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This paper presents MEGAIReF, a medium-scale estimated dynamic stochastic general equilibrium (DSGE) model for the Spanish economy. The model describes a small open economy with heterogeneous households —Ricardian and Hand-to-Mouth— nominal rigidities in price and wage setting, and real rigidities such as monopolistic competition, investment adjustment costs, and a frictional labor market giving rise to unemployment dynamics. It also incorporates a banking sector with financial intermediation frictions, generating a financial accelerator mechanism. In addition, MEGAIReF features a comprehensive fiscal block encompassing multiple expenditure categories — public consumption, public investment, and public employment— as well as a detailed specification of revenue instruments, including taxes on consumption, labor income, and personal and corporate income. All fiscal instruments respond endogenously to macroeconomic conditions through a set of estimated fiscal rules. The model is estimated with Bayesian methods using data for Spain and the Euro area.

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1 Introduction

This paper presents MEGAIReF, a new estimated small open-economy dynamic stochastic general equilibrium (DSGE) model developed for the Spanish economy. The model serves as a quantitative framework to analyze the joint behavior of macroeconomic and fiscal variables in an open economy under a common monetary policy. MEGAIReF combines a rich set of nominal and real frictions, with a detailed fiscal structure, and is conceived as a tool for quantitative policy analysis, and the evaluation of macroeconomic scenarios for AIReF, the Spanish Independent Authority for Fiscal Responsibility.

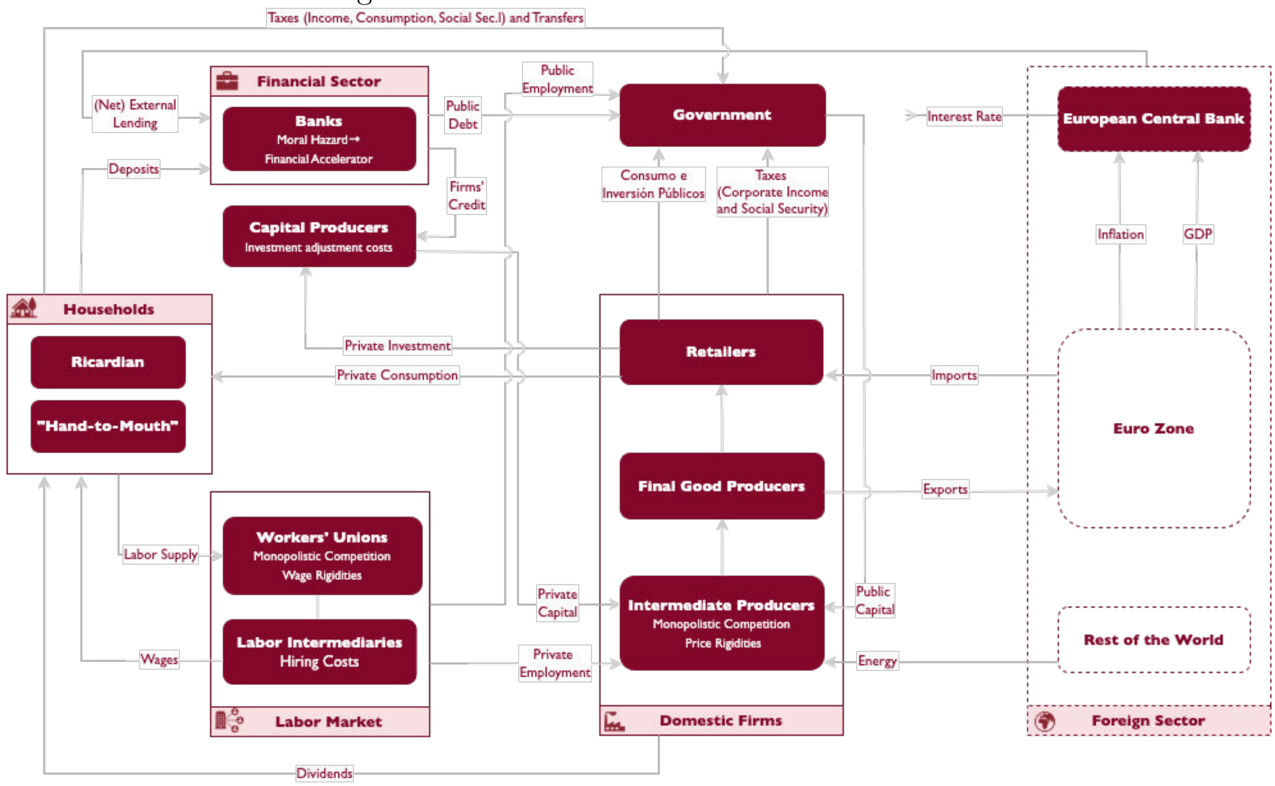
The structure of the model captures key features of the Spanish economy. It distinguishes between optimizing (Ricardian) and hand-to-mouth households, embeds a frictional labor market with wage rigidities and hiring costs, and includes a banking sector subject to financial frictions that generate an endogenous credit spread and give rise to a financial accelerator mechanism. The fiscal block provides a granular description of revenues and expenditures —covering taxes, public consumption, investment, and employment— where each instrument evolves according to estimated fiscal rules. The open-economy setting links domestic variables to euro area conditions through trade and financial flows, with monetary policy determined by the European Central Bank.

