt to output being above/below a certain threshold. For example, fiscal stimulus via government consumption would be effective with

[3] Corsetti et al (2012), Ramey and Zubairy (2018) and Fotiou (2022) find empirical evidence that the size of fiscal multipliers depends on the state of the economy.

probability of 57% when public debt to output ratio is lower than 90%; while this probability substantially decreases to 12% when this ratio exceeds the 90% threshold.

The rest of the paper is organized as follows. Section 2 sets out the model. Section 3 lays out the calibration and the estimation approach. Section 4 presents the methodology of computing state-dependent multipliers and quantitative results. Finally, section 5 concludes. Modelling details and additional results are in an online Appendix.

2 Model

This section develops our model. The model shares several key characteristics that have been used in the literature on fiscal multipliers (see e.g., Zubairy (2014), Leeper et al. (2017) and Malley and Philippopoulos (2023)). Most of these papers use closed economies models. Our paper utilizes a medium scale small open economy DSGE model. The small open economy is a member of a currency union and thus abandons monetary policy independence, thus the only macroeconomic tool left is national fiscal policy.

The small open economy consists of domestic households, firms and a national government. We incorporate two types of households, i.e. Ricardians (Savers) and non-Ricardians (Non-Savers). The production sector of the economy consists of two sectors, namely a tradable and a non-tradable sector. Final good packers produce the final good using a composite tradable good and the non-tradable good. Monopolistically competitive firms import a continuum of differentiated goods, this pricing power leads to a violation of the law of one price.

Households and the national government can participate in international financial and capital markets. The nominal interest rate at which they borrow from the rest of the world is debt elastic as in e.g., Schmitt-Grohé and Uribe (2003). Since our model is estimated using Irish data the rest of the world is approximated by the Euro Area, the US and the UK which are the main trading partners of Ireland.

2.1 Households

The economy is populated by a continuum of households on the interval $[0,1]$, of which a fraction ν are Ricardians/Savers and a fraction $1-\nu$ are non-Ricardian households. Superscript R indicates a variable associated with Ricardians/Savers and NR with non-Ricardians.

Ricardian households (Savers). Each Ricardians household, $j \in [0,\nu]$, maximizes its expected discounted lifetime utility in any given period t:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^b \left(\ln \left(C_t^{\star R}(j) - h\tilde{C}_{t-1}^{\star R} \right) - \varepsilon_t^L \int_0^1 \frac{\left(L_t^R(j,l)\right)^{1+\kappa}}{1+\kappa} dl \right) \tag{1}$$

where $\beta \in (0,1)$ is the discount rate. $C_t^{\star R}(j) \equiv C_t^R(j) + \vartheta^g Y_t^g$ denotes composite consumption comprising of consumption of private final good, $C_t^R(j)$, and consumption of public good, Y_t^g, produced by a state firm. The parameter ϑ^g measures the degree of substitutability (if $\vartheta^g > 0$) or complementarity (if $\vartheta^g < 0$) between public and private consumption. The term $h\tilde{C}_{t-1}^{\star R}$ is lagged composite consumption and captures external habit formation, where $h \in [0,1)$. Each Ricardian household, j, supplies a continuum of differentiated labour inputs, $L_t^R(j,l)$, $l \in [0,1]$. The corresponding aggregate quantity of these labour service is $L_t^R(j) \equiv \int_0^1 L_t^R(j,l)\,dl$. ε_t^b is a preference shock and ε_t^L is a labour supply shock.

The nominal flow budget constraint for Ricardian household, j, in period t is given by:

$$
\begin{aligned}
&P_t\left[\left(1+\tau_t^C\right)C_t^R(j)+I_t^H(j)+I_t^{NT}(j)\right]+\mathbb{E}_t\left[M_{t,t+1}D_{t+1}(j)\right]+P_t^L B_t(j)+\tfrac{S_t P_t^{L*}F_t(j)}{\Phi(\cdot)} \qquad (2)\\
&=\left(1-\tau_t^L\right)W_t L_t^R(j)+P_t Z_t^R(j)+\Pi_t(j)+D_t(j)+P_t^L R_t^L B_{t-1}(j)+S_t P_t^{L*}R_t^{L*}F_{t-1}(j)\\
&+\left(1-\tau_t^K\right)P_t\left(r_t^{k,H}u_t^H(j)\bar{K}_{t-1}^H(j)+r_t^{k,NT}u_t^{NT}(j)\bar{K}_{t-1}^{NT}(j)\right)\\
&-P_t\left(\eta\left(u_t^H(j)\right)\bar{K}_{t-1}^H(j)+\eta\left(u_t^{NT}(j)\right)\bar{K}_{t-1}^{NT}(j)\right)
\end{aligned}
$$

where P_t is the nominal price of the final good. W_t is the aggregate nominal wage received by the household j. Z_t^R is government lump-sum transfers and Π_t is profit of firms redistributed to Ricardian households

There are three broad classes of assets: a portfolio of short-term financial assets, D_t, the long-term government bonds (i.e. B_{t-1} and F_{t-1}) and capital ($\bar{K}_{t-1}^H$ and $\bar{K}_{t-1}^{NT}$). Since Ricardian households are the only owners of these assets, we suppress the superscript R on assets. D_t represents payments from the portfolio of financial assets, $M_{t,t+1}$ is the stochastic discount factor used for evaluating consumption streams, so that $E_t\left[M_{t,t+1}D_{t+1}\right]$ corresponds to the state-contingent market value of portfolio purchases at time t. B_t and F_t denote the long-term nominal government bonds denominated in domestic and foreign currency. S_t is the nominal exchange rate expressed as the domestic currency price of one unit of foreign currency. Following the formulation in Woodford (2001), we consider the long-term domestic bond as perpetuities with coupon equal to ρ^s paid at time $t+1+s$, for $s \geq 0$. The duration is thus given by $(1-\rho\beta)^{-1}$. The gross yield to maturity of domestic bond, R_t^L, is related to its price, P_t^L, in a simple way, i.e., $R_t^L = \frac{1}{P_t^L}+\rho$.

Analogously, Woodford's formulation (2001) applies to foreign bonds with maturity decays at the rate, ρ^*, to yield the duration, $(1-\rho^*\beta)^{-1}$ in line with the average duration of external debt in the Irish economy. Ricardian households face a cost of undertaking positions in the foreign bonds market. The cost function, $\Phi(\cdot)$, depends on the aggregate level of external debt that individual households take as given (see e.g., Schmitt-Grohé and Uribe, 2003, Garcia-Cicco et al, 2010).[4] τ_t^C, τ_t^L and τ_t^K are tax rates on consumption, labour income and capital income.

In addition, Ricardian households own capital in the traded and non-traded sectors. Superscript $H(NT)$ indicates a variable associated with the traded (non-traded) sector. r_t^k denotes the real rental rates of capital. Effective capital is related to capital stock by $K_t = u_t\bar{K}_{t-1}$, where u_t is the utilization rate of capital. Changing utilisation incurs a cost of $\eta(u_t)$ per unit of capital. In steady-state, $u=1$, and, $\eta(1)=0$. Define parameter $\phi \in [0,1)$ such that $\frac{\eta''(1)}{\eta'(1)} \equiv \frac{\phi}{1-\phi}$ as in Smets and Wouters (2003). The laws of motion for physical capital in the traded and non-traded sectors follow Christiano et al. (2005):

$$
\bar{K}_t^H(j) = (1-\delta)\bar{K}_{t-1}^H(j)+\varepsilon_t^{i,H}\left[1-\Psi\left(\frac{I_t^H(j)}{I_{t-1}^H(j)}\right)\right]I_t^H(j) \tag{3}
$$

$$
\bar{K}_t^{NT}(j) = (1-\delta)\bar{K}_{t-1}^{NT}(j)+\varepsilon_t^{i,NT}\left[1-\Psi\left(\frac{I_t^{NT}(j)}{I_{t-1}^{NT}(j)}\right)\right]I_t^{NT}(j) \tag{4}
$$

[4] The cost function, $\Phi(\cdot)$, is given by the following expression: $\Phi(\cdot) = \left[1+\psi\left(e^{(a_t-\bar{a})}-1\right)\right]e^{\widetilde{\phi}_t}$, where $a_t \equiv \frac{S_t P_t^{L*}F_t^* - S_t P_t^{L*}F_t}{P_t Y^{GDP}}$ is expressed as the net foreign asset position to GDP ratio. $S_t P_t^{L*}F_t^*$ is debt issued by the Irish government, expressed in domestic currency, held by foreigners. $\widetilde{\phi}_t$ is a shock to the risk premium. In the steady-state, it is assumed that $\Phi(0)=1$.

where δ denotes the rate of depreciation and the adjustment cost functions for investment, $\Psi(\cdot)$, is an increasing and convex function (i.e. $\Psi' > 0$). Furthermore, in the steady-state $\overline{\Psi} = \overline{\Psi}' = 0$ and $\overline{\Psi}'' > 0$. $\varepsilon_t^{i,H}$ and $\varepsilon_t^{i,NT}$ denote sector-specific investment shocks.

Each Ricardian household j maximizes its lifetime utility (1) by choosing the consumption good, the portfolio of financial assets, the domestic and foreign government bonds, the end-of-period capital stocks, utilization rates and investments in the traded and non-traded sectors, subject to the constraints (2), (3) and (4). The Lagrangian multiplier associated with constraint (2), is denoted with Λ_t and measures Ricardian household j marginal utility.

Non-Ricardian households. Non-Ricardian households have the same preferences as the Ricardian households. Non-Ricardian households receive income from working in the tradable, non-tradable and public sectors, but they have no access to capital and financial markets. In other words, they live hand-to-mouth and consume their after tax labour income plus government lump-sum transfers, Z_t^{NR}. The nominal flow budget constraint for a non-Ricardian household, $j \in (\nu, 1]$ is:

$$\left(1+\tau_t^C\right) P_t C_t^{NR}(j) = \left(1-\tau_t^L\right) W_t L_t^{NR}(j) + P_t Z_t^{NR}(j) \tag{5}$$

2.2 Wage setting and labour aggregation

Labor unions hire differentiated labour services, l, from Ricardian and non-Ricardian households. Then, a perfectly competitive labour packer combines these labour services into a composite labour input, L_t, according to:

$$L_t = \left(\int_0^1 L_t(l)^{\frac{\varepsilon^W-1}{\varepsilon^W}}\right)^{\frac{\varepsilon^W}{\varepsilon^W-1}}$$

where $\varepsilon^W \geq 0$ is the elasticity of subsitution among labour types. The labour packer takes each labour type's nominal wage rate $W_t(l)$ as given. Solving the profit maximisation problem of the labour packer yields the demand function for labour type l :

$$L_t(l) = \left(\frac{W_t(l)}{W_t}\right)^{-\varepsilon^W} L_t \tag{6}$$

where L_t is the demand for composite labour services, and W_t is the aggregate nominal wage. Combining this condition with the zero profit condition for the labour packer, we obtain an expression for the aggregate wage index W_t as a function of the wage specific to the l-th labour input,

$$W_t = \left[\int_0^1 W_t(l)^{1-\varepsilon^W} dl\right]^{\frac{1}{1-\varepsilon^W}}$$

The union sets wages for the type l-th labour subject to Calvo-type nominal rigidities. Wages get reset with the probability, $1-\theta^W$, in each period t, while with the complementary probability, θ^W, are adjusted by the past inflation, π_{t-1}, according to the rule:

$$W_t(l) = \left(\pi_{t-1} e^{\gamma+\varepsilon_{t-1}^a}\right)^{1-\lambda^W} \left(\pi e^{\gamma}\right)^{\lambda^W} W_{t-1}(l)$$

where, λ^W, is parameter that governs the partial indexation of nominal wages.

A labor union who can reset wage at period t, maximizes the present discounted value of future labour incomes

$$\max_{W_t(l)} \mathbb{E}_t \sum_{k=0}^{\infty} \left(\beta\theta^W\right)^k \Lambda_{t+k} \left[W_t(l) \left(\prod_{s=1}^{k} \left(\pi_{t+s-1} e^{\gamma+\varepsilon^a_{t+s-1}}\right)^{1-\lambda^W} \left(\pi e^{\gamma}\right)^{\lambda^W} \right) - W^{MC}_{t+k}(l) \right] L_{t+k}(l)$$

subject to the labour demand function (6) at period $t+k$, where, Λ_t is the Ricardian household's marginal utility of consumption at time t, and, $W^{MC}_{t+k}(l) \equiv \frac{\varepsilon^b_{t+k}\varepsilon^L_{t+k}(L_{t+k}(l))^{\kappa}}{\Lambda_{t+k}\left(1-\tau^L_{t+k}\right)}$, is the marginal cost of supplying additional l-type labour. It is assumed that labour union treats Ricardian and non-Ricardian households equally. As a result, the optimal wage above applies to both types of households, while non-Ricardian households work the same number of hours as the Ricardian household across sectors.

Finally, the evolution of the aggregate wage index is given by:

$$W_t = \left[\left(1-\theta^W\right)\left(\tilde{W}_t\right)^{1-\varepsilon^W} + \theta^W \left(W_{t-1}\left(\pi_{t-1}e^{\gamma+\varepsilon^a_{t-1}}\right)^{1-\lambda^W} \left(\pi e^{\gamma}\right)^{\lambda^W} \right)^{1-\varepsilon^W} \right]^{\frac{1}{1-\varepsilon^W}}$$

The labor packer also bears the responsibility of allocating the composite labor L_t in tradable, non-tradable and public sectors. Following Chang et al (2021), we allow for imperfect substitutability of labour inputs across different sectors to capture frictions in labour mobility. The total amount of composite labour is a constant-elasticity-of-substitution (CES) aggregate of the labour used in the traded, L^H_t, non-traded, L^{NT}_t, and public, L^g_t, sectors:

$$L_t = \left[\left(\varphi^H\right)^{\frac{1}{-\mu^W}} \left(L^H_t\right)^{\frac{\mu^W+1}{\mu^W}} + \left(\varphi^{NT}\right)^{\frac{1}{-\mu^W}} \left(L^{NT}_t\right)^{\frac{\mu^W+1}{\mu^W}} + \left(1-\varphi^H-\varphi^{NT}\right)^{\frac{1}{-\mu^W}} \left(L^g_t\right)^{\frac{\mu^W+1}{\mu^W}} \right]^{\frac{\mu^W}{\mu^W+1}}$$

where φ^H and φ^{NT} are structural parameters that govern the composite labour worked in the traded and non-traded sectors. μ^W is the elasticity of substitution between sectoral hours worked.

Solving the profit maximisation of the labor packer for selling sectoral labor services subject to the CES labor aggregate, we obtain the demand functions of composite labour inputs for the traded, non-traded and public sectors:

$$L^H_t = \varphi^H \left(\frac{W^H_t}{W_t}\right)^{\mu^W} L_t$$

$$L^{NT}_t = \varphi^{NT} \left(\frac{W^{NT}_t}{W_t}\right)^{\mu^W} L_t$$

$$L^g_t = \left(1-\varphi^H-\varphi^{NT}\right) \left(\frac{W^g_t}{W_t}\right)^{\mu^W} L_t \tag{7}$$

and the aggregate wage index (obtained by imposing zero profit condition):

$$W_t = \left[\varphi^H \left(W^H_t\right)^{1+\mu^W} + \varphi^{NT}\left(W^{NT}_t\right)^{1+\mu^W} + \left(1-\varphi^H-\varphi^{NT}\right)\left(W^g_t\right)^{1+\mu^W} \right]^{\frac{1}{1+\mu^W}}$$

where W^H_t, W^{NT}_t and W^g_t are the nominal wage rates paid in the traded, non-traded and public sectors, respectively.

2.3 Firms

Final goods firms. We assume that the final goods are produced in two stages by wholesale and retail firms. First, a continuum of wholesale firms purchase a composite final tradable good, Y_t^T, and a composite non-tradable good, Y_t^{NT}, to produce a differentiated final good $Y_t(i)$ in the unit interval:

$$Y_t(i) = \left[\omega^{\frac{1}{\zeta}} \left(Y_t^T\right)^{\frac{\zeta-1}{\zeta}} + (1-\omega)^{\frac{1}{\zeta}} \left(Y_t^{NT}\right)^{\frac{\zeta-1}{\zeta}}\right]^{\frac{\zeta}{\zeta-1}}, i \in [0,1] \tag{8}$$

where ω denotes the fraction of final tradable goods that are used for the production of the final good, and ζ denotes the elasticity of substitution between the composite final tradable goods and non-tradable goods. The wholesale firm, i, minimises cost subject to its production function (8) that yields the demand functions:

$$Y_t^T = \omega \left(\frac{P_t^T}{MC_t^Y}\right)^{-\zeta} Y_t(i), \;\; Y_t^{NT} = (1-\omega) \left(\frac{P_t^{NT}}{MC_t^Y}\right)^{-\zeta} Y_t(i) \tag{9}$$

where P_t^T and P_t^{NT} are the price level of tradables and non-tradables, respectively. Thus, $MC_t^Y = \left[\omega \left(P_t^T\right)^{1-\zeta} + (1-\omega)\left(P_t^{NT}\right)^{1-\zeta}\right]^{\frac{1}{1-\zeta}}$ is the marginal cost for the wholesale firm.