MEGAIReF advances the existing DSGE literature by bringing together within a single estimated framework several elements that are present in separate models for the Spanish economy. Previous works on the Spanish economy, such as FiMOD (St ahler and Thomas (2021)) and REMS (BoscáÂ et. al. (2020)) incorporated, respectively, a detailed fiscal structure and a banking sector with financial frictions. MEGAIReF combines and extends these approaches, estimating structural and policy parameters from the data. In particular, using Bayesian methods and Spanish and euro area data, we estimate a comprehensive set of fiscal rules that govern the behavior of key policy instruments —including taxes, public spending, and transfers. The estimated parameters reveal systematic yet heterogeneous fiscal reactions to debt dynamics and the business cycle, providing quantitative evidence on the stabilizing role of fiscal responses in Spain.

In what follows, we illustrate several potential applications of MEGAIReF. For instance, we show that the size of the government spending multipliers under the baseline calibration is close to values obtained in previous quantitative and empirical studies. However, we also show how the size of the multiplier may vary substantially depending on structural features, especially related to international linkages through trade and financial flows. In our open-economy setting, we find that the degree of household heterogeneity has a modest effect on the size of the multipliers.

The remainder of the paper is organized as follows. Section 2 presents the structure of the model, describing households, firms, the financial sector, and the behavior of fiscal and monetary authorities. Section 3 outlines the calibration and estimation strategy. Section 4 discusses possible applications, including impulse responses to macro shocks, the analysis of the determinants of fiscal multipliers, and a computation of Laffer curves for the Spanish economy. Section 5 concludes by summarizing the main findings and potential applications of the model for policy analysis.

Figure 1: Overview of the MEGAIReF model



2 The Model

This section presents the details of the MEGAIReF model. We consider a small-open economy (Spain) in a monetary union (the EMU) populated by two types of households (Hand-to-Mouth and Ricardian, three types of firms (intermediate good producers, final good producers, and retailers), labor intermediaries (unions and "labor packers"), financial intermediaries (banks), and the government. Monetary policy is chosen by a supra-national central bank (the ECB) setting monetary policy in response to union-wide macroeconomic variables, which are taken as exogenous to the model.

The structure of MEGAIReF reflects five core blocks, as summarized in Figure 1. First, a household sector with heterogeneous agents, which allows the model to potentially capture the role of inequality in income and wealth for the transmission of macroeconomics and fiscal shocks.

Second, a frictional labor market, due to the presence of exogenous separations, firms' hiring costs, and labor union monopolistic power and nominal wage rigidities. This structure allows the model to reproduce cyclical variations in employment, unemployment and wages, and to analyze the transmission of fiscal and macro shocks through the labor market.

Third, the financial sector, with banks that intermediate between depositors and firms, operating under borrowing constraints that depend on the net worth of financial intermediaries. These constraints generate an endogenous amplification of macro-financial disturbances through a financial accelerator mechanism, linking credit conditions, asset prices, and real activity.