Second, retail firms purchase the differentiated final goods, $Y_t(i)$, to produce the homogeneous final good, Y_t, that is used for household consumption, investment and government production. A retail firm acts as a competitive good packer of differentiated final goods,

$$Y_t = \left[\int_0^1 Y_t(i)^{\frac{\varepsilon_t^y - 1}{\varepsilon_t^y}}\right]^{\frac{\varepsilon_t^y}{\varepsilon_t^y - 1}} \tag{10}$$

where ε_t^y is a time-varying elasticity of substitution between types of final goods. Following Rabanal and Tuesta (2010), profit maximisation by wholesale firms yields,

$$P_t = \frac{\varepsilon_t^y}{\varepsilon_t^y - 1} MC_t^Y \equiv \mu_t^y MC_t^Y$$

where the price of final good, P_t, can fluctuate over its real marginal cost due to an exogenous mark-up shock, $\ln\left(\mu_t^y\right) = \ln(\mu^y) + \varepsilon_t^{\mu^y}$.

Final tradable goods firms. The composite final tradable goods, Y_t^T, involved in wholesale firms' production is produced using home and foreign-produced intermediate tradable goods in the following manner:

$$Y_t^T = \left[\left(\omega^H\right)^{\frac{1}{\zeta^H}} \left(Y_t^{H,d}\right)^{\frac{\zeta^H - 1}{\zeta^H}} + \left(1-\omega^H\right)^{\frac{1}{\zeta^H}} \left(Y_t^F\right)^{\frac{\zeta^H - 1}{\zeta^H}}\right]^{\frac{\zeta^H}{\zeta^H - 1}} \tag{11}$$

where ζ^H is the elasticity of substitution between home and foreign-produced tradable goods, and ω^H is the share of domestic tradable goods, $Y_t^{H,d}$, used in the production of composite final tradable goods. $Y_t^{H,d}$ and Y_t^F are Dixit-Stiglitz aggregators of all intermediate tradable goods produced at home and foreign countries, respectively,

$$Y_t^{H,d} = \left[\int_0^1 Y_t^{H,d}(h)^{\frac{\epsilon^H - 1}{\epsilon^H}} dh\right]^{\frac{\epsilon^H}{\epsilon^H - 1}}, \;\; Y_t^F = \left[\int_0^1 Y_t^F(f)^{\frac{\epsilon^F - 1}{\epsilon^F}} df\right]^{\frac{\epsilon^F}{\epsilon^F - 1}} \tag{12}$$

where ϵ^H is the elasticity of substitution between home-produced intermediate tradable goods, and ϵ^F is for foreign-produced tradables.

The profit maximisation of the producer of final tradable goods yields the following input demand functions for the home and foreign-produced intermediate tradable goods:

$$Y_t^{H,d} = \omega^H \left(\frac{P_t^H}{P_t^T}\right)^{-\zeta^H} Y_t^T, \;\; Y_t^{H,d}(h) = \left(\frac{P_t^H(h)}{P_t^H}\right)^{-\epsilon^H} Y_t^{H,d} \tag{13}$$

$$Y_t^F = \left(1-\omega^H\right)\left(\frac{P_t^F}{P_t^T}\right)^{-\zeta^H} Y_t^T, \;\; Y_t^F(f) = \left(\frac{P_t^F(f)}{P_t^F}\right)^{-\epsilon^F} Y_t^F \tag{14}$$

where

$$P_t^H = \left[\int_0^1 P_t^H(h)^{1-\epsilon^H} dh\right]^{\frac{1}{1-\epsilon^H}}, \; P_t^F = \left[\int_0^1 P_t^F(f)^{1-\epsilon^F} df\right]^{\frac{1}{1-\epsilon^F}}$$

and

$$P_t^T = \left[\omega^H \left(P_t^H\right)^{1-\zeta^H} + \left(1-\omega^H\right)\left(P_t^F\right)^{1-\zeta^H}\right]^{\frac{1}{1-\zeta^H}}$$

Intermediate tradable goods firms. The continuum of intermediate tradable firms operate in the monopolistically competitive market, producing differentiated goods for domestic consumption, $Y_t^{H,d}(h)$ and exports, $Y_t^{H,*}(h)$. Following Drautzburg and Uhlig (2015) and Chang et al. (2021), we assume that the public sector output, Y_t^g, can also enhance the productivity of private firms. Thus, the production technology for each good h is:

$$Y_t^{H,d}(h) + Y_t^{H,*}(h) = \left[K_t^H(h)\right]^{a^H} \left[A_t X_t^H L_t^H(h)\right]^{1-a^H} \left(\frac{Y_t^g}{\int_0^1 Y_t^H(h)\, dh}\right)^{\frac{\chi^H}{1-\chi^H}} \tag{15}$$

where a^H measures the capital share in the production of the tradable output and χ^H is the productivity share of the public good in the tradable sector.

There are two technology shocks in the production function: A_t is a labour augmenting aggregate world technology shock, which has a unit root with drift, γ,

$$\ln A_t = \gamma + \ln A_{t-1} + \varepsilon_t^a$$

Thus, on average technology grows at the rate, γ, and ε_t^a captures exogenous fluctuations in the technology growth rate. X_t^H is a sector-specific stationary productivity shock to tradable sector at time t, which evolves according to an AR(1) process: $\ln X_t^H = \rho^{X,H} \ln X_{t-1}^H + \varepsilon_t^{X,H}$.

The intermediate tradable good producers solve a cost minimization problem which yields the marginal cost of production,

$$MC_t^H = \frac{\left(W_t^H\right)^{1-a^H} \left(P_t r_t^{k,H}\right)^{a^H} \left(\frac{Y_t^g}{\int_0^1 Y_t^H(h) dh}\right)^{-\frac{\chi^H}{1-\chi^H}}}{\left(A_t X_t^H\right)^{1-a^H} \left(a^H\right)^{a^H} \left(1-a^H\right)^{1-a^H}}$$

and the optimal capital-labour ratio is given by,

$$\frac{K_t^H(h)}{L_t^H(h)} = \frac{a^H}{1-a^H} \frac{W_t^H}{P_t r_t^{k,H}}$$

Intermediate tradable goods producers choose the price that maximizes the expected sum of discounted profits subject to a Calvo-type nominal rigidities. In each period, a fraction $1-\theta^H$ of firms will change optimally their price whereas the remaining fraction, θ^H, index their prices to past sectoral inflation according to the rule,

$$P_t^H(h) = \left(\pi_{t-1}^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H} P_{t-1}^H(h) \tag{16}$$

where $\pi_{t-1}^H \equiv \frac{P_{t-1}^H}{P_{t-2}^H}$ is the inflation rate in the tradable sector, π^H is the steady-state sectorial inflation rate, and $\lambda^H \in [0,1]$ an indexation parameter. An intermediate tradable goods producer, h, who can adjust its price at time t, chooses, $\tilde{P}_t^H(h)$, to maximise:

$$\max_{\tilde{P}_t^H(h)} \mathbb{E}_t \sum_{k=0}^{\infty} \left(\theta^H\right)^k M_{t,t+k} \left\{ \left[\tilde{P}_t^H(h) \left(\prod_{s=1}^{k} \left(\pi_{t+s-1}^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H} \right) - \varepsilon_{t+k}^{p,H} MC_{t+k}^H \right] \right.$$
$$\left. \left(Y_{t+k}^{H,d}(h) + Y_{t+k}^{H,*}(h) \right) \right\}$$

where $\varepsilon_{t+k}^{p,H}$ is a tradable good markup shock that follows an AR(1) process. The first-order condition yields the New Keynesian Phillips Curve in the traded sector. Finally, the evolution of the price deflator in the tradable sector is given by:

$$P_t^H = \left\{ (1-\theta^H) \left(\tilde{P}_t^H\right)^{1-\epsilon^H} + \theta^H \left[P_{t-1}^H \left(\pi_{t-1}^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H} \right]^{1-\epsilon^H} \right\}^{\frac{1}{1-\epsilon^H}}$$

Final and Intermediate non-tradable goods firms. The composite non-tradable good used in the final good production combines all differentiated varieties of non-tradable goods,

$$Y_t^{NT} = \left[\int_0^1 Y_t^{NT}(\mathfrak{n})^{\frac{\epsilon^{NT}-1}{\epsilon^{NT}}} di \right]^{\frac{\epsilon^{NT}}{\epsilon^{NT}-1}} \tag{17}$$

where ϵ^{NT} is the elasticity of substitution between differentiated varieties $\mathfrak{n}$. The production technology for each variety, $\mathfrak{n}$, is given by:

$$Y_t^{NT}(\mathfrak{n}) = \left[K_t^{NT}(\mathfrak{n})\right]^{a^{NT}} \left[A_t X_t^{NT} L_t^{NT}(\mathfrak{n})\right]^{1-a^{NT}} \left(\frac{Y_t^g}{\int_0^1 Y_t^{NT}(\mathfrak{n})\, d\mathfrak{n}} \right)^{\frac{\chi^{NT}}{1-\chi^{NT}}} \tag{18}$$

where, a^{NT} and χ^{NT} measure the shares of capital and public goods, respectively, used in the production of intermediate non-tradables. X_t^{NT} is the AR(1) shock specific to the non-tradable sector, $\ln X_t^{NT} = \rho^{X,NT} \ln X_{t-1}^{NT} + \varepsilon_t^{X,NT}$.

An intermediate non-tradable good firm, $\mathfrak{n}$, faces Calvo-type nominal rigidities choosing its price, $\tilde{P}_t^{NT}(\mathfrak{n})$, in order to maximize the expected sum of discounted profits:

$$\max_{\tilde{P}_t^{NT}(\mathfrak{n})} \mathbb{E}_t \sum_{k=0}^{\infty} \left(\theta^{NT}\right)^k M_{t,t+k} \left[\tilde{P}_t^{NT}(\mathfrak{n}) \left(\prod_{s=1}^{k} \left(\pi_{t+s-1}^{NT}\right)^{\lambda^{NT}} \left(\pi^{NT}\right)^{1-\lambda^{NT}} \right) - \varepsilon_{t+k}^{p,NT} MC_{t+k}^{NT} \right] Y_{t+k}^{NT}(\mathfrak{n})$$

where θ^{NT} and λ^{NT} are the Calvo and inflation indexation parameters corresponding to the non-tradable sector. MC_t^{NT} is the the marginal cost derived from the cost minimisation problem of non-tradable intermediate goods producers. $\varepsilon_{t+k}^{p,NT}$ is an AR(1) markup shock specific to non-tradable good producers.

Domestic Importers. There are a large number of importing firms, indexed by f, who import foreign-produced intermediate tradable goods for which the law of one price (LOOP) holds 'at the dock'. Following Monacelli (2005), we assume that importers are monopolistically competitive firms. This pricing power leads to a violation of the LOOP both in the short- and long-run. The LOOP gap is defined as:

$$\widetilde{\psi}_t^F \equiv \frac{S_t P_t^{F*}}{P_t^F} < 1.$$

where P_t^{F*} is the price of foreign-produced traded good denominated in foreign currency.

The importer firms face a similar Calvo-type nominal rigidities in their price setting problem by choosing an optimal price, $\tilde{P}_t^F(f)$, which maximises the expected sum of discounted profits:

$$\max_{\tilde{P}_t^F(f)} \mathbb{E}_t \sum_{k=0}^{\infty} \left(\theta^F\right)^k M_{t,t+k} \left[\tilde{P}_t^F(f) \left(\prod_{s=1}^{k} \left(\pi_{t+s-1}^F\right)^{\lambda^F} \left(\pi^F\right)^{1-\lambda^F}\right) - \varepsilon_{t+k}^{p,F} S_{t+k} P_{t+k}^{F*}\right] Y_{t+k}^F(f)$$

where $S_t P_t^{F*}$ is the marginal cost faced by domestic importers at the dock where the LOOP holds, while θ^F, λ^F and $\varepsilon_{t+k}^{p,F}$ represent the Calvo parameter, indexation parameter, and an AR(1) markup shock specific to domestic importing firms, respectively.

2.4 Government

The government combines purchases of final goods produced by the final good producer, C_t^g, and the composite labour supplied by the households, L_t^g, to produce the public sector output, G_t. The public sector output evaluated at its production cost is given by the sum of government purchases of final goods and the public wage bill:

$$G_t \equiv C_t^g + \frac{W_t^g}{P_t} L_t^g$$

where public wage, W_t^g, is set by the fiscal authority, and L_t^g is determined via the labour demand equation in (7). The value added government production to aggregate output is given by:

$$Y_t^g = G_t - C_t^g \tag{19}$$

Thus, the value added government production is equal to public sector compensation of employees:

$$Y_t^g = \frac{W_t^g}{P_t} L_t^g$$

As in Forni et al. (2010) and Chang et al. (2021), the GDP, Y_t^{GDP}, is defined as the sum of private sectors production and public wage bills:

$$P_t Y_t^{GDP} \equiv P_t^H Y_t^H + P_t^{NT} Y_t^{NT} + W_t^g L_t^g$$

The government budget constraint in nominal and aggregate terms is given by:

$$P_t^L B_t + \frac{S_t P_t^{L*} F_t^*}{\Phi(\cdot)} = \left(1 + \rho P_t^L\right) B_{t-1} + \left(1 + \rho^* P_t^{L*}\right) S_t F_{t-1}^* + P_t G_t + P_t Z_t - P_t T_t \tag{20}$$

The left-hand side of expression (20) is the market value, in nominal terms, of total long-term debt issued by the national government at time t. In turn, $P_t^L B_t$ is the debt held by domestic Ricardian households, and $S_t P_t^{L*} F_t^*$ is the debt expressed in domestic currency held by foreigners. The Irish government faces the same cost, $\Phi(\cdot)$, as domestic households when participating in the international asset market. The right-hand side features the cost of servicing bonds maturing at time t as well as aggregate tax revenues, T_t, expenditures, G_t and transfers, Z_t. Total tax revenues are defined as:

$$T_t \equiv \tau_t^C \left[\nu C_t^R + (1-\nu) C_t^{NR}\right] + \tau_t^L \frac{W_t}{P_t} L_t + \tau_t^K \nu \left(r_t^{k,H} u_t^H \bar{K}_{t-1}^H + r_t^{k,NT} u_t^{NT} \bar{K}_{t-1}^{NT}\right) \tag{21}$$

where $L_t = \int_0^1 L_t(j)\, dj = L_t^R = L_t^{NR}$, as the average Ricardian and non-Ricardian households work the same number of hours.

Lump-sum transfers are also identical across households, such that,

$$Z_t = \int_0^1 Z_t(j)\, dj = Z_t^R = Z_t^{NR} \tag{22}$$

Fiscal rules. The government has three tax instruments from the revenues side, i.e, τ_t^C, τ_t^L and τ_t^K are tax rates on consumption, labour income and capital income. It also has three instruments on the expenditures side, i.e., public purchase, C_t^g, public sector wage, W_t^g, and lump-sum subsidies, Z_t.

$$\frac{\tau_t^C}{\tau^C} = \left(\frac{\tau_{t-1}^C}{\tau^C}\right)^{\rho^C} \left(\frac{d_{t-1}}{d}\right)^{(1-\rho^C)\gamma^C} \epsilon_t^{\tau^C} \tag{23}$$

$$\frac{\tau_t^L}{\tau^L} = \left(\frac{\tau_{t-1}^L}{\tau^L}\right)^{\rho^L} \left(\frac{d_{t-1}}{d}\right)^{(1-\rho^L)\gamma^L} \epsilon_t^{\tau^L} \tag{24}$$

$$\frac{\tau_t^K}{\tau^K} = \left(\frac{\tau_{t-1}^K}{\tau^K}\right)^{\rho^K} \left(\frac{d_{t-1}}{d}\right)^{(1-\rho^K)\gamma^K} \epsilon_t^{\tau^K} \tag{25}$$

$$\frac{C_t^g}{c^g A_t} = \left(\frac{C_{t-1}^g}{c^g A_{t-1}}\right)^{\rho^{cg}} \left(\frac{d_{t-1}}{d}\right)^{-(1-\rho^{cg})\gamma^{cg}} \epsilon_t^{cg} \tag{26}$$

$$\frac{W_t^g}{w^g P_t A_t} = \left(\frac{W_{t-1}^g}{w^g P_{t-1} A_{t-1}}\right)^{\rho^{W^g}} \left[\left(\frac{W_{t-1}^{NT}}{w^{NT} P_{t-1} A_{t-1}}\right)^{\gamma^{W^{NT}}} \left(\frac{W_{t-1}^H}{w^H P_{t-1} A_{t-1}}\right)^{\gamma^{W^H}} \left(\frac{d_{t-1}}{d}\right)^{-\gamma^{W^g}}\right]^{1-\rho^{W^g}} \epsilon_t^{wg} \tag{27}$$

$$\frac{Z_t}{z A_t} = \left(\frac{Z_{t-1}}{z A_{t-1}}\right)^{\rho^Z} \epsilon_t^z \tag{28}$$

where $d_t \equiv \frac{P_t^L B_t + S_t P_t^{L*} F_t^*}{P_t Y_t^{GDP}}$ denotes the total public debt to GDP ratio, and d is the steady state value. $\{c^g,\, w^g,\, w^{NT},\, w^H,\, z\} \equiv \{\frac{C^g}{A},\, \frac{W^g/P}{A},\, \frac{W^{NT}/P}{A},\, \frac{W^H/P}{A},\, \frac{Z}{A}\}$ are the steady states of scaled government purchases, wages, and transfers, respectively. Finally, we assume that fiscal shocks, ϵ_t^χ, $\chi \in \{\tau^C,\, \tau^L,\, \tau^K,\, cg,\, wg,\, z\}$ are log-normally distributed with mean zero and standard deviations, σ^χ.