Fourth, the fiscal block provides a granular representation of government accounts, distinguishing between public consumption, investment, employment, and transfers. Fiscal revenues include taxes on consumption, personal income, and corporate income, as well as social security contributions. Unlike most existing models, the fiscal instruments in MEGAIReF follow estimated fiscal rules, whereby each tax and expenditure category responds endogenously to the cyclical position of the economy and public debt. Thus, this specification nests both systematic and discretionary responses.

Finally, the open-economy dimension reflects Spain's integration in the euro area, with trade and financial linkages to the rest of the monetary union and a common monetary policy determined by the European Central Bank. Domestic conditions are thus influenced by area-wide developments and transmitted through interest rates and external demand.

The following subsections describe the model in detail.

2.1 Households

The household sector is modeled to capture in a tractable but realistic manner two salient features that may have important aggregate implications: (i) the presence of households with heterogeneous marginal propensities to consume out of their disposable income, which is crucial to determine the size of fiscal multipliers; and (ii) the presence of cyclical unemployment rate.

The economy is populated by two types of infinitely-lived households. A (constant) share λ^H of households are assumed to behave in a Hand-to-Mouth (HtM) fashion, and entirely consume their disposable income at each point in time. This behavior could be explained by the presence of myopia, lack of access to capital markets, borrowing constraints, fear of saving or unawareness of intertemporal trading opportunities.

The remaining fraction $1 - \lambda^H$ of the population are instead standard optimizing households, with unlimited access to financial markets, and thus able to smooth their consumption inter-temporally. Henceforth, we refer to these two types of households as Hand-to-Mouth and Ricardian, and denote the corresponding variables with superscript H and R , respectively. It is also assumed that Ricardian and Hand-to-Mouth households have different labor and profits income, as well as a different exposure to interest rate fluctuations. As shown in Debortoli and GalíÂ (2024), such a formulation allows to capture the presence of both "poor" and "wealthy" hand-to-mouth —i.e. households who are liquidity constrained, but may get a net inflow from (partially) illiquid financial assets— and constitutes a good approximation to richer heterogeneous-agent models (e.g. Kaplan, Moll and Violante (2018) and Auclert et. al (2024)) for the purposes of analyzing the role of household heterogeneity for aggregate fluctuations.

Each household is composed by a continuum of size one of heterogeneous individuals $j \in [0, 1]$, where each individual provides an indivisible unit of labor to monopolistically competitive labor unions setting wages in a staggered fashion. As shown by Blanchard and Galí (2010) and Galí, Smets and Wouters (2012), the presence of indivisible labor and labor market frictions gives rise to a notion of involuntary unemployment which is consistent with its empirical counterpart.[1]

[1]The assumption of indivisible labor implies that variations in hired labor input take place exclusively at the extensive margin. This is consistent with the empirical evidence of Lafuente et. al. (2022), among others, who show that in the Spanish economy (as in many advanced economies) most of the cyclical variations in hours worked are due to variations

Formally, each individual derives utility from consumption of a bundle of domestic and foreign goods $C_t^h(j)$ subject to (external) consumption habits, and has a disutility of work given by j^{φ} if the individual is employed, with $\varphi > 0$, and zero otherwise.

Income is pooled within each household, which thus act as risk sharing mechanism –i.e. consumption is equalized among all the household members. In particular, the (period) utility of an individual member j of a household of type h is given by

$$U^h(j) \equiv \log \tilde{C}_t^h - \mathbb{1}_t(j)\, \varepsilon_t^n \mathcal{E}_t^h j^{\varphi}$$

where $\tilde{C}_t^h(j) \equiv C_t^h(j) - \mathcal{H}\bar{C}_{t-1}^h$, with $\mathcal{H} \in [0,1]$ and with $\bar{C}_{t-1}^h$ denoting (lagged) group-specific consumption (taken as given by each household) capturing the incidence of (group-specific) consumption habits. The term ε_t^n denotes an exogenous labor supply shock, which is common across households. The term $\mathcal{E}_t^h \equiv 1/\left(\bar{C}_t^h - \mathcal{H}\bar{C}_{t-1}^h\right)$ constitutes instead an endogenous preference shifter, which is taken as given by each individual household. As explained in GalíÂ, Smets and Wouters (2012), the role of the endogenous preference shifter is to offset the consumption externality on the labor supply, thus guaranteeing the existence of a balanced growth path.