2.5 Aggregation and Resource Constraints

The aggregate demand for final goods is equal to the consumption of all households, investments to both trade and non-tradable sectors, capital utilisation costs and government consumption:

$$Y_t = \nu C_t^R + (1-\nu) C_t^{NR} + \nu I_t^H + \nu I_t^{NT} + \nu\eta\left(u_t^H\right)\bar{K}_{t-1}^H + \nu\eta\left(u_t^{NT}\right)\bar{K}_{t-1}^{NT} + C_t^g$$

while the evolution of net foreign asset position is given by:

$$\frac{S_t P_t^{L*}\left(F_t - F_t^*\right)}{\Phi(\cdot)} = S_t\left(1 + \rho^* P_t^{L*}\right)\left(F_{t-1} - F_{t-1}^*\right) + P_t^H Y_t^{H,*} - P_t^F Y_t^F \tag{29}$$

when $S_t P_t^{L*}\left(F_t - F_t^*\right) < 0$ (> 0) the small open economy is a net debtor (creditor).

2.6 Monetary and Exchange Rate Regime

In order to mimic participation in a monetary union, we assume that the nominal depreciation rate, $\epsilon_t \equiv \frac{S_t}{S_{t-1}}$, is exogenously set. The Ricardian household's first-order conditions imply that the nominal interest rate on domestic government bonds, R_{t+1}^L, is driven by fluctuations of the nominal interest rate at which the domestic country borrows from the international capital markets, R_{t+1}^{L*}, plus a sovereign premium $\Phi(\cdot) = \left[1 + \psi\left(e^{(a_t - \bar{a})} - 1\right)\right] e^{\widetilde{\phi}_t}$, where, $a_t \equiv \frac{S_t P_t^{L*} F_t^* - S_t P_t^{L*} F_t}{P_t Y_t}$, is expressed as the net foreign asset position to total domestic demand ratio. Thus, the sovereign premium is an increasing function of the net external debt of the small open economy. The higher is public and private debt to the rest-of-the-world the higher the sovereign premium:

$$\mathbb{E}_t \frac{\Lambda_{t+1}}{\Lambda_t}\left[\frac{R_t^L - \rho}{R_{t+1}^L - \rho} R_{t+1}^L - \frac{R_t^{L*} - \rho^*}{R_{t+1}^{L*} - \rho^*}\frac{S_{t+1}}{S_t} R_{t+1}^{L*}\Phi(\cdot)\right] = 0 \tag{30}$$

where Λ_t is the Lagrangian multiplier associated with Ricardian household's budget constraint.

The real exchange rate is defined as:

$$RER_t \equiv \frac{S_t P_t^*}{P_t} \tag{31}$$

where P_t^* is the aggregate foreign price.

2.7 Closing the Small Open Economy

We link the rest-of-the-world output, Y_t^*, to the Irish exports, $Y_t^{H,*}$, as follows,

$$Y_t^{H,*} = \left(\frac{P_t^H}{S_t P_t^*}\right)^{-\zeta^*} Y_t^*$$

where Y_t^* and P_t^* are approximated as the trade-weighted output and CPI of the Euro area, the US and the UK, respectively. S_t is the nominal effective exchange rate of Ireland with respect to the rest of world represented by these three areas. Additionally, we assume that $P_t^* = P_t^{F*}$, and the LOOP gap is re-defined as,

$$\widetilde{\psi}_t^F \equiv \frac{S_t P_t^*}{P_t^F}$$

Finally, we assume the rest of world follows an exogenous VAR(1) process:

$$\mathcal{W}_{t+1} = \Omega \mathcal{W}_t + \epsilon_{t+1}$$

where $\mathcal{W}_t = \left\{Y_t^*, \pi_t^*, R_t^{L*}\right\}$.

3 Calibration and Estimation

This section brings the model to the data. We employ quarterly data for Ireland over the period 1999Q1-2020Q1. Some parameters of the model are calibrated to target specific long-run averages observed in the Irish data or are set equal to values widely used in the literature. The calibration of these parameters is laid out in section 3.2, while the remaining parameters are estimated through Bayesian inference analyzed in section 3.3.

3.1 Data

As it is well known (see e.g., FitzGerald (2020)[5]), Ireland's key macroeconomic variables are distorted by the impact of the operations of a small number of large multinational enterprises, thus, to address this issue we have excluded macroeconomic variables from our sample that are deemed highly distortive by the Central Statistical Office of Ireland and we have replaced them with their undistorted counterparts. We utilize a sample of twenty-one observable macroeconomic variables, which are categorized into seven macroeconomic aggregates, four sectoral variables and six fiscal variables. We also construct four RoW indicators.

The seven macroeconomic indicators are real modified domestic demand[6], real consumption, real investment, hours worked, real wages, CPI, and the nominal interest rate on 10-year Ireland's government bond yield.

Regarding the sectoral aggregates, we choose to rely primarily on aggregates related to the non-tradable sector of the Irish economy. This choice is motivated by the fact that the tradable sector is burdened with the bulk of distortions in Irish national accounts. Specifically, the four sectoral macroeconomic variables consists of the non-tradable output, non-tradable investment and the respective deflator, while we only employ the deflator from the tradable sector. Consequently, sectoral aggregates such as tradable output and investment are treated as latent variables and are inferred by the estimated model.

Fiscal variables are real government consumption, real public wages, income tax, consumption tax, capital tax, public debt and the share fraction of public debt held by foreigners. Finally, we assume that the RoW consists of the Euro Area, the US and the UK, which are the main trading partners of Ireland. Thus, the RoW variables are constructed by employing trade-weighted averages of output, CPI, and the nominal interest rates on 10-year government bonds from the respective country specific variables. Appendix B provides a detailed description of our data.

[5] FitzGerald (2020) discusses the challenges encountered by users of the current system of national accounts arising from globalisation, with a specific focus on the case of Ireland. Interested readers are referred to the Central Statistics Office (CSO) (2016) and the Department of Finance (2018).

[6] Central Statistics Office publishes a quarterly aggregate indicator, namely modified total domestic demand. This time series is used as proxy of total domestic demand in an attempt to go further in trying to exclude large transactions of foreign corporations that do not have big impact on the domestic economy, see e.g., the Report of the Economic Statistic Review Group (ESRG) (2016) and more recently Casey (2023).

3.2 Calibration

TABLE 1 lists the values of the calibrated parameters. These parameters includes the discount factor, β, which is set equal to 0.99. This implies an annualised steady state real interest rate of 4%. The depreciation rate, δ, is set equal to 0.025 which implies an annual rate of capital depreciation equal to 10%. The elasticities of subsitution among differentiated intermediate tradable, ϵ^H, imported, ϵ^F, and non-tradable goods, ϵ^{NT}, as well as among differentiated labour services, ε^W, are set equal to 6, a value widely used in the literature (see e.g., Rabanal and Tuesta (2010 and 2013)). The parameter value associated with the capital share in the tradable sector, a^H, is set equal to 0.33. On the other hand, the parameter values pertaining to the capital share in the non-tradable sector, a^{NT}, and the shares of composite hours worked in the tradable, φ^H, and non-tradable, φ^{NT}, sectors are jointly calibrated. This calibration aims to capture the relatively higher labor intensity of the non-tradable sector compared to the tradable sector and to target the average ratios of hours worked in the tradable and non-tradable sectors relative to total hours worked. The parameter value ω^H, representing the share of the composite home tradable good in the production of the composite tradable good, is set at 0.5, consistent with the literature. The parameter ω, quantifying the share of the composite tradable good in the production of the final good, is calibrated to match the average ratio of non-tradable output to total gross value added across both sectors over the estimated sample period. Additionally, the proportion of non-Ricardian households, $1-\nu$, is fixed at 0.36, aligning with the model-consistent share from the 2018 Household Finance and Consumption Survey for Ireland.[7]

We calibrate the steady-state values of technology growth, γ, inflation, π, and fiscal variables using sample averages over the period from 1999Q1 to 2020Q1. Government consumption to domestic demand ($\frac{c^g}{y}$) is fixed at 0.18, while the public wage bill to domestic demand is set at 0.15. Long-run values of tax instruments align with sample average effective tax rates, computed according to the methodology outlined in Mendoza et al. (1994).[8] Consequently, consumption, τ^C, labour, τ^L, and capital taxes, τ^K, are established at 0.24, 0.33, and 0.19, respectively. Total public debt to domestic demand ($\frac{b+RERf^*}{4y}$) is set equal to 0.83 to align with data averages. Lastly, lump-sum transfers are adjusted residually to satisfy the government budget constraint.

To facilitate the estimation process, $\bar{a} \equiv \frac{RER(f^*-f)}{y^{GDP}}$, is left to be determined residually to satisfy the steady-state of equation (29) conditional on the estimated model parameters. As a result, the resulting threshold value indicates that the trade balance to GDP closely approximates its data average over the estimated sample period.

[7] We thank Reamonn Lydon from the Central Bank of Ireland who provide us with the associated data.

[8] The quarterly effective tax rates are seasonally adjusted and are consistent with the counterpart annual estimates in Kostarakos and Varthalitis (2019).

TABLE 1
CALIBRATED PARAMETERS

Parameters	Values
Structural Parameters	
β, discount factor	0.99
δ, depreciation rate	0.025
$\epsilon^H, \epsilon^{NT}, \epsilon^F$, elasticity of substitution	6
ε^W, steady-state wage markup	6
ω^H, share of home tradable goods	0.50
ω, fraction of final tradable	0.535
a^H, capital share of tradable	0.33
a^{NT}, capital share of non-tradable	0.174
ρ, ρ^*, to target average duration of 30 years	$\left(1-\frac{1}{30}\right)\frac{1}{\beta}$
$1-\nu$, share of non-Ricardian households	0.36
φ^H, share of labour worked in tradable	0.29
φ^{NT},share of labour worked in non-tradable	0.61
Technology growth, inflation, fiscal variables	
100γ, quarter-to-quarter per capita output growth rate	0.295
$400(\pi-1)$, annualized quarter-to-quarter inflation	1.70
$\frac{c^g}{y}$, government consumption to domestic demand	0.18
$b/(b+RERf^*)$, share of debt held by residents to domestic demand	0.497
$\frac{b+RERf^*}{4y}$, total debt to domestic demand	0.826
$\frac{w^g L^g}{y}$, public wage bill to domestic demand	0.15
τ^C, consumption tax	0.24
τ^L, labor tax	0.33
τ^K, capital tax	0.19

3.3 Parameter Posterior Distribution

TABLE 2 presents the prior distributions for the remaining parameters. These priors closely align with commonly utilized distributions in the literature, e.g., Smets and Wouters (2007), Adolfson et al. (2008), Rabanal and Tuesta (2013), Leeper et al. (2017), and Chang et al. (2021). Prior means are selected to match estimates from these studies, while standard errors are set to encompass a plausible range of parameter values. We construct posterior distributions, combining priors with the likelihood function, which is calculated using the Kalman filter. TABLE 2 also presents the means and 90-percent intervals of the posterior distributions.[9]

We first evaluate the impact of the public sector output on household utility and the productivity of private firms through parameters ϑ^g, χ^H and χ^{NT}. The prior for ϑ^g follows a uniform distribution with a zero mean and a standard deviation of 0.866. Public good productivity-enhancinng parameters, χ^H and χ^{NT} are set to follow a gamma distribution with a mean of 0.05 and a standard deviation of 0.01. Different from the empirical studies based on US data, such as Leeper et al. (2017) and Chang et al. (2021), all three posterior means significantly deviate

[9]The posterior is generated with five chains consisting of 500,000 draws each with an acceptance rate around 0.33. The first 100,000 draws were discarded from each chain and the sample is thinned by every 100 draws to remove serial correlation between the draws, leaving a final sample size of 20,000.

from zero. Specifically, the posterior mean of ϑ^g at -0.557 suggests a complementary relationship between public and private goods consumption. Furthermore, posterior values of χ^H and χ^{NT} indicate that the public good enhances productivity in both tradable and non-tradable sectors.

In addition, we use the same prior for fiscal adjustment parameters, γ^{W^g}, γ^{cg}, γ^K, γ^L, and γ^C (the response to lagged government debt), which have gamma distributions of mean 0.2 and the standard deviation of 0.05. The posterior values imply that Irish national government utilizes primarily consumption tax, see posterior mean of γ^C, and government spending, see posterior mean of γ^{c^g}, to react to public debt deviations from its target, secondarily, public wages, see posterior mean of γ^{W^g}. On the other hand, relatively more distortionary fiscal instruments, namely, labour and capital taxes are not used for public debt stabilization rather are kept relatively constant, as implied by the posterior means of γ^L and γ^K.

Moreover, we estimate the elasticity of the sovereign premium, ψ, using a prior characterized by an inverse gamma distribution, featuring a mean of 0.01 and a standard deviation of 0.5. The mean estimate for ψ falls towards the lower range of values typically observed in the literature, specifically at 0.004, with a 90 percent confidence interval ranging between 0.002 and 0.005. The prior for the elasticity of substitution between home and foreign produced tradable goods, ζ^H, is set to follow a Gamma distribution with a mean of 1.5 and a standard deviation of 0.25. The same prior is applied to the elasticity of substitution between the final tradable and non-tradable goods, ζ, ,and the price elasticity of Irish tradable goods exported to the RoW, ζ^*. The posterior of ζ^H is consistent with Faia and Monacelli (2008), but higher than Rabanal and Tuesta (2010, 2013) which lies between $[0, 1]$. The relatively higher value of the ζ^H posterior reflects the relatively higher degree of openness of the Irish tradable sector, as home and foreign traded goods are closer subsitutes and changes in relative prices can generate larger shifts in the quantity demanded of these goods.

Finally, prior choices for standard structural parameters, such as the investment adjustment cost convexity parameter, v_i; the utilization cost elasticity parameter, ϕ; habit formation, h; and wage and price nominal rigidities (θ^H, θ^{NT}, θ^F, θ^W) and indexation (λ^H, λ^{NT}, λ^F, λ^W), are set at values commonly found in Smets and Wouters (2003 and 2007). Their estimated values also closely resemble those found in the literature. However, the estimated probability of not resetting prices, θ^{NT}, and the partial indexation parameter, λ^{NT}, are higher in the nontradable sector than the tradable and imported goods sectors. This indicates a higher level of nominal rigidity in the nontradable goods sector.

Table 2

estimated parameters

Parameters	Prior			Posterior	
	func.	mean	std.	mean	90% int.
Preferences, frictions and fiscal policy					
ϑ^g,degree of substitutability	U	0.0	0.866	-0.557	(-1.5,0.473)
χ^H,public good share of tradable	G	0.05	0.01	0.060	(0.040,0.079)
χ^{NT},public good share of nontradable	G	0.05	0.01	0.059	(0.039,0.078)
h, habit	B	0.5	0.1	0.927	(0.897,0.957)
κ,inverse Frisch	G	2.0	0.5	2.514	(1.663,3.343)
ψ, risk elast.	IG	0.01	0.5	0.004	(0.002,0.005)
ϕ, capital utilization	B	0.5	0.1	0.117	(0.074,0.161)
v_i, invest.adjustment cost	G	2.0	0.25	3.859	(3.348,4.365)
ζ^H,substitution. elast.	G	1.5	0.25	1.457	(1.069,1.843)
ζ,substitution. elast.	G	1.5	0.25	1.734	(1.426,2.034)
ζ^*,substitution. elast.	G	1.5	0.25	1.332	(0.969,1.689)
θ^H,Calvo tradables price	B	0.5	0.05	0.855	(0.828,0.884)
θ^{NT},Calvo nontradables price	B	0.5	0.05	0.874	(0.851,0.897)
θ^F,Calvo import price	B	0.5	0.05	0.485	(0.407,0.562)
θ^W,Calvo wage	B	0.5	0.05	0.628	(0.566,0.694)
λ^H,Index. tradables price	B	0.5	0.1	0.329	(0.184,0.469)
λ^{NT},Index. nontradables price	B	0.5	0.1	0.416	(0.248,0.584)
λ^F,Index. import price	B	0.5	0.1	0.368	(0.220,0.517)
λ^W, Index. wage	B	0.5	0.1	0.487	(0.333,0.644)
γ^{W^g},public wage to debt	G	0.20	0.05	0.085	(0.044,0.123)
$\gamma^{W^{NT}}$,public wage to nontradables wage	G	0.15	0.10	0.066	(0.010,0.120)
γ^{W^H},public wage to tradables wage	G	0.15	0.10	0.068	(0.015,0.118)
γ^{cg},govt consumption to debt	G	0.20	0.05	0.113	(0.065,0.159)
γ^K,capital tax to debt	G	0.20	0.05	0.028	(0.013,0.044)
γ^L,labor tax to debt	G	0.20	0.05	0.037	(0.024,0.051)
γ^C,consumption tax to debt	G	0.20	0.05	0.217	(0.130,0.303)

Table 2 Estimated Parameters (cont'd)

Parameters	Prior			Posterior	
	func.	mean	std.	mean	90% int
Serial correlation in disturbances					
ρ^{a}, technology	B	0.5	0.1	0.442	(0.300,0.583)
ρ^{rp}, risk	B	0.5	0.1	0.657	(0.583,0.730)
$\rho^{i,H}$,tradables investment	B	0.5	0.1	0.328	(0.205,0.447)
$\rho^{i,NT}$,nontradables investment	B	0.5	0.1	0.297	(0.183,0.410)
ρ^{b},preference	B	0.5	0.1	0.275	(0.179,0.369)
ρ^{L},labor supply	B	0.5	0.1	0.270	(0.166,0.371)
$\rho^{X,H}$,tradables productivity	B	0.5	0.1	0.520	(0.426,0.615)
$\rho^{X,NT}$,nontradables productivity	B	0.5	0.1	0.539	(0.454,0.626)
$\rho^{p,H}$,tradables markup	B	0.5	0.1	0.320	(0.205,0.438)
$\rho^{p,NT}$,nontradables markup	B	0.5	0.1	0.367	(0.248,0.489)
$\rho^{p,F}$, importer markup	B	0.5	0.1	0.337	(0.210,0.464)
Serial correlation in fiscal rules					
ρ^{W^g},public wage	B	0.5	0.1	0.690	(0.543,0.841)
ρ^{cg},govt consumption	B	0.5	0.1	0.667	(0.528,0.806)
ρ^{L},labor tax	B	0.5	0.1	0.608	(0.484,0.734)
ρ^{K},capital tax	B	0.5	0.1	0.571	(0.433,0.711)
ρ^{C},consumption tax	B	0.5	0.1	0.779	(0.696,0.863)
ρ^{Z},govt transfers	B	0.5	0.1	0.506	(0.339,0.672)
Standard deviation in disturbances					
σ^{a}, technology	IG	0.1	0.5	0.014	(0.012,0.017)
σ^{rp}, risk	IG	0.1	0.5	0.019	(0.015,0.023)
$\sigma^{i,H}$,tradables investment	IG	0.1	0.5	0.050	(0.040,0.059)
$\sigma^{i,NT}$,nontradables investment	IG	0.1	0.5	0.061	(0.050,0.071)
σ^{b},preference	IG	0.1	0.5	0.017	(0.013,0.021)
σ^{L},labor supply	IG	0.1	0.5	0.013	(0.011,0.015)
$\sigma^{X,H}$,tradables productivity	IG	0.1	0.5	0.368	(0.316,0.417)
$\sigma^{X,NT}$,nontradables productivity	IG	0.1	0.5	0.377	(0.322,0.429)
$\sigma^{p,H}$,tradables markup	IG	0.1	0.5	0.031	(0.025,0.037)
$\sigma^{p,NT}$,nontradables markup	IG	0.1	0.5	0.018	(0.015,0.021)
$\sigma^{p,F}$, importer markup	IG	0.1	0.5	0.163	(0.120,0.204)
σ^{μ^y},final goods markup	IG	0.1	0.5	0.121	(0.105,0.136)
σ^{wg},public wage	IG	0.1	0.5	0.017	(0.014,0.020)
σ^{cg},govt consumption	IG	0.1	0.5	0.022	(0.019,0.025)
σ^{τ^K},capital tax	IG	0.1	0.5	0.021	(0.018,0.024)
σ^{τ^C},consumption tax	IG	0.1	0.5	0.356	(0.259,0.447)
σ^{τ^L},labor tax	IG	0.1	0.5	0.015	(0.013,0.017)
σ^{z},govt transfers	IG	0.1	0.5	0.069	(0.025,0.110)

Notes: B stands for beta distribution, N for normal distribution,G stands for gamma, IG stands for inverse gamma and U stands for uniform distribution. The posterier is generated with five chains consisting of 500,000 draws each (with the first 100,000 draws being discarded each chain). The log data density is -4632.732285.

4 Quantitative results

Following Sims and Wolff (2018a, 2018b), we compute state-dependent tax and spending multipliers. In general, a nonlinear solution is required to make initial condition matter for impulse response functions. To examine the state-dependence of fiscal multipliers, we solve the model at a second order approximation and compute state-dependent fiscal multipliers through simulations starting from a possible matrix of states. The calibrated structural parameters are set equal to their values reported in TABLE 1, while the estimated parameters are set equal to their posterior means as reported in TABLE 2.

4.1 State-dependent multipliers

We compute fiscal multipliers as nonlinear impulse responses to a specific fiscal shock. We work as follows. Initially, we solve numerically the model via a second order perturbation method in order to simulate the initial state matrix, $\mathcal{S}_{t-1}$. Specifically, we simulate the model 1100 times starting from the non-stochastic steady state. We drop the first 100 simulated state vectors as a burn-in the remaining 1000 simulated series constitute the initial state matrix for computing impulse response functions. The size of the initial state matrix is equal to the number of predetermined variables times the number of simulations.

We start by perturbing the model focusing on the vector of aggregate shocks, $\left\{\varepsilon_t^a, \varepsilon_t^b, \varepsilon_t^L, \mu_t^y, \widetilde{\phi}_t\right\}$, namely, shocks to technology, preference, labor supply, price mark-up and sovereign premium, respectively.[10] This reduces overall uncertainty and facilitates the interpretation of our results. Moreover, all fiscal shocks are muted off to avoid the possibility that all state dependent properties of the fiscal multipliers are due to fiscal shocks themselves. It also has the advantage that the same initial states will be used as initial condition in computations of all fiscal shocks. Then, we compute the impulse responses again via numerical simulations. Specifically, the impulse response function at horizon h of the vector of endogenous variables of the model, $\mathcal{Y}_t$, with respect to a fiscal shock $\epsilon_t^{\mathcal{X}}$ is defined as:

$$IRF_{\epsilon^{\mathcal{X}}}(h) = \{E_t \mathcal{Y}_{t+h} - E_{t-1}\mathcal{Y}_{t+h} \mid \mathcal{S}_{t-1}, \epsilon_t^{\mathcal{X}} = \pm 1\}, \ h \geq 0 \tag{32}$$

The procedure is as follows. We solve the model via a second order perturbation conditional on each of the 1000 initial state vectors, namely, $\mathcal{S}_{t-1}$. Conditional on each initial state vector, we simulate the model by drawing random numbers for the aggregate shocks from their posterior distribution up to horizon h. We repeat this process for $N = 150$ times, then take the average to compute $E_{t-1}\mathcal{Y}_{t+h} \mid \mathcal{S}_{t-1}$ for h quarters. Subsequently, we repeat the same process for each initial state vector but we also switch on a specific fiscal shock. The size of the fiscal shock is normalized to 1 and -1 standard deviation for government spending and tax instruments, respectively. This process is again repeated 150 times and averaged to compute, $E_{t-1}\mathcal{Y}_{t+h} \mid \mathcal{S}_{t-1}, \epsilon_t^{\mathcal{X}} = \pm 1$. The nonlinear impulse response function is thus the difference between the two simulated series for each initial state vector. Consequently, we are able to get a vector of 1000 impulse responses for each variable in the model for h quarters.

Following Sims and Wolff (2018a), we define the multiplier, $FM^{\mathcal{Y}}$,of any endogenous variable in the vector, $\mathcal{Y}$, as the ratio of the impulse respones of this variable with respect to the associated

[10] In the Appendix, we also examine sectoral shocks divided into tradable and non-tradable sectors, $\left\{X_t^H, X_t^{NT}, \varepsilon_t^{i,H}, \varepsilon_t^{i,NT}, \varepsilon_t^{p,H}, \varepsilon_t^{p,NT}\right\}$, and rest of the world shocks $\left\{y_t^*, \pi_t^*, R_t^{L*}, \varepsilon_t^{p,F}\right\}$. This classification reduces overall uncertainty and facilitates the interpretation of our findings. Furthermore, it enables us to examine how various exogenous shocks, which may propagate differently in a small open economy, affect the effectiveness of fiscal policy. In other words, we investigate whether the fiscal policy mix should vary depending on the nature of the shocks that impact the economy.

steady state response of fiscal spending/tax revenue. Specifically, we are interested in computing multipliers for domestic demand, y, GDP, y^{GDP}, and sectoral outputs ,$p^H y^H$ and $p^{NT} y^{NT}$ with respect to the following fiscal instruments, namely government spending, c^g, public wages, w^g, consumption, τ^C, labour, τ^L, and capital tax, τ^K. The vector of spending multipliers is given by:

$$FM_{\chi}^{\mathcal{Y}}(h) = \left(\frac{dy_{t+h}}{dG}, \frac{dy_{t+h}^{GDP}}{dG}, \frac{dp_{t+h}^{H} y_{t+h}^{H}}{dG}, \frac{dp_{t+h}^{NT} y_{t+h}^{NT}}{dG} \right) \mid \mathcal{S}_{t-1}, \epsilon_t^{\chi} = 1 \text{ for } \chi = \{c^g, w^g\}$$

while the vector of tax multipliers is given by:

$$FM_{\chi}^{\mathcal{Y}}(h) = -\left(\frac{dy_{t+h}}{dT}, \frac{dy_{t+h}^{GDP}}{dT}, \frac{dp_{t+h}^{H} y_{t+h}^{H}}{dT}, \frac{dp_{t+h}^{NT} y_{t+h}^{NT}}{dT} \right) \mid \mathcal{S}_{t-1}, \epsilon_t^{\chi} = -1 \text{ for } \chi = \left\{\tau^C, \tau^L, \tau^K\right\}$$

4.2 Aggregate multipliers

Table 3 presents domestic demand multipliers on impact for each fiscal instrument, while Figure 2a plots the respective histograms of the distributions for each fiscal instrument. [11] Using the mean values in column 1 of Table 3 for each fiscal instrument, we can see that spending multipliers are generally two to three times larger than tax multipliers. Specifically, government consumption generates the largest domestic demand multiplier, equal to 1.28, followed by the public wage multiplier, which increases domestic demand by 0.86. Regarding tax multipliers, the larger increase in domestic demand is achieved by cutting the relatively more distortionary taxes, i.e., capital and labor taxes, which yield domestic demand multipliers of 0.42 and 0.38, respectively. The smaller impact multiplier is generated by cutting consumption tax, and it is equal to 0.34.

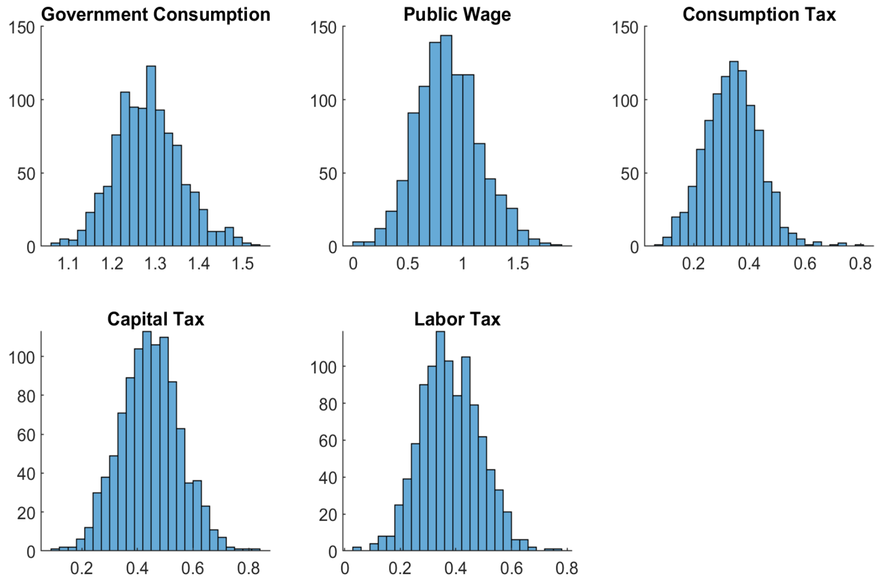
Table 3
Domestic demand multiplier

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	1.2826	0.0757	1.0709	1.5311	16.9373
w^g	0.8664	0.2863	0.0053	1.8410	3.0259
τ^C	0.3384	0.0980	0.0717	0.8072	3.4532
τ^K	0.4458	0.1069	0.1031	0.8379	4.1695
τ^L	0.3797	0.1059	0.0442	0.7527	3.5850

Columns 2 to 5 of Table 3 present some interesting statistics from the respective distributions for each fiscal instrument. For example, Table 3 indicates that government spending not only generates the largest multiplier, but also this value is the least dispersed across states, i.e., it has the smallest standard deviation (see column 2). This can also be seen by comparing the distributions in Figure 2a and their fitted normal density functions in Figure 2b. This essentially means that government spending would yield a relatively larger multiplier irrespective of the state of the economy. On the other hand, the respective distribution of the public wage multiplier is the most dispersed. This implies that the public wage multiplier would be larger only in some states (good states) of the economy while it could be very low in other states (bad states). The dispersion of tax multipliers is very close to each other and in between the two spending multipliers.

[11] In Appendix C, we compute the respective Tables and Figures for GDP multipliers.

Figure 2a:histograms of domestic demand multipliers

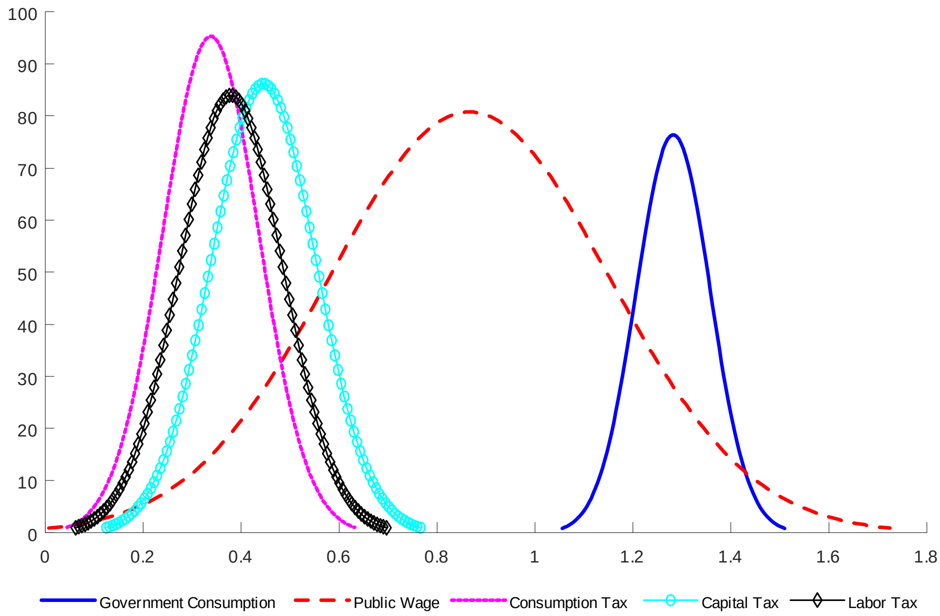


Notes: The x-axis measures the size of domestic demand multiplier.

To rank fiscal multipliers taking into account both statistics, i.e., the mean and the dispersion around the mean. In column [5] of Table 3, we compute the standardized mean by dividing the mean by the standard deviation. The results are clear-cut, with government consumption being the most efficient fiscal instrument across states, followed by capital, labor, and consumption tax. Public wage is the least efficient fiscal instrument.[12]

[12] Note that the numerical value of the standardized mean does not have an economic interpretation like the mean and should only be used for relative comparison across fiscal instruments.

Figure 2b: Fitted normal density functions of domestic demand multipliers



Notes: As in Figure 2A.

4.3 Sectoral multipliers

We will now focus on sectoral output multipliers, specifically, tradable and non-tradable output. Table 4 and Table 5 present impact tradable and non-tradable output multipliers, respectively, for each fiscal instrument. Figure 3A plots the histograms of tradable (blue bars) and non-tradable (red bars) output multipliers for each fiscal policy instrument. Comparing columns [1] of Table 4 and Table 5 illustrates that the mean multiplier is always higher in the non-tradable sector than in the tradable sector. Additionally, Figure 3b shows that the distributions of non-tradable output multipliers are to the right of the respective distributions of tradable output multipliers, indicating that non-tradable multipliers are higher than tradable ones across states and fiscal instruments.