The risk-sharing assumption implies that $C_t^h(j) = C_t^h$ for all members belonging to the same household. Thus, the (period) utility of a household can be obtained aggregating the preferences of its individual members, and is given by

$$\begin{aligned} U\left(\tilde{C}_t^h, N_t^h\right) &\equiv \log \tilde{C}_t^h - \varepsilon_t^n \mathcal{E}_t^h \int_0^{N_t^h} j^{\varphi} dj \\ &= \log \tilde{C}_t^h - \varepsilon_t^n \mathcal{E}_t^h \frac{\left(N_t^h\right)^{1+\varphi}}{1+\varphi} \end{aligned}$$

where $N_t^h \in [0,1]$ denotes the employment rate in period t and $\tilde{C}_t^h \equiv C_t^h - \mathcal{H}\bar{C}_{t-1}^h$.

Importantly, each household takes as given the employment rate N_t^h, since it has no influence on wages (set by unions) or employment (determined by firms and the government). Thus, the only decisions made by households involve the optimal intertemporal allocation of consumption, as described below.

Consumption choices: Hand-to-Mouth vs Ricardian Households

As explained above, the distinction between Hand-to-Mouth and Ricardian households is based on the difference in their marginal propensity to consume, as well as on the heterogeneous exposure to labor vs financial income. In particular, following in Debortoli and GalíÂ (2024), we propose a formulation based on the following assumptions:

1. HtM households are assumed to have lower labor efficiency than Ricardian households. Formally, we define $\Xi^H \leq 1$ as the efficiency of HtM households, and with $\Xi^R \equiv \left(1 - \Xi^H \lambda^H\right) / \left(1 - \lambda^H\right) > 1$ the efficiency of Ricardian households.[2]

in the employment rate, rather than variations on hours per worker.

[2]According to this normalization, we have that in any period, aggregate efficiency is constant and equal to $\Xi \equiv$

2. All households can save / borrow into liquid financial assets (deposits), issued by competitive financial intermediaries. However, HtM households are assumed to be permanently against a borrowing constraint, $D_t^H = P_t \underline{d} < 0$.

3. Households receive financial income F_t from their holdings of (illiquid) stocks of firms and financial intermediaries. Thus, we denote with $\Theta^H \geq 0$ the financial income share of a HtM households, and with $\Theta^R = 1 - \frac{\lambda^H}{1-\lambda^H}\Theta^H$ the share of a Ricardian households.

The previous assumptions imply that in each period $t = 0, 1, \ldots$, consumption of HtM households $\left(C_t^H\right)$ must satisfy the budget constraint

$$(1+\tau_t^c)\, C_t^H = \frac{1}{P_t}\left[(1-\tau_t^w)\,\Xi^H exp\left(\mu_t^H\right) W_t N_t^H\right] + (1-\tau_t^y)\,\Theta^H F_t + \left(\frac{R_{t-1}^d}{\Pi_t} - 1\right)\underline{d} - \tau_t^y \frac{\left(R_{t-1}^d - 1\right)}{\Pi_t}\underline{d} + T_t^H \tag{1}$$

where τ_t^c is the consumption tax, P_t is the price index (CPI), $\Xi^H W_t N_t^H$ denotes the nominal labor income, F_t denotes aggregate financial income, and R_t^d is the nominal interest rate on deposits between period t and period $t+1$. The term $\tau^w = \tau^y + \tau^{sh}$ denotes the tax rate on labor income, which is given by the sum of the general income tax rate τ^y, the social security contribution rate paid by households τ^{sh}, while and T_t^H are lump-sum transfers (possibly including unemployment benefits). Instead, the term μ_t^H —hencerforth referred to as "minimum wage" shifter—represents an additional markup on the salary of Hand-to-Mouth households, that can result from legal measures aimed at guaranteeing a salary to these type of households above the level that would arise in the labor market for their specific productivity.

The budget constraint of Ricardian households is instead given by

$$(1+\tau_t^c)\, C_t^R + \frac{D_t^R}{P_t} = \frac{1}{P_t}\left[(1-\tau_t^w)\, exp\left(\mu_t^R\right)\Xi^R W_t N_t^R\right] + (1-\tau_t^y)\,\Theta^R F_t + \frac{R_{t-1}^d}{\Pi_t}\frac{D_{t-1}^R}{P_{t-1}} - \tau_t^y \frac{\left(R_{t-1}^d - 1\right)}{\Pi_t}\frac{D_{t-1}^R}{P_{t-1}} + T_t^R \tag{2}$$

where D_t^R denote nominal deposits and T_t^R denote lump-sum transfers.[3]

Thus, taking as given (the path of) of labor income, financial income and taxes, a Ricardian household makes its consumption and savings decisions maximizing $\mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \varepsilon_t^d U\left(C_t^R, N_t^R\right)$, subject to the sequence of constraints (2) for all periods $t = 0, 1, \ldots$, where $\beta \in (0,1)$ is the discount factor, and ε_t^d is an exogenous discount factor shock. The resulting optimality condition are given by

$$\Lambda_t = \beta \mathbb{E}_t\left\{\left[R_t^d - \tau_{t+1}^y\left(R_t^d - 1\right)\right]\Lambda_{t+1}\Pi_{t+1}^{-1}\right\} \tag{3}$$

$$\Lambda_t = \frac{1}{1+\tau_t^c}\frac{1}{\left[C_t^R - \mathcal{H}C_{t-1}^R\right]}\varepsilon_t^d \tag{4}$$

where $\Pi_{t+1} \equiv P_{t+1}/P_t$ denotes the (gross) inflation rate between period t and period $t+1$.

$\lambda^H \Xi^H + \left(1-\lambda^H\right)\Xi^R = 1$.

[3]Throughout, we assume that for Ricardian Households the "minimum wage" shifter $\mu_t^R = 0$.

Aggregate consumption is then defined as

$$C_t \equiv \lambda^H C_t^H + \left(1 - \lambda^H\right) C_t^R \tag{5}$$

For later convenience, it is useful to define a "reservation" wage schedule (per efficiency unit), defined as the hypothetical wage schedule would prevail in a perfectly competitive labor market, and is given by

$$\frac{\tilde{W}_t^h}{P_t} \equiv \varepsilon_t^n \frac{1+\tau_t^c}{1-\tau_t^w} \frac{\left[N_t^h\right]^{\varphi}}{\Xi^h}. \tag{6}$$

As explained below, the presence of labor market frictions would generally imply that, at any given employment rate, the actual wage would be higher than the reservation wage, thus leading to an inefficiently low employment rate.[4]

2.2 The Labor Market

In order to describe the labor market conditions of the Spanish economy, we consider a labor market featuring a set of rigidities giving rise to inefficient levels of employment and unemployment. In particular, we introduce real rigidities in terms of hiring costs for firms (paid through labor intermediaries) and monopolistic power of unions , and nominal rigidities in the form staggered wage setting.

Formally, on the supply side, it is assumed that workers from each households can be assigned to differentiated labor services. Separate unions act as monopolists for a specific service, and set nominal wages in a staggered manner. On the demand side, perfectly competitive labor intermediaries recruit different labor varieties, subject to hiring costs, and provide the composite labor service to firms (the intermediate goods producers) and to the government.[5]

Labor Intermediaries

There is a unit mass of perfectly competitive labor intermediaries, each purchasing the different labor varieties from unions, and providing a composite labor service according to the Dixit-Stiglitz aggregator

$$N_t \equiv \left[\int_0^1 N_t(\ell)^{\frac{\varepsilon^w - 1}{\varepsilon^w}} d\ell\right]^{\frac{\varepsilon^w}{\varepsilon^w - 1}},$$

where $\varepsilon^w > 1$ denotes the elasticity of substitution between labor varieties.[6] The labor bundle is then sold to firms at a wage W_t^f and to the government at a wage W_t^g, where the latter determined exogenously.