Table 4
fiscal multiplier on tradable output

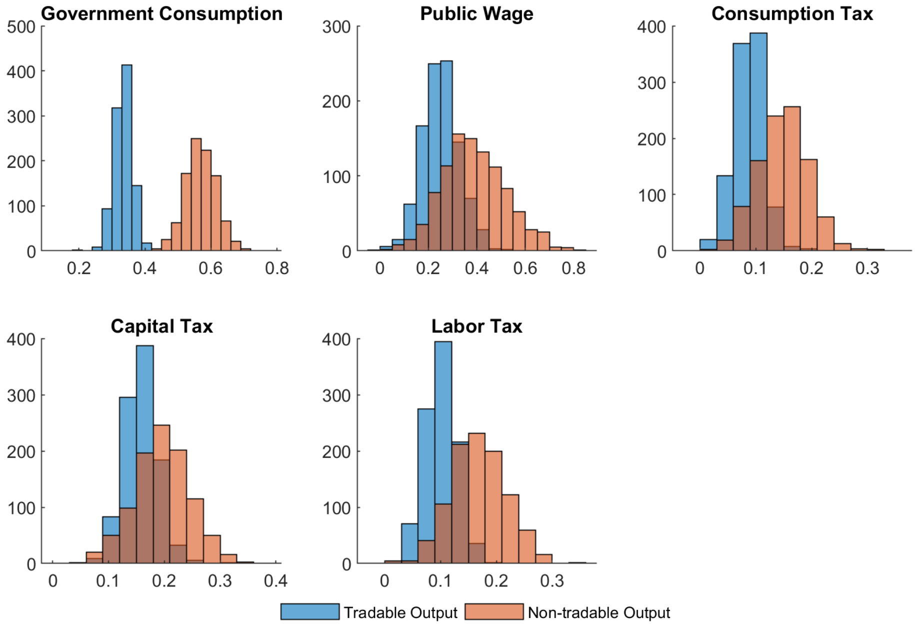
	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.3332	0.0281	0.1296	0.4178	11.8754
w^g	0.2519	0.0764	0.0184	0.5181	3.2951
τ^C	0.0869	0.0269	-0.0165	0.2079	3.2256
τ^K	0.1588	0.0308	0.0581	0.3236	5.1562
τ^L	0.1011	0.0286	-0.0166	0.2034	3.5382

Column [1] of Table 4 quantifies the size of fiscal multipliers in the tradable sector. Specifically, government consumption generates the largest multiplier equal to 0.33, followed by the public wage multiplier, 0.26, capital tax, 0.15, labour tax, 0.1, and the smallest impact multiplier is generated via cutting consumption tax, which is equal to 0.09. Column [1] of Table 5 quantifies the size of fiscal multipliers in the non-tradable sector. Specifically, government consumption generates the largest multiplier equal to 0.57, followed by the public wage multiplier, 0.39, capital tax, 0.19, labour tax, 0.17, and the smallest impact multiplier is generated via cutting consumption tax, which is equal to 0.15.

Table 5
fiscal multiplier on non-tradable output

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.5689	0.0474	0.3709	0.7520	12.0025
w^g	0.3888	0.1308	-0.0057	0.8114	2.9728
τ^C	0.1493	0.0455	0.023	0.3599	3.2798
τ^K	0.1959	0.0503	0.0149	0.3729	3.8961
τ^L	0.1683	0.0498	-0.0037	0.3383	3.3781

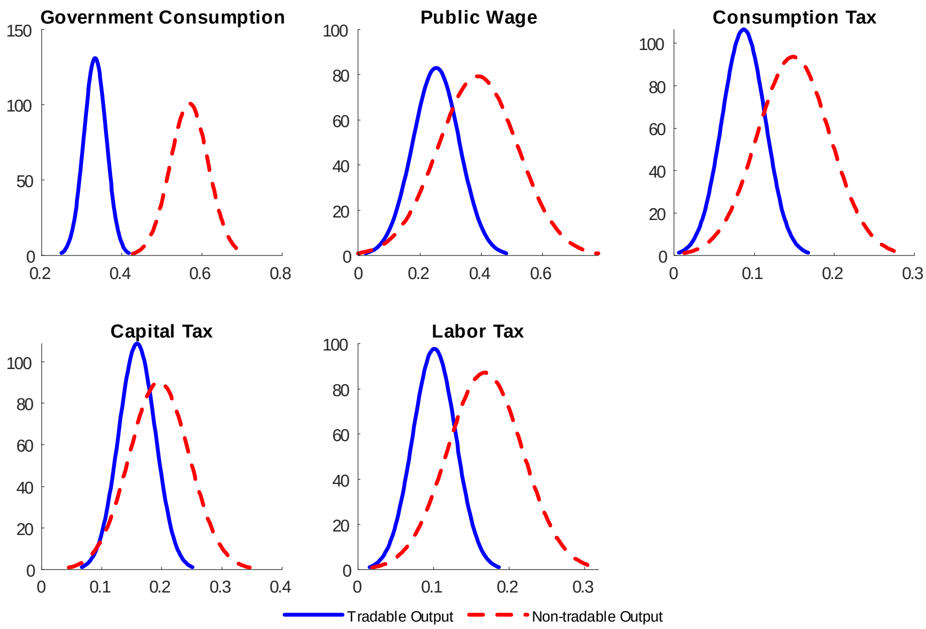
Figure 3a: histograms of sectoral multipliers



Notes: As in Figure 2A.

Another interesting finding is that the distributions of non-tradable output multipliers are more dispersed than the respective distributions of tradable output multipliers. This can be observed by comparing columns [2] of Tables 5 with 4 and/or the distributions in Figure 3b. Following the same logic as before, in column [5] of Table 4 and Table 5, we compute the standardized mean multipliers. The results are similar to the domestic demand multiplier.

Figure 3b: fitted normal density functions of the histograms of tradable and non-tradable output multipliers to fiscal instruments.



Notes: As in Figure 2A.

4.4 Public debt and the fiscal multiplier

In this section, we further investigate the relationship between public debt and the size of fiscal multipliers. Specifically, section 4.4.1 focuses on how public debt affects the size of the aggregate fiscal multiplier and discusses the underlying mechanisms. Section 4.4.2 decomposes the effect on the two sectors of the small open economy, while in section 4.4.3 we compute a metric that can be used in this class of models to assess whether fiscal stimulus would be effective.

4.4.1 Public debt and the size of aggregate multiplier

In our small open economy setup, public debt can influence the small open economy economy via at least three channels. We start by explaining these channels, namely the direct fiscal policy channel, the relative prices channel and the sovereign premium channel. The direct fiscal policy channel operates via the fiscal rules and the government budget constraint. Specifically, higher public debt introduces an endogenous feedback on the current and future paths of fiscal policy instruments via the fiscal rules (see equations 23-27). Consequently, the change in the path of fiscal policy instruments impacts the optimal economic decisions of agents, such as individual choices between savings-consumption and hours worked-leisure, thus affecting the macroeconomic equilibrium outcome.

In addition to this effect, there is an impact through relative prices which in our open economy setup is enriched by the international trade with respect to the RoW, i.e., the real exchange rate, and the two sectors, i.e., the relative prices of tradable vis-à-vis the non tradable goods. Changes in current and future fiscal policy would change these relative prices and eventually influence the allocations of resources between the tradable and non-tradable sector, as well as between the small open economy and the rest of the world.

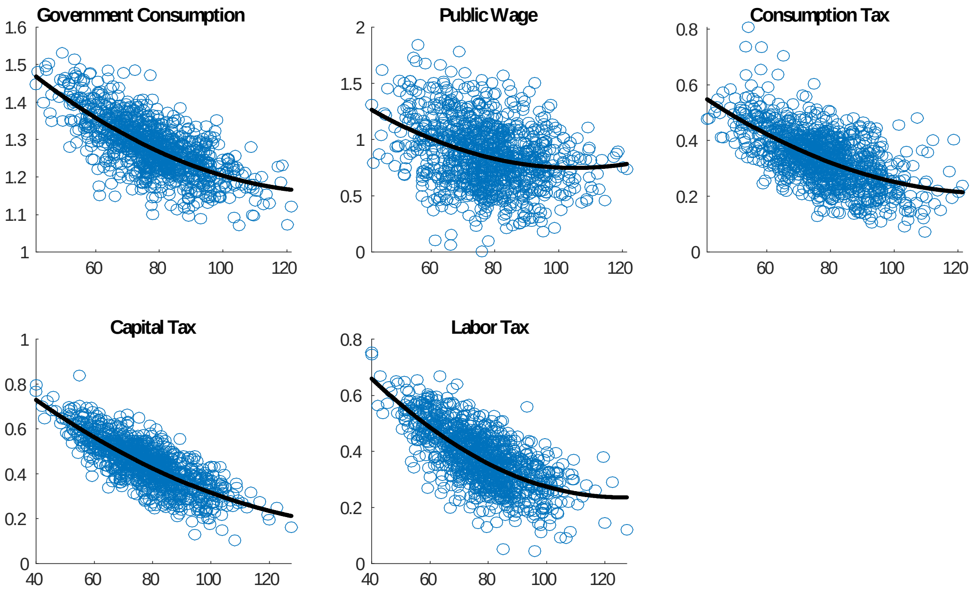
Finally, higher public debt would affect the small open economy via the sovereign premium channel (see equation 30). *Ceteris paribus*, higher public debt would raise the international borrowing cost of domestic agents i.e.,households and government, from the international financial markets. Due to these rather rich mechanisms, our small open economy model could serves a well-equipped tool to assess the endogenous relationship between public debt and the size of fiscal multipliers.

In Figure 4a, we plot the impact fiscal multiplier of an aggregate indicator, namely, total domestic demand, on the y-axis against the public debt-to-output ratio on the x-axis.[13] We do this for each of the five fiscal instruments. Each point in the scatter plot corresponds to a draw from the initial states vectors. The black solid line is a fitted second order polynomial curve that best fits the data plotted in the scatter plot. Upon visual inspection of this figure, it becomes apparent that states with a relatively higher public debt will have a relatively lower fiscal multiplier. In other words, our model generates multipliers displaying a negative relationship between public debt and the size of fiscal multipliers.

Figure 4b collects the fitted curves (i.e., black solid lines of Figure 4a) of spending (left panel) and tax (right panel) instruments, respectively. The tax fitted curves are steeper than the corresponding spending ones, indicating that a higher public debt would diminish the positive effects of tax cuts relatively more than it would erode the positive effects of spending increases. Thus, fiscal stimulus via spending seems relatively more effective, compared to other fiscal instruments, in states of high public debt. Focusing on the taxes (right panel), the capital tax rate has the steepest fitted curve, indicating a greater reduction in the multiplier in states with higher public debt. The labor tax has a relatively flatter curve, while the consumption tax has the flattest among all tax instruments. Interestingly, if we focus on states with higher public debt the ranking of tax multipliers reverses (see Figure 4B for public debt to output higher than 120%).

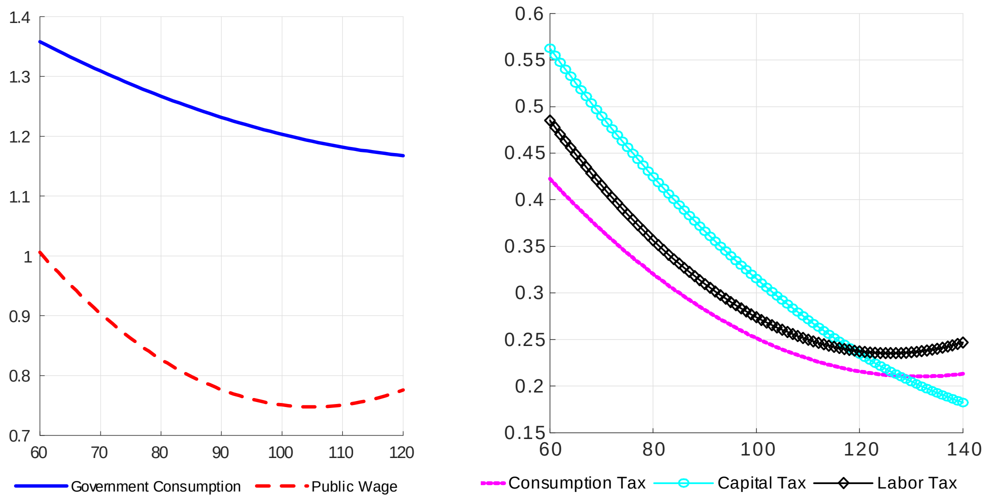
[13] In the Appendix, we present the analogous graph with domestic GDP on the y-axis. The main message remains identical.

FIGURE 4A:FISCAL MULTIPLIERS OF DOMESTIC DEMAND VERSUS PUBLIC DEBT



NOTES: Horizontal axis, public debt to domestic demand ratio ×100; Vertical axis, size of fiscal multipliers.

Figure 4b: fiscal multipliers of domestic demand versus public debt (polynomial fitted curves)



4.4.2 Public debt and the size of sectoral multipliers

Figures 5a and 5b (and Figure 6a and 6b) are analogous to Figure 4a and 4b, but for sectoral outputs. That is, we plot the fiscal multiplier of tradable and non-tradable output on the y-axis against the public debt-to-output ratio on the x-axis, respectively. The negative relationship between the fiscal multiplier and public debt remains for sectoral outputs as well. Perhaps a more interesting finding is that for spending instruments, the fitted curves are steeper in the tradable sector with respect to the respective curves of the non-tradable sector. Using spending stimulus not only has a larger impact on the non-tradable sector of the economy (vis-à-vis the tradable sector), but also this impact is more resilient in states of high public debt (compared to the resilience of the impact in the tradable sector). On the other hand, for tax instruments, the fitted curves are steeper in the non-tradable sector than in the tradable sector. This implies that the positive effect of tax cuts reduces more in states of high public debt in the non-tradable sector than in the tradable sector.

Figure 5a: fiscal multipliers of tradable output versus public debt

Notes: Horizontal axis: public debt to domestic demand ratio $\times 100$; Vertical axis: size of fiscal multipliers.

Figure 5b: fiscal multipliers of tradable output versus public debt (polynomial fitted curves)

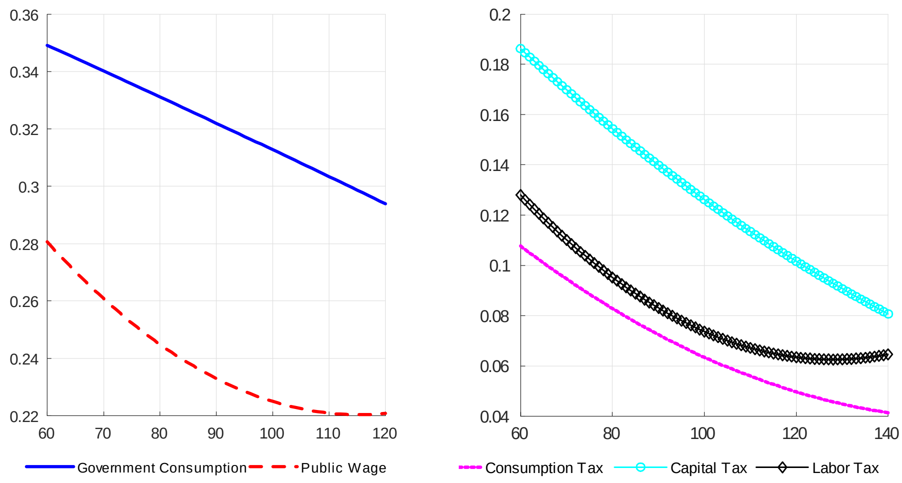
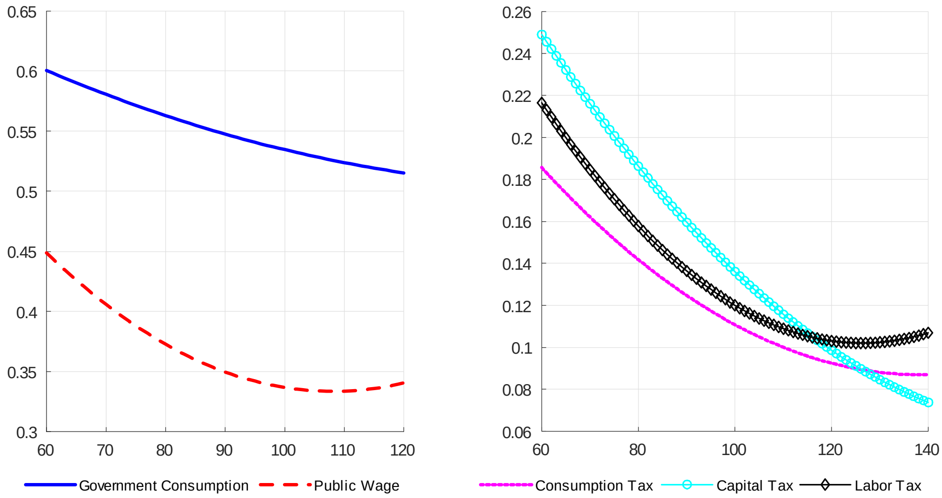


Figure 6a: fiscal multipliers of non-tradable output versus public debt

Notes: Horizontal axis: public debt to domestic demand ratio $\times 100$; Vertical axis: size of fiscal multipliers.