[4] For the case of Hand-to-Mouth households, the presence of a minimum wage shifter gives rise to inefficiently low employment even in an economy with perfectly competitive labor markets.

[5] As is common in the literature (e.g. Smets and Wouters (2007)), the presence of labor unions and intermediaries is made for convenience, in order to separate the household consumption-saving decisions and the firms' price-setting decision from the wage determination process.

[6] To save on notation, since all labor intermediaries face an identical problem, we do not distinguish between labor provided by the single intermediary and aggregate labor, as the two variables are identical in a symmetric equilibrium considered throughout.

Thus, the (average) unit revenue of labor intermediaries is given by

$$\hat{W}_t = \frac{N_t^f W_t^f + N_t^g \left(1 + \tau_t^s\right) W_t^g}{N_t} \tag{7}$$

where N_t^f and N_t^g denote labor hired by the firms and the government, respectively.

In each period, labor intermediaries provide new hires to firms equal to $H_t \equiv N_t - (1 - s_t) N_{t-1}$, where $s_t \in [0, 1]$ captures an exogenous time-varying separation rate, which is identical across all firms. In turn, the recruiting and hiring process involves a non-wage cost per hire equal to $a_t^N(\cdot)$ (in real terms), which depends on aggregate economic conditions, and is thus taken as given by the individual intermediaries. Following Blanchard and GalíÂ (2010), we assume a hiring cost function $a_t^N(\cdot) = \frac{1}{\Theta_t^N} (H_t/U_t)^{\frac{\theta^N}{1-\theta^N}}$. The main consequence of the presence of hiring costs is that current labor demand N_t depends on the pre-existing level of employment N_{t-1}, thus generating some degree of inertia in employment dynamics even in the absence of nominal rigidities. In this respect, our model is similar to models with search-and-matching frictions found in Diamond-Mortensen-Pissarides. In the hiring cost function definition, H_t/U_t denotes the ratio between new hires and unemployment rate, or market "tightness", while $\Theta^N > 0$ and $\theta^N \in (0, 1)$ can be interpreted, respectively, as the exogenous time-varying "matching" efficiency and the matching elasticity.[7]

Formally, the problem of labor intermediaries can be divided into two stages. In a first stage, the intermediaries solve an intertemporal problem, and choose how many units of composite labor to supply at each point in time. In a second stage, they choose how to optimally allocate labor across the different varieties solving a static cost minimization problem.

Solving backward, the cost minimization problem implies that the demand for a specific labor variety at any given point in time t is given by

$$N_t(\ell) = \left(\frac{W_t(\ell)}{W_t}\right)^{-\varepsilon^w} N_t$$

where $W_t \equiv \left[\int_0^1 W_t(\ell)^{1-\varepsilon^w} d\ell\right]^{\frac{1}{1-\varepsilon^w}}$ denotes the aggregate wage, and the associated total wage cost is given by $W_t N_t = \int_0^1 W_t(\ell) N_t(\ell) d\ell$.

The intertemporal problem consists of solving the profit maximization problem

$$\max_{\{N_t\}} \sum_{t=0}^{\infty} \beta^t \Lambda_t \left\{ \frac{\hat{W}_t}{P_t} N_t - \left(1 + \tau_t^s\right) \frac{W_t}{P_t} N_t - a_t^N \left(N_t - (1 - s) N_{t-1}\right) \right\}$$

where $\hat{W}_t/P_t$ denotes the total labor cost faced by firms (in real terms). The optimality condition to

[7]See Blanchard and GalíÂ (2010) for a discussion about the correspondence between an environment with hiring costs and the standard search-and-matching framework featuring a Cobb-Douglas matching function.

this problem implies that

$$\frac{\hat{W}_t}{P_t} = (1+\tau_t^s)\frac{W_t}{P_t} + a_t^N - \beta(1-s)\mathbb{E}_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}a_{t+1}^N\right\} \tag{8}$$

which indicates the total labor cost equals the the wage plus the net hiring cost $a_t^N - \beta(1-s)\mathbb{E}_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}a_{t+1}^N\right\}$. Thus, at each point in time, labor costs include both a wage and a non-wage component, as well as social security contributions.

2.2.1 Workers' Unions

We assume that nominal wages are set by monopolistically competitive unions, each representing a different labor service, subject to nominal wage rigidities. Following Calvo (1983), we assume that in each period the nominal wage for a labor service of a given type can only be reset with probability $1-\theta_w$. Thus, and by the law of large numbers, a fraction of workers θ_w do not reoptimize their wages in any given period, making that parameter a natural index of nominal wage rigidities. Furthermore, all unions who reoptimize their wage choose an identical wage, denoted by W_t^r, since they face an identical problem. Following Smets and Wouters (2007), we also allow for partial indexation between re-optimization periods, by making the nominal wages adjust mechanically in proportion to past price inflation. Formally, and letting $W_{t+k|t}$ denote the nominal wage in period $t+k$ for workers who last re-optimized their wage in period t, we assume that

$$W_{t+k|t} = W_t^r X_{t,t+k}^w$$

where $X_{t,t+k}^w \equiv \Pi_{t,t+k}^{\iota_w}\left(\Pi^k\right)^{1-\iota_w}$, while $\Pi_{t,t+k} \equiv P_{t+k}/P_t$ denotes the (gross) inflation rate between period t and $t+k$, Π is the steady state inflation rate, and $\iota_w \in [0,1]$ denotes the degree of indexation to past inflation.

The union is assumed to set the new wage W_t^r and implied employment rates $\left\{N_{t+k|t}\right\}_{\forall k}$ in a way consistent with the maximization of an "average" household (as opposed as considering a specific household or its individual members) and subject to the sequence of demand schedules of the form

$$N_{t+k|t} = \left(\frac{W_{t+k|t}}{W_{t+k}}\right)^{-\varepsilon^w} N_{t+k}, \tag{9}$$

where $N_{t+k|t}$ denote period $t+k$ employment among workers whose wage was last reoptimized in period t, and where ε^w is the wage elasticity of the relevant demand schedule. Once workers are hired, the union assigns jobs randomly across households, which implies an identical employment rate across HtM and Ricardian households, i.e. $N_t^H = N_t^R = \tilde{N}_t \equiv \int_0^1 N_t(\ell)\,d\ell$, and that all households receive the same salary W_t. In other words, by the law-of-large-numbers, all households have an identical proportion of workers assigned to different firms, and to the government.

The optimality conditions of the union's problem is given by

$$\mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta_w)^k \frac{1}{P_{t+k}} \left[W_t^r X_{t,t+k} - \mathcal{M}^w \tilde{W}_{t+k} \right] N_{t+k|t} = 0 \tag{10}$$

where $\mathcal{M}^w \equiv \frac{\varepsilon^w}{\varepsilon^w - 1} > 1$ and

$$\frac{\tilde{W}_{t+k}}{P_{t+k}} \equiv \varepsilon_{t+k}^n \frac{1+\tau_{t+k}^c}{1-\tau_{t+k}^w} \bar{\Xi}_t \tilde{N}_{t+k}^{\varphi} \tag{11}$$

represents the average reservation wage between HtM and Ricardian households, which is taken as given by a union and where $\bar{\Xi}_t \equiv \frac{exp(\mu_t^H)\lambda^H}{\Xi^H} + \frac{1-\lambda^H}{\Xi^R}$ captures the effects of minimum wages and heterogeneity on the labor supply.[8]

The latter expressions indicates that optimal wages are set as a markup over the wage that would prevail under perfectly competitive markets.

The evolution of aggregate (real) wages is then given by a weighted average between the newly set wages, and the previous period real wages (indexed by inflation)

$$\frac{W_t}{P_t} = \left[\int_0^1 W_t(\ell)^{1-\epsilon^w} d\ell \right]^{\frac{1}{1-\varepsilon^w}} = \left[(1-\theta_w) \left(\frac{W_t^r}{P_t} \right)^{1-\epsilon^w} + \theta_w \left[\left(\frac{\Pi}{\Pi_t} \right)^{1-\iota_w} \frac{W_{t-1}}{P_{t-1}} \right]^{1-\epsilon^w} \right]^{\frac{1}{1-\epsilon^w}} . \tag{12}$$

Unemployment Rate

As mentioned above, households take as given wages (set by unions) and employment (determined by firms and government labor demand). Nevertheless, given the prevailing market conditions, it is possible to determine how many individuals are participating to the labor market, and the consequent unemployment rate.