Figure 6b: fiscal multipliers of non-tradable output versus public debt (polynomial fitted curves)



4.4.3 Probability of effective fiscal stimulus conditional on the level of public debt

Fiscal policymakers are often interested whether at a particular period a fiscal stimulus policy would be effective. Our methodology allows us to compute a useful metric which can answer this question. Specifically, we compute the probability of each fiscal multiplier being higher than a fiscal policy target, say the associated mean of the distribution, conditional on the economy being in a state where public debt is higher or lower than a certain threshold value, say 90%.[14]

Tables 6 presents these probabilities when the economy is in a high (low) public debt state, i.e., whether public debt to output ratio is higher (lower) than the 90% threshold. The respective probabilities are presented in the second and third columns, respectively, while each row corresponds to one fiscal instrument.

As can be seen in the first columns of these tables, the probability of a multiplier being higher than the mean, conditional on the public debt-to-output ratio being lower than 90%, is quite high, and more than half in all cases. In contrast, the probability of a multiplier being higher than the mean, conditional on the debt-to-output ratio being above 90%, is much smaller. The policy message from these results is that fiscal stimulus is more likely to be effective independently on the instrument used when public finances are in a good state of the economy. However, it is much less likely for a fiscal stimulus to be effective in a state of weak public finances. But, the most likely instruments to work on impact are public wages, consumption and labour taxes.

[14]This is an ad hoc threshold, however, it is in accordance with Reinhart and Rogoff (2010) who find a negative relation emerges between public debt and macroeconomic outcomes when public debt to output ratio exceeds a threshold of 90%. It is also in accordance with the average public debt ratios in the era of Euro Area.

Table 6

Probability of an effective domestic demand fiscal stimulus

Fiscal instrument	Low public debt state	High debt state
Government consumption (c^g)	56.69%	11.80%
Public wage (w^g)	50.85%	32.58%
Consumption tax $\left(\tau^C\right)$	57.30%	19.10%
Capital tax $\left(\tau^K\right)$	58.37%	5.49%
Labour tax $\left(\tau^L\right)$	55.50%	9.76%

4.5 Conclusions

Our analysis suggests that spending multipliers are higher than tax multipliers across states in a small open economy model, which is a member of a monetary union. More importantly, fiscal stimulus predominantly benefits the non-tradable sector of an open economy compared to the tradable sector. Although fiscal stimulus has an aggregate output effect, our analysis also sheds light on the compositional effect, i.e., tradable vis-à-vis non-tradable sectors. In an open economy, fiscal stimulus is more likely to crowd out the tradable sector while crowding in the non-tradable sector by affecting its international competitiveness.

Furthermore, our analysis implies a steady, non-linear negative relation between public debt and the fiscal multiplier, with spending instruments exhibiting a less steep decline compared to tax instruments against states of higher public debt. This suggests that spending measures are more effective in mitigating economic downturns, particularly during periods of fiscal stress, by stimulating the non-tradable sector.

In this paper, we have focused on how the size of fiscal multipliers varies with the state of the economy, and specifically, the state of public finances by setting the estimated structural parameters of the model equal to their posterior means. However, it would be interesting to study the interplay of state uncertainty with another important source of fiscal multiplier uncertainty, namely, uncertainty in parameter values related to the underlying structure of the economy. We leave these as future work.

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A The Equilibrium System

We will focus on a stationary equilibrium with variables written in real terms. Let small letters to represent real detrended terms of variables. Since the economy features a permanent labour augmenting aggregate world technology shock, A_t, to induce stationarity we detrend the following real variables: $c_t^{\star R} = \frac{C_t^{\star R}}{A_t}$, $c_t^R = \frac{C_t^R}{A_t}$, $c_t^{NR} = \frac{C_t^{NR}}{A_t}$, $\bar{k}_t^H = \frac{\bar{K}_t^H}{A_t}$, $\bar{k}_t^{NT} = \frac{\bar{K}_t^{NT}}{A_t}$, $k_t^H = \frac{K_t^H}{A_t}$, $k_t^{NT} = \frac{K_t^{NT}}{A_t}$, $i_t^H = \frac{I_t^H}{A_t}$, $i_t^{NT} = \frac{I_t^{NT}}{A_t}$, $y_t^{GDP} = \frac{Y_t^{GDP}}{A_t}$, $y_t = \frac{Y_t}{A_t}$, $y_t^T = \frac{Y_t^T}{A_t}$, $y_t^{NT} = \frac{Y_t^{NT}}{A_t}$, $y_t^F = \frac{Y_t^F}{A_t}$, $y_t^H = \frac{Y_t^H}{A_t}$, $y_t^{H,d} = \frac{Y_t^{H,d}}{A_t}$, $y_t^{H,*} = \frac{Y_t^{H,*}}{A_t}$, $y_t^* = \frac{Y_t^*}{A_t}$, $y_t^g = \frac{Y_t^g}{A_t}$, $g_t = \frac{G_t}{A_t}$, $c_t^g = \frac{C_t^g}{A_t}$, $\tau_t = \frac{T_t}{P_t A_t}$, $z_t = \frac{Z_t}{A_t}$; We also define $\Lambda_t = \frac{\lambda_t}{P_t A_t}$, $b_t = \frac{P_t^L B_t}{P_t A_t}$, $f_t = \frac{P_t^{L*} F_t}{P_t^* A_t}$, $f_t^* = \frac{P_t^{L*} F_t^*}{P_t^* A_t}$, $w_t = \frac{W_t}{P_t A_t}$, $\tilde{w}_t = \frac{\tilde{W}_t}{P_t A_t}$, $w_t^H = \frac{W_t^H}{P_t A_t}$, $w_t^{NT} = \frac{W_t^{NT}}{P_t A_t}$, $w_t^g = \frac{W_t^g}{P_t A_t}$. We re-express nominal marginal costs to their real terms, $mc_t^H = \frac{MC_t^H}{P_t}$, $mc_t^{NT} = \frac{MC_t^{NT}}{P_t}$, and nominal prices in terms of relative prices or inflation rates: $p_t^T = \frac{P_t^T}{P_t}$, $p_t^F = \frac{P_t^F}{P_t}$, $p_t^* = \frac{P_t^*}{P_t}$, $p_t^H = \frac{P_t^H}{P_t}$, $p_t^{NT} = \frac{P_t^{NT}}{P_t}$, $\tilde{p}_t^H = \frac{\tilde{P}_t^H}{P_t^H}$, $\tilde{p}_t^{NT} = \frac{\tilde{P}_t^{NT}}{P_t^{NT}}$, $\tilde{p}_t^F = \frac{\tilde{P}_t^F}{P_t^F}$, $\pi_t = \frac{P_t}{P_{t-1}}$, $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$, $\pi_t^{NT} = \frac{P_t^{NT}}{P_{t-1}^{NT}}$, $\pi_t^* = \frac{P_t^*}{P_{t-1}^*}$, $\epsilon_t = \frac{S_t}{S_{t-1}}$ and $RER_t = \frac{S_t P_t^*}{P_t}$.

The equilibrium system consists of the following equations:

- The FOC w.r.t. consumption:

$$\lambda_t \left(1 + \tau_t^C\right) = \frac{\varepsilon_t^b}{c_t^{\star R} - \frac{h}{e^\gamma} c_{t-1}^{\star R} e^{-\varepsilon_t^a}} \tag{A.1}$$

- Definition of $c_t^{\star R}$:

$$c_t^{\star R} = c_t^R + \vartheta^g y_t^g \tag{A.2}$$

- The stochastic discount factor:

$$\mathbb{E}_t M_{t,t+1} = \mathbb{E}_t \left(\frac{\beta}{e^\gamma} e^{-\varepsilon_{t+1}^a} \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \right) \tag{A.3}$$

- The FOC w.r.t. long-term domestic bond:

$$\mathbb{E}_t \left(\frac{\beta}{e^\gamma} e^{-\varepsilon_{t+1}^a} \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \frac{R_t^L - \rho}{R_{t+1}^L - \rho} R_{t+1}^L \right) = 1 \tag{A.4}$$

- The uncovered interest rate parity condition:

$$\mathbb{E}_t \left(\frac{\beta}{e^\gamma} e^{-\varepsilon_{t+1}^a} \frac{\lambda_{t+1}}{\lambda_t} \frac{1}{\pi_{t+1}} \right) \left[\frac{R_t^L - \rho}{R_{t+1}^L - \rho} R_{t+1}^L - \frac{R_t^{L*} - \rho^*}{R_{t+1}^{L*} - \rho^*} R_{t+1}^{L*} \Phi\left(\cdot\right) \epsilon_{t+1} \right] = 0 \tag{A.5}$$

where

$$\Phi\left(\cdot\right) = \left[1 + \psi \left(e^{(a_t - \bar{a})} - 1\right)\right] e^{\tilde{\phi}_t} \tag{A.6}$$

and

$$a_t \equiv \frac{RER_t \left(f_t^* - f_t\right)}{y_t^{GDP}} \tag{A.7}$$

- Ricardian Household's FOC w.r.t. capital for traded sector:

$$q_t^H = \mathbb{E}_t \left\{ \left(\frac{\beta}{e^\gamma} e^{-\varepsilon_{t+1}^a} \frac{\lambda_{t+1}}{\lambda_t} \right) \left[\left(1 - \tau_{t+1}^K\right) r_{t+1}^{k,H} u_{t+1}^H - \eta \left(u_{t+1}^H\right) + (1 - \delta) q_{t+1}^H \right] \right\} \tag{A.8}$$

- Ricardian Household's FOC w.r.t. capital for non-traded sector:

$$q_t^{NT} = \mathbb{E}_t \left\{ \left(\frac{\beta}{e^\gamma} e^{-\varepsilon_{t+1}^a} \frac{\lambda_{t+1}}{\lambda_t} \right) \left[\left(1 - \tau_{t+1}^K\right) r_{t+1}^{k,NT} u_{t+1}^{NT} - \eta \left(u_{t+1}^{NT}\right) + (1 - \delta) q_{t+1}^{NT} \right] \right\} \tag{A.9}$$

- Ricardian Household's FOC w.r.t. investment for traded sector:

$$\begin{aligned} & 1 - q_t^H \varepsilon_t^{i,H} \left\{ 1 - \frac{v_i}{2} \left(\frac{i_t^H e^{\varepsilon_t^a}}{i_{t-1}^H} - 1 \right)^2 - v_i \left(\frac{i_t^H e^{\varepsilon_t^a}}{i_{t-1}^H} - 1 \right) \frac{i_t^H e^{\varepsilon_t^a}}{i_{t-1}^H} \right\} \\ = \quad & \mathbb{E}_t \left\{ e^\gamma \left(\frac{\beta}{e^\gamma} \frac{\lambda_{t+1}}{\lambda_t} e^{-\varepsilon_{t+1}^a} \right) q_{t+1}^H \varepsilon_{t+1}^{i,H} \left[v_i \left(\frac{i_{t+1}^H e^{\varepsilon_{t+1}^a}}{i_t^H} - 1 \right) \right] \left(\frac{i_{t+1}^H e^{\varepsilon_{t+1}^a}}{i_t^H} \right)^2 \right\} \end{aligned} \tag{A.10}$$

- Ricardian Household's FOC w.r.t. investment for non-traded sector

$$\begin{aligned} & 1 - q_t^{NT} \varepsilon_t^{i,NT} \left\{ 1 - \frac{v_i}{2} \left(\frac{i_t^{NT} e^{\varepsilon_t^a}}{i_{t-1}^{NT}} - 1 \right)^2 - v_i \left(\frac{i_t^{NT} e^{\varepsilon_t^a}}{i_{t-1}^{NT}} - 1 \right) \frac{i_t^{NT} e^{\varepsilon_t^a}}{i_{t-1}^{NT}} \right\} \\ = \quad & \mathbb{E}_t \left\{ e^\gamma \left(\frac{\beta}{e^\gamma} \frac{\lambda_{t+1}}{\lambda_t} e^{-\varepsilon_{t+1}^a} \right) q_{t+1}^{NT} \varepsilon_{t+1}^{i,NT} \left[v_i \left(\frac{i_{t+1}^{NT} e^{\varepsilon_{t+1}^a}}{i_t^{NT}} - 1 \right) \right] \left(\frac{i_{t+1}^{NT} e^{\varepsilon_{t+1}^a}}{i_t^{NT}} \right)^2 \right\} \end{aligned} \tag{A.11}$$

- FOC w.r.t. utilisation capacity for traded sector

$$\left(1 - \tau_t^K\right) r_t^{k,H} = \eta' \left(u_t^H\right) \tag{A.12}$$

- FOC w.r.t. utilisation capacity for non-traded sector

$$\left(1 - \tau_t^K\right) r_t^{k,NT} = \eta' \left(u_t^{NT}\right) \tag{A.13}$$

- The law of motion for capital for traded sector

$$\bar{k}_t^H = \left(\frac{1 - \delta}{e^\gamma} \right) \bar{k}_{t-1}^H e^{-\varepsilon_t^a} + \varepsilon_t^{i,H} \left[1 - \frac{v_i}{2} \left(\frac{i_t^H}{i_{t-1}^H} e^{\varepsilon_t^a} - 1 \right)^2 \right] i_t^H \tag{A.14}$$

- The law of motion for capital for non-traded sector

$$\bar{k}_t^{NT} = \left(\frac{1 - \delta}{e^\gamma} \right) \bar{k}_{t-1}^{NT} e^{-\varepsilon_t^a} + \varepsilon_t^{i,NT} \left[1 - \frac{v_i}{2} \left(\frac{i_t^{NT}}{i_{t-1}^{NT}} e^{\varepsilon_t^a} - 1 \right)^2 \right] i_t^{NT} \tag{A.15}$$

- Non-Ricardian households budget constraint

$$\left(1+\tau_t^C\right) c_t^{NR} = \left(1-\tau_t^L\right) w_t L_t + z_t \tag{A.16}$$

- Optimal wage set by the Ricardian household (we use the recursive form)

$$\tilde{w}_t\left(l\right)^{1+\varepsilon^W\kappa} = \frac{\varepsilon^W}{\varepsilon^W-1}\frac{w_t^N}{w_t^D} \tag{A.17}$$

$$w_t^N = \frac{1}{1-\tau_t^L}\varepsilon_t^W \varepsilon_t^b \varepsilon_t^L w_t^{\varepsilon^W(1+\kappa)} L_t^{1+\kappa} + \beta\theta^W \left(\frac{\pi_{t+1}e^{\varepsilon_{t+1}^a}}{\left(\pi_t e^{\varepsilon_t^a}\right)^{1-\lambda^W}\left(\pi\right)^{\lambda^W}}\right)^{\varepsilon^W(1+\kappa)} \mathbb{E}_t w_{t+1}^N \tag{A.18}$$

$$w_t^D = \lambda_t \left(w_t\right)^{\varepsilon^W} L_t + \beta\theta^W \left(\frac{\pi_{t+1}e^{\varepsilon_{t+1}^a}}{\left(\pi_t e^{\varepsilon_t^a}\right)^{1-\lambda^W}\left(\pi\right)^{\lambda^W}}\right)^{\varepsilon^W-1} \mathbb{E}_t w_{t+1}^D \tag{A.19}$$

- Aggregate wage evolution:

$$w_t = \left[\left(1-\theta^W\right)\left(\tilde{w}_t\right)^{1-\varepsilon^W} + \theta^W\left(w_{t-1}\frac{\left(\pi_{t-1}e^{\varepsilon_{t-1}^a}\right)^{1-\lambda^W}\pi^{\lambda^W}}{e^{\varepsilon_t^a}\pi_t}\right)^{1-\varepsilon^W}\right]^{\frac{1}{1-\varepsilon^W}} \tag{A.20}$$

- Aggregate wage equation:

$$w_t = \left[\varphi^H\left(w_t^H\right)^{1-\mu^W} + \varphi^{NT}\left(w_t^{NT}\right)^{1-\mu^W} + \left(1-\varphi^H-\varphi^{NT}\right)\left(w_t^g\right)^{1-\mu^W}\right]^{\frac{1}{1-\mu^W}} \tag{A.21}$$

- Hours worked in the tradable sector:

$$L_t^H = \varphi^H\left(\frac{w_t^H}{w_t}\right)^{-\mu^W} L_t \tag{A.22}$$

- Hours worked in the non-tradable sector:

$$L_t^{NT} = \varphi^{NT}\left(\frac{w_t^{NT}}{w_t}\right)^{-\mu^W} L_t \tag{A.23}$$

- Public sector employment

$$L_t^g = \left(1-\varphi^H-\varphi^{NT}\right)\left(\frac{w_t^g}{w_t}\right)^{-\mu^W} L_t \tag{A.24}$$

- The production function of wholesale firms:

$$y_t = \left[\omega^{\frac{1}{\zeta}}\left(y_t^T\right)^{\frac{\zeta-1}{\zeta}} + (1-\omega)^{\frac{1}{\zeta}}\left(y_t^{NT}\right)^{\frac{\zeta-1}{\zeta}}\right]^{\frac{\zeta}{\zeta-1}} \tag{A.25}$$

- The optimal demand of traded and non-traded goods:

$$\frac{y_t^T}{y_t^{NT}} = \frac{\omega}{1-\omega}\left(\frac{p_t^T}{p_t^{NT}}\right)^{-\zeta} \tag{A.26}$$