In equilibrium, an individual j of a household of type h would participate in the labor market in a given period t if and only if the prevailing wage satisfies

$$\frac{W_t}{P_t} \Xi^h exp\left(\mu_t^h\right) \geq \varepsilon_t^n \frac{1+\tau_t^c}{1-\tau_t^w} j^{\varphi}$$

Thus, we can denote the marginal supplier of labor in a given household h by

$$L_t^h \equiv \left(\frac{W_t}{P_t} \Xi^h \frac{exp\left(\mu_t^h\right)}{\varepsilon_t^n} \frac{1-\tau_t^w}{1+\tau_t^c} \right)^{\frac{1}{\varphi}} \tag{13}$$

which can be interpreted as the participation rate. The unemployment rate can then be defined as

$$U_t^h \equiv 1 - N_t^h / L_t^h. \tag{14}$$

In other words, the unemployment rate denotes the fraction of individuals would like to be working

[8]The aggregation of labor schedule is facilitated by the log-utility assumption which is a common assumption in the literature, see e.g. Burriel et. al. (2010) and BoscáÂ et. al. (2020) for applications to the Spanish economy.

(given current labor market conditions), but are not currently employed. In other words, unemployment arises because, due to the union monopolistic power, the equilibrium wage is generally higher than the reservation wage, which implies that the number of employed workers is lower than the fraction of individuals who would be willing to work at the prevailing wage.

Notice that different types of households generally have different unemployment rates, which arise from differences in the participation rate. The total unemployment rate in the economy is then given by

$$U_t = \lambda^H U_t^H + \left(1 - \lambda^H\right) U_t^R. \tag{15}$$

2.3 Financial and Capital Markets

Financial markets are characterized by the presence of a continuum of perfectly competitive financial intermediaries (banks) that collect deposits from households (D_t) and (net) foreign borrowings ($-B_t^*$) —at a (gross) interest rate R_t^d and R_t^b, respectively— and provide credit in terms of government bonds (B_t) and loans to firms (intermediate producers) to purchase capital. Following Gertler and Karadi (2013), we introduce financial frictions which limits the banks' ability to borrow as a function of their equity capital. This gives rise to an endogenous leverage constraint which leads to the presence of an endogenous spread between lending and funding rates. Notably, the banks' ability to borrow varies countercyclically, thus giving rise to a financial accelerator mechanism.

Formally, it is assumed that in each period t banks give (state-contigent) loans to firms' to finance their acquisitions of capital from capital goods producers, for an amount $Q_t K_t$, where Q_t denotes the price of capital in terms of consumption goods. Firms use this capital for production in period $t+1$, which can then be sold at the end of the period for a price Q_{t+1}. Since banks operate in a perfectly competitive market, the (gross) real return on the loans R_t^ℓ must equal to the firms' return on capital, and is given by

$$R_{t+1}^\ell = \frac{r_{t+1}^k + (1-\delta)\, Q_{t+1}}{Q_t}. \tag{16}$$

In addition, banks lend to the government at an (ex-post) real interest rate $R_t^b \Pi_{t+1}^{-1}$ and lend or borrow from foreign investors at the real rate $R_t^* \Phi_t \Pi_{t+1}^{-1}$, where R_t^* denotes the nominal interest set by the union-wide monetary policy authority, while Φ_t denotes an exogenous spread which increases with external debt-to-GDP ratio, and is needed to ensure stationarity of the equilibrium of the small-open economy model. Following Schmitt-Grohe and Uribe (2003), we assume that this spread evolves according to the follow equation

$$\log \Phi_t = \rho_b \log \Phi_{t-1} - (1-\rho_b)\, \bar{\phi} \left(\exp\left(B_t^*/GDP_t\right) - 1\right) + \log \varepsilon_t^b \tag{17}$$

where GDP_t denotes domestic GDP (defined