- The price-setting equation:

$$1 = \mu_t^y\left[\omega\left(p_t^T\right)^{1-\zeta} + (1-\omega)\left(p_t^{NT}\right)^{1-\zeta}\right]^{\frac{1}{1-\zeta}} \tag{A.27}$$

- The production function of the composite tradable goods:

$$y_t^T = \left[\left(\omega^H\right)^{\frac{1}{\zeta^H}}\left(y_t^{H,d}\right)^{\frac{\zeta^H-1}{\zeta^H}} + \left(1-\omega^H\right)^{\frac{1}{\zeta^H}}\left(y_t^F\right)^{\frac{\zeta^H-1}{\zeta^H}}\right]^{\frac{\zeta^H}{\zeta^H-1}} \tag{A.28}$$

- The optimal demand of home traded and foreign goods:

$$\frac{y_t^{H,d}}{y_t^F} = \frac{\omega^H}{1-\omega^H}\left(\frac{p_t^H}{p_t^F}\right)^{-\zeta^H} \tag{A.29}$$

- The price index of the composite tradable good:

$$p_t^T = \left[\omega^H\left(p_t^H\right)^{1-\zeta^H} + \left(1-\omega^H\right)\left(p_t^F\right)^{1-\zeta^H}\right]^{\frac{1}{1-\zeta^H}} \tag{A.30}$$

- The marginal production cost for intermediated tradable goods:

$$mc_t^H = \frac{\left(r_t^{k,H}\right)^{a^H}\left(\left(1-\varsigma^P\right)w_t^H\right)^{1-a^H}\left(\frac{y_t^g}{y_t^H\Delta_t^H}\right)^{\frac{-\chi^H}{1-\chi^H}}}{\left(X_t^H\right)^{1-a^H}\left(a^H\right)^{a^H}\left(1-a^H\right)^{1-a^H}} \tag{A.31}$$

- The optimal capital-labour ratio:

$$\frac{u_t^H\frac{\bar{k}_{t-1}^H}{e^\gamma}e^{-\varepsilon_t^a}}{L_t^H} = \frac{a^H}{1-a^H}\frac{\left(1-\varsigma^P\right)w_t^H}{r_t^{k,H}} \tag{A.32}$$

- The production function:

$$y_t^H\Delta_t^H = \left[\left(u_t^H\frac{\bar{k}_{t-1}^H}{e^\gamma}e^{-\varepsilon_t^a}\right)^{a^H}\left(X_t^H L_t^H\right)^{1-a^H}\right]^{1-\chi^H}\left(y_t^g\right)^{\chi^H} \tag{A.33}$$

- The price-setting equation:

$$\tilde{p}_t^H = \frac{\epsilon^H}{\epsilon^H - 1} \frac{p_t^{N,H}}{p_t^{D,H}}. \tag{A.34}$$

$$p_t^{N,H} = \varepsilon_t^{p,H} mc_t^H \left(y_t^{H,d} + y_t^{H,*}\right) + \beta\theta^H \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_{t+1}^H}{\left(\pi_t^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H}}\right)^{\epsilon^H} \mathbb{E}_t p_{t+1}^{N,H} \tag{A.35}$$

$$p_t^{D,H} = p_t^H \left(y_t^{H,d} + y_t^{H,*}\right) + \beta\theta^H \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_{t+1}^H}{\left(\pi_t^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H}}\right)^{\epsilon^H - 1} \mathbb{E}_t p_{t+1}^{D,H} \tag{A.36}$$

- The evolution of the price level of tradables is:

$$1 = (1 - \theta^H) \left(\tilde{p}_t^H\right)^{1-\epsilon^H} + \theta^H \left[\frac{\left(\pi_{t-1}^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H}}{\pi_t^H}\right]^{1-\epsilon^H} \tag{A.37}$$

- The price dispersion index:

$$\Delta_t^H = (1 - \theta^H) \left(\tilde{p}_t^H\right)^{-\epsilon^H} + \theta^H \left[\frac{\left(\pi_{t-1}^H\right)^{\lambda^H} \left(\pi^H\right)^{1-\lambda^H}}{\pi_t^H}\right]^{-\epsilon^H} \Delta_{t-1}^H \tag{A.38}$$

- The marginal production cost for intermediated non-tradable goods:

$$mc_t^{NT} = \frac{\left(r_t^{k,NT}\right)^{a^{NT}} \left(w_t^{NT}\right)^{1-a^{NT}} \left(\frac{y_t^g}{Y_t^{NT}\Delta_t^{NT}}\right)^{-\frac{\chi^{NT}}{1-\chi^{NT}}}}{\left(X_t^{NT}\right)^{1-a^{NT}} \left(a^{NT}\right)^{a^{NT}} \left(1 - a^{NT}\right)^{1-a^{NT}}} \tag{A.39}$$

- The optimal capital-labour ratio:

$$\frac{u_t^{NT} \frac{\bar{k}_{t-1}^{NT}}{e^\gamma} e^{-\varepsilon_t^a}}{L_t^{NT}} = \frac{a^{NT}}{1 - a^{NT}} \frac{w_t^{NT}}{r_t^{k,NT}} \tag{A.40}$$

- The production function:

$$y_t^{NT}\Delta_t^{NT} = \left[\left(u_t^{NT} \frac{\bar{k}_{t-1}^{NT}}{e^\gamma} e^{-\varepsilon_t^a}\right)^{a^{NT}} \left(X_t^{NT} L_t^{NT}\right)^{1-a^{NT}}\right]^{1-\chi^{NT}} (y_t^g)^{\chi^{NT}} \tag{A.41}$$

- The price-setting equation:

$$\tilde{p}_t^{NT} = \frac{\epsilon^{NT}}{\epsilon^{NT} - 1} \frac{p_t^{N,NT}}{p_t^{D,NT}}. \tag{A.42}$$

$$p_t^{N,NT} = \varepsilon_t^{p,NT} mc_t^{NT} y_t^{NT} + \beta\theta^{NT} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_{t+1}^{NT}}{\left(\pi_t^{NT}\right)^{\lambda^{NT}} \left(\pi^{NT}\right)^{1-\lambda^{NT}}}\right)^{\epsilon^{NT}} \mathbb{E}_t p_{t+1}^{N,NT} \tag{A.43}$$

$$p_t^{D,NT} = p_t^{NT} y_t^{NT} + \beta\theta^{NT} \frac{\lambda_{t+1}}{\lambda_t} \left(\frac{\pi_{t+1}^{NT}}{\left(\pi_t^{NT}\right)^{\lambda^{NT}} \left(\pi^{NT}\right)^{1-\lambda^{NT}}} \right)^{\epsilon^{NT}-1} \mathbb{E}_t p_{t+1}^{D,NT} \tag{A.44}$$

- The evolution of the price level of nontradables is:

$$1 = \left(1-\theta^{NT}\right) \left(\tilde{p}_t^{NT}\right)^{1-\epsilon^{NT}} + \theta^{NT} \left[\frac{\left(\pi_{t-1}^{NT}\right)^{\lambda^{NT}} \left(\pi^{NT}\right)^{1-\lambda^{NT}}}{\pi_t^{NT}} \right]^{1-\epsilon^{NT}} \tag{A.45}$$

- The price dispersion index:

$$\Delta_t^{NT} = \left(1-\theta^{NT}\right) \left(\tilde{p}_t^{NT}\right)^{-\epsilon^{NT}} + \theta^{NT} \left[\frac{\left(\pi_{t-1}^{NT}\right)^{\lambda^{NT}} \left(\pi^{NT}\right)^{1-\lambda^{NT}}}{\pi_t^{NT}} \right]^{-\epsilon^{NT}} \Delta_{t-1}^{NT} \tag{A.46}$$

- Government budget constraint:

$$b_t + \frac{f_t^* RER_t}{\Phi(\cdot)} = \frac{R_t^L b_{t-1}}{\pi_t e^{\gamma+\varepsilon_t^a}} + \frac{R_t^{L*} f_{t-1}^* RER_t}{\pi_t^* e^{\gamma+\varepsilon_t^a}} + g_t + z_t - \tau_t \tag{A.47}$$

- Total tax revenues:

$$\begin{aligned} \tau_t \quad = \quad & \tau_t^C \left[\nu c_t^R + (1-\nu) c_t^{NR}\right] + \tau_t^L w_t L_t - \varsigma^P w_t^H L_t^H \\ & + \tau_t^K \nu \left\{ r_t^{k,H} u_t^H \bar{k}_{t-1}^H + r_t^{k,NT} u_t^{NT} \bar{k}_{t-1}^{NT} \right\} e^{-(\gamma+\varepsilon_t^a)} \end{aligned} \tag{A.48}$$

- Total government spending:

$$g_t = c_t^g + w_t^g L_t^g \tag{A.49}$$

- The value added of government production to aggregate output is:

$$y_t^g = w_t^g L_t^g \tag{A.50}$$

- Definition of GDP:

$$y_t^{GDP} \equiv p_t^H y_t^H + p_t^{NT} y_t^{NT} + w_t^g L_t^g \tag{A.51}$$

- Fiscal rules:

$$\frac{\tau_t^C}{\tau^C} = \left(\frac{\tau_{t-1}^C}{\tau^C}\right)^{\rho^C} \left(\frac{d_{t-1}}{d}\right)^{\left(1-\rho^C\right)\gamma^C} \epsilon_t^{\tau^C} \tag{A.52}$$

$$\frac{\tau_t^L}{\tau^L} = \left(\frac{\tau_{t-1}^L}{\tau^L}\right)^{\rho^L} \left(\frac{d_{t-1}}{d}\right)^{\left(1-\rho^L\right)\gamma^L} \epsilon_t^{\tau^L} \tag{A.53}$$

$$\frac{\tau_t^K}{\tau^K} = \left(\frac{\tau_{t-1}^K}{\tau^K}\right)^{\rho^K} \left(\frac{d_{t-1}}{d}\right)^{\left(1-\rho^K\right)\gamma^K} \epsilon_t^{\tau^K} \tag{A.54}$$

$$\frac{c_t^g}{c^g} = \left(\frac{c_{t-1}^g}{c^g}\right)^{\rho^{cg}} \left(\frac{d_{t-1}}{d}\right)^{-(1-\rho^{cg})\gamma^{cg}} \epsilon_t^{cg} \tag{A.55}$$

$$\frac{w_t^g}{w^g} = \left(\frac{w_{t-1}^g}{w^g}\right)^{\rho^{W^g}} \left[\left(\frac{w_{t-1}^{NT}}{w^{NT}}\right)^{\gamma^{W^{NT}}} \left(\frac{w_{t-1}^H}{w^H}\right)^{\gamma^{W^H}} \left(\frac{d_{t-1}}{d}\right)^{-\gamma^{W^g}}\right]^{1-\rho^{W^g}} \epsilon_t^{wg} \tag{A.56}$$

$$\frac{z_t}{z} = \left(\frac{z_{t-1}}{z}\right)^{\rho^Z} \varepsilon_t^z \tag{A.57}$$

- Final goods market equilibrium:

$$y_t = \nu c_t^R + (1-\nu) c_t^{NR} + \nu i_t^H + \nu i_t^{NT} + \nu\eta\left(u_t^H\right)\frac{\bar{k}_{t-1}^H}{e^\gamma} e^{-\varepsilon_t^a} + \nu\eta\left(u_t^{NT}\right)\frac{\bar{k}_{t-1}^{NT}}{e^\gamma} e^{-\varepsilon_t^a} + c_t^g \tag{A.58}$$

- Tradable good market:

$$y_t^H = y_t^{H,d} + y_t^{H*} \tag{A.59}$$

- The law of motion of the internationally traded bonds:

$$\frac{RER_t\left(f_t - f_t^*\right)}{\Phi(\cdot)} = \frac{R_t^{L*} RER_t\left(f_{t-1} - f_{t-1}^*\right)}{\pi_t^* e^{\gamma+\varepsilon_t^a}} + p_t^H y_t^{H,*} - p_t^F y_t^F \tag{A.60}$$

- The world demand function:

$$y_t^{H,*} = \left(\frac{p_t^H}{RER_t}\right)^{-\zeta^*} y_t^* \tag{A.61}$$

- L.O.P.gap:

$$\widetilde{\psi}_t^F = \frac{RER_t}{p_t^F} \tag{A.62}$$

- Price-setting equations of importing firms:

$$\tilde{p}_t^F = \frac{\epsilon^F}{\epsilon^F - 1}\frac{p_t^{N,F}}{p_t^{D,F}} \tag{A.63}$$

$$p_t^{N,F} = \varepsilon_t^{p,F}\widetilde{\psi}_t^F p_t^F y_t^F + \beta\theta^F\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_{t+1}^F}{\left(\pi_t^F\right)^{\lambda^F}\left(\pi^F\right)^{1-\lambda^F}}\right)^{\epsilon^F} \mathbb{E}_t p_{t+1}^{N,F} \tag{A.64}$$

$$p_t^{D,F} = p_t^F y_t^F + \beta\theta^F\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{\pi_{t+1}^F}{\left(\pi_t^F\right)^{\lambda^F}\left(\pi^F\right)^{1-\lambda^F}}\right)^{\epsilon^F-1} \mathbb{E}_t p_{t+1}^{D,F} \tag{A.65}$$

- Evolution of general price of imported goods:

$$1 \equiv \left(1-\theta^F\right)\left(\tilde{p}_t^F\right)^{1-\epsilon^F} + \theta^F\left[\frac{\left(\pi_{t-1}^F\right)^{\lambda^F}\left(\pi^F\right)^{1-\lambda^F}}{\pi_t^F}\right]^{1-\epsilon^F}. \tag{A.66}$$

- Definition of home tradable inflation:

$$p_t^H = \frac{\pi_t^H}{\pi_t} p_{t-1}^H \tag{A.67}$$

- Definition of non-tradable inflation:

$$p_t^{NT} = \frac{\pi_t^{NT}}{\pi_t} p_{t-1}^{NT} \tag{A.68}$$

- Definition of imported inflation

$$p_t^F = \frac{\pi_t^F}{\pi_t} p_{t-1}^F \tag{A.69}$$

- Definition of real exchange rate:

$$RER_t = \epsilon_t \frac{\pi_t^*}{\pi_t} RER_{t-1} \tag{A.70}$$

- Definition of total public debt to GDP ratio:

$$d_t = \frac{b_t + RER_t f_t^*}{y_t^{GDP}} \tag{A.71}$$

- Effective capital of tradable sector:

$$k_t^H = u_t^H \frac{\bar{k}_{t-1}^H}{e^\gamma} e^{-\varepsilon_t^a} \tag{A.72}$$

- Effective capital of non-tradable sector:

$$k_t^{NT} = u_t^{NT} \frac{\bar{k}_{t-1}^{NT}}{e^\gamma} e^{-\varepsilon_t^a} \tag{A.73}$$

B Data Appendix

This appendix provides details on the data series used in estimating the model. We primarily utilize data from the following sources: the Economic and Social Research Institute (ESRI) database, the Central Statistics Office (CSO), quarterly national accounts (QNA), Eurostat, OECD, and the Federal Reserve Economic Data (FRED) from St. Louis FED.

- **Domestic demand:** Domestic demand or absorption is "Modified total domestic demand at current market prices and seasonally" adjusted taken from CSO QNA (Table NQQ46).
- **Private consumption:** Private consumption is "personal expenditures on consumer goods and services at current market prices and seasonally adjusted" taken from CSO QNA (Table NQQ46).

- **Private investment:** Private investment is "Modified gross domestic fixed capital formation at current market prices and seasonally adjusted" taken from CSO QNA (Table NQQ46).
- **Hours worked:** Hours worked are total thousands hours worked taken from Eurostat (Employment A*10 industry breakdowns [namq_10_a10_e]).
- **Wages:** Wages is compensation of employees at current prices total all NACE activities taken from Eurostat (Gross value added and income A*10 industry breakdowns [namq_10_a10]).
- **CPI:** CPI is constructed as the ratio of "Modified Total Domestic Demand and Components of Modified Gross Domestic Fixed Capital Formation at Current Market Prices at current market prices seasonally adjusted" to "Modified Total Domestic Demand and Components of Modified Gross Domestic Fixed Capital Formation at constant market prices seasonally Adjusted". These data series are taken from CSO QNA (Table NQQ46).
- **Nominal interest rate:** The nominal interest rate is constructed using monthly data on Irish 10 year government bond yield from Eurostat "EMU convergence criterion series-quarterly data [irt_lt_mcby_q]".
- **Non-tradable output:** Non-tradable output is counstructed using Eurostat time series in "Gross value added and income A*10 industry breakdowns [namq_10_a10]". The classification of NACE sectors into tradable and non-tradable follows the methodology used in the ESRI database (see e.g., Bergin et al. (2017)). Based on NACE.R2 classification of industries, the non-tradable sector is constructed as the sum of "A=Aggriculture, forestry and fishing", "B=Mining and quarrying", "D=Electricity,gas,steam and air-conditioning supply", "E=Water supply,sewerage, waste management and remediation" , "F= Construction" , "G= Wholesale and retail trade, repair of motor vehicles and motorcycles", "H=Transportation and storage", "I= Accomodation and food services", "L= Real estate activities", "R= Arts, entertainment and recreation", "S= Other services", "T= Activities of households as employers", "U=Activities of extra-territorial organisations and bodies". Which implies that the Irish tradable sector includes "C=manufacturing", "J=Information & Communications", "F=Financial and insurance activities", "M=Professional, scientific and technical activities and "N=administrative and support service activities".
- **Investment in the non-tradable sector:** Investment in the non-tradable sector is taken from ESRI database (see e.g. Bergin et al. (2017)).
- **Tradable output deflator:** This deflator is constructed as the ratio of nominal GVA to real GVA in the tradable sector. The tradable sector consists of the NACE activities C, J, F, M and N as defined above.
- **Non-tradable output deflator:** This deflator is constructed as the ratio of nominal GVA to real GVA in the non-tradable sector. The non-tradable sector consists of the NACE activities A, B, D, E, F, G, H, I, L, R, S, T and U. as defined above.
- **Government consumption:** Government consumption of goods and services is "net expenditure by central and local govt. on goods and services at current market prices and seasonally adjusted" taken from CSO QNA (Table NQQ46).
- **Public wages:** Public wages is the compensation of employees in the Public administration, defence, education, human health and social work activities. Data are taken from Eurostat (Gross value added and income A*10 industry breakdowns [namq_10_a10]).

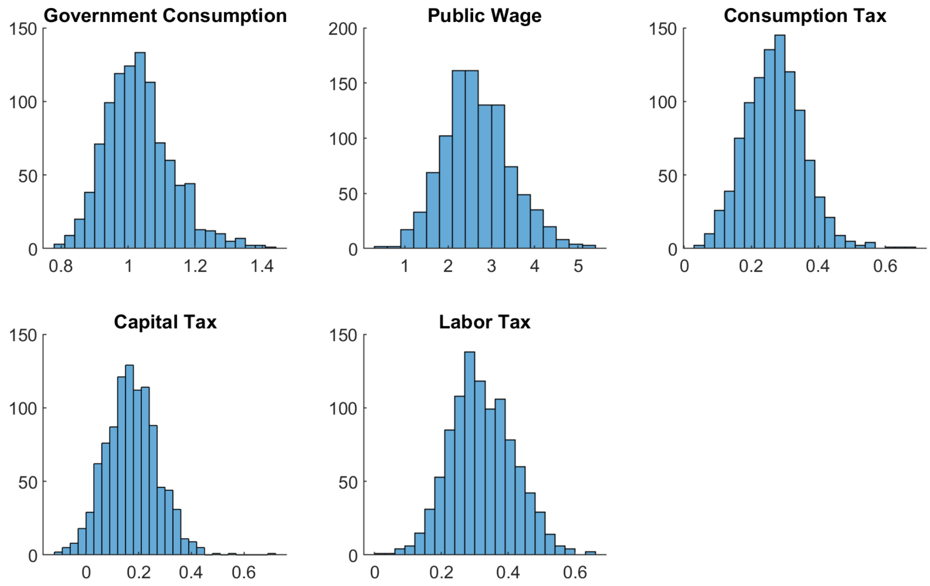
- **Quarterly effective tax rates (ETR):** Effective tax rates on consumption, labour and capital income are constructed following Fiorito and Padrini (2001) and are in line with the associated annual ETRs computed in Kostarakos and Varthalitis (2020).
- **Public debt:** Public debt is taken from National Treasury Management Agency database.
- **Rest of the World (RoW) trade weights:** RoW trade weights are constructed using OECD.stat data on quarterly international trade statistics by partner country, i.e., imports and exports. The main trading partners of Ireland are Eurozone, UK and USA.
- **RoW output:** RoW output is the trade-weighted GDP of Eurozone, UK and USE. Data are taken from Federal Reserve Economic Data.
- **RoW CPI:** RoW CPI is the trade-weighted CPI of Eurozone, UK and USE. Data are taken from Federal Reserve Economic Data.
- **RoW Nominal interest rate:** Nominal interest rate is the trade-weighted nominal interest rate on 10 year government bond yields of Eurozone, UK and USE. Data are taken from Federal Reserve Economic Data.

C Additional Results

C.1 GDP multipliers

Table C.1
GDP multiplier

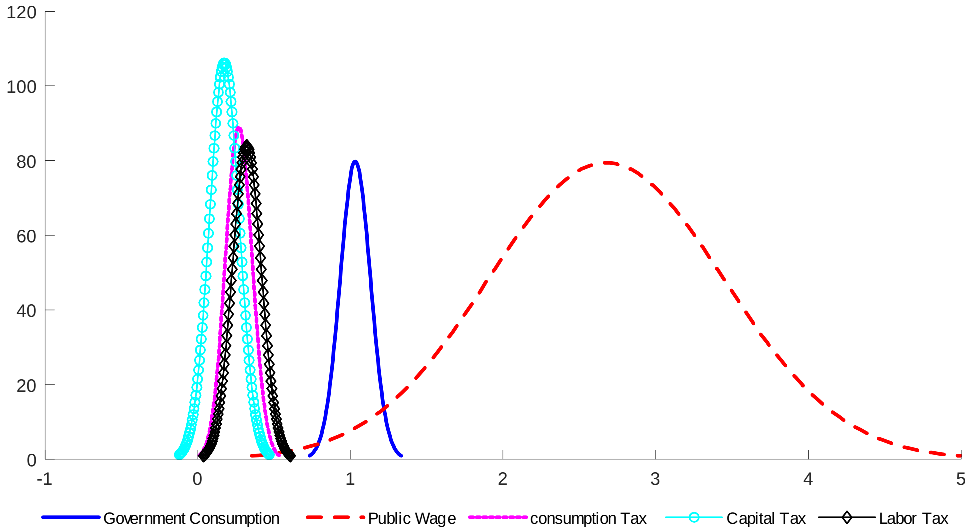
	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	1.0318	0.1000	0.7966	1.4272	10.3143
w^g	2.6745	0.7736	0.3124	5.2084	3.4572
τ^C	0.2704	0.0873	0.0423	0.6610	3.0958
τ^K	0.1738	0.0981	-0.1058	0.7144	1.7727
τ^L	0.3214	0.0951	0.0290	0.6593	3.3795



NOTES: This figure plots histograms of GDP multipliers to fiscal instruments. These multipliers are constructed following the method specified in Section4.1.

FIGURE C.1A
HISTOGRAMS OF GDP MULTIPLIERS

To rank fiscal multipliers taking into account both statistics, i.e., the mean and the dispersion around the mean. In column [5] of TABLE 3, we compute the standardized mean by dividing the mean by the standard deviation. The results are clear-cut, with government consumption being the most efficient fiscal instrument across states, followed by capital, labor, and consumption tax. Public wage is the least efficient fiscal instrument.[15]

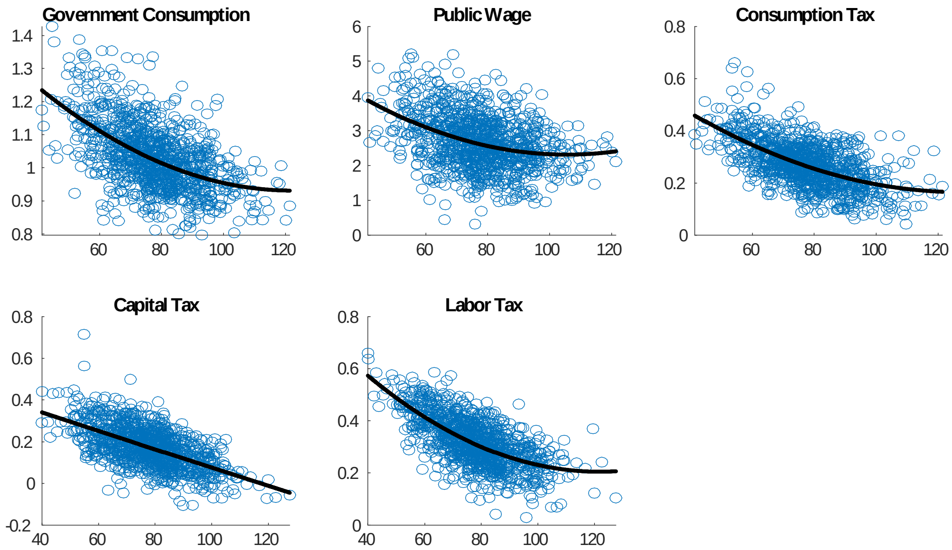


NOTES: This figure plots fitted normal density functions of GDP multipliers to fiscal instruments.

FIGURE C.1B
FITTED NORMAL DENSITY FUNCTIONS OF GDP MULTIPLIERS

[15] Note that the numerical value of the standardized mean does not have an economic interpretation like the mean and should only be used for relative comparison across fiscal instruments.

C.2 Public debt and GDP multipliers



NOTES: y-axis illustrates the size of the domestic demand fiscal multiplier; x-axis illustrates public debt; x-axis illustrates public debt to domestic demand multiplied by 100.

FIGURE C.2A
FISCAL MULTIPLIERS OF GDP VERSUS PUBLIC DEBT (POLYNOMIAL FITTED CURVES)

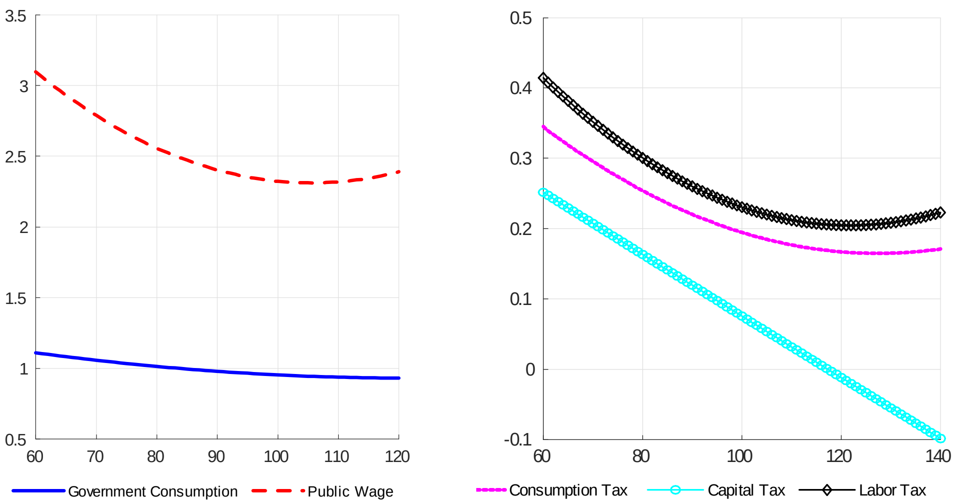


Figure C.2b
fiscal multipliers of GDP versus public debt (polynomial fitted curves)

C.3 Probability of GDP effective fiscal stimulus conditional on the level of public debt

Table C.2: Probability of GDP multiplier higher than the mean multiplier conditional on being in high/low public debt state

	Low public debt state	High debt state
χ	$Prob\left(FM_{\chi}^{y^{GDP}}(0) > \overline{FM}_{\chi}^{y^{GDP}} \vert \frac{d_t}{y_t} < 0.9\right)$	$Prob\left(FM_{\chi}^{y^{GDP}}(0) > \overline{FM}_{\chi}^{y^{GDP}} \vert \frac{d_t}{y_t} > 0.9\right)$
c^g	52.19%	18.54%
w^g	50.97%	29.21%
τ^C	0.12%	0.56%
τ^K	0.12%	0.61%
τ^L	0.12%	0.61%

C.4 Probability of sectoral effective fiscal stimulus conditional on the level of public debt

Table C.3: Probability of tradable output higher than the mean multiplier conditional on being in high/low public debt state

	Low public debt state	High debt state
χ	$Prob\left(FM_{\chi}^{p^H y^H}(0) > \overline{FM}_{\chi}^{p^H y^H} \vert \frac{d_t}{y_t} < 0.9\right)$	$Prob\left(FM_{\chi}^{p^H y^H}(0) > \overline{FM}_{\chi}^{p^H y^H} \vert \frac{d_t}{y_t} > 0.9\right)$
c^g	57.79%	18.54%
w^g	51.34%	38.20%
τ^C	58.52%	21.35%
τ^K	56.94%	7.93%
τ^L	56.70%	11.59%

Table C.4: Probability of higher than the mean non-tradable output multiplier conditional on being in high/low public debt state

	Low public debt state	High debt state
χ	$Prob\left(FM_{\chi}^{p^{NT} y^{NT}}(0) > \overline{FM}_{\chi}^{p^{NT} y^{NT}} \vert \frac{d_t}{y_t} < 0.9\right)$	$Prob\left(FM_{\chi}^{p^{NT} y^{NT}}(0) > \overline{FM}_{\chi}^{p^{NT} y^{NT}} \vert \frac{d_t}{y_t} > 0.9\right)$
c^g	55.47%	23.03%
w^g	50.73%	34.83%
τ^C	56.57%	22.47%
τ^K	58.73%	6.10%
τ^L	55.86%	10.37%

D Other types of shocks

D.1 Tradable shocks

Table D.1a: Impact domestic demand multiplier (tradable shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	1.2700	0.0715	1.0545	1.5911	17.7615
w^g	1.1085	0.2912	-0.0536	2.3464	3.8069
τ^C	0.3045	0.0989	0.0145	0.6943	3.0772
τ^K	0.3768	0.1125	0.0187	0.8098	3.3497
τ^L	0.3349	0.1090	-0.0340	0.7072	3.0732

Table D.1b: Impact tradable output multiplier (tradable shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.3389	0.0341	0.2169	0.4450	9.9233
w^g	0.3799	0.0896	0.0238	0.6360	4.2387
τ^C	0.0773	0.0333	-0.0404	0.2091	2.3178
τ^K	0.2110	0.0481	0.0302	0.4665	4.3816
τ^L	0.0908	0.0366	-0.0687	0.2017	2.4839

Table D.1c: Impact non-tradable output multiplier (tradable shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.5583	0.0382	0.3639	0.6710	14.6124
w^g	0.4836	0.1184	0.0457	0.8549	4.0837
τ^C	0.1348	0.0418	-0.0203	0.2973	3.2234
τ^K	0.1596	0.0494	0.0026	0.3489	3.2296
τ^L	0.1482	0.0464	-0.0135	0.2917	3.1916

D.2 Non-tradable shocks

Table D.2a: Impact domestic demand multiplier (non-tradable shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	1.2486	0.0713	1.0466	1.5888	17.5124
w^g	1.0642	0.2908	-0.0950	2.3602	3.6601
τ^C	0.3122	0.0983	0.0274	0.7073	3.1775
τ^K	0.3838	0.1108	0.0560	0.7880	3.4649
τ^L	0.3510	0.1091	-0.0131	0.6964	3.2156

Table D.2b: Impact tradable output multiplier (non-tradable shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.3211	0.0220	0.2253	0.3950	14.6069
w^g	0.3042	0.0693	0.0650	0.5116	4.3904
τ^C	0.0801	0.0243	-0.0139	0.1673	3.2970
τ^K	0.1360	0.0284	0.0550	0.2920	4.7845
τ^L	0.0922	0.0267	-0.0103	0.1644	3.4497

Table D.2c: Impact non-tradable output multiplier (non-tradable shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.5504	0.0508	0.3613	0.6970	10.8254
w^g	0.4891	0.1395	-0.0309	0.9767	3.5067
τ^C	0.1348	0.0504	-0.0431	0.3151	2.6726
τ^K	0.1711	0.0574	-0.0157	0.3677	2.9796
τ^L	0.1546	0.0567	-0.0529	0.3151	2.7276

D.3 World shocks

Table D.3a: Impact domestic demand multiplier (world shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	1.2520	0.0727	1.0340	1.5733	17.2285
w^g	0.8775	0.2915	-0.1361	1.8941	3.0098
τ^C	0.3184	0.0969	0.0605	0.6483	3.2874
τ^K	0.4217	0.1103	0.0852	0.8531	3.8233
τ^L	0.3569	0.1102	0.0326	0.7670	3.2375

Table D.3b: Impact tradable output multiplier (world shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.3380	0.0299	0.2184	0.4438	11.3180
w^g	0.2695	0.0845	-0.0125	0.5334	3.1885
τ^C	0.0847	0.0285	-0.0115	0.1791	2.9719
τ^K	0.1646	0.0372	0.0444	0.3822	4.4289
τ^L	0.0982	0.0323	-0.0286	0.2101	3.0409

Table 3c: Impact non-tradable output multiplier (world shocks)

	[1]	[2]	[3]	[4]	[5]
χ	Mean	Std	Min	Max	Mean/Std
c^g	0.5615	0.0542	0.3635	0.7538	10.3634
w^g	0.3977	0.1442	-0.1009	0.9010	2.7585
τ^C	0.1408	0.0494	0.0083	0.3042	2.8513
τ^K	0.1872	0.0562	0.0113	0.4033	3.3303
τ^L	0.1600	0.0557	-0.0131	0.3556	2.8726

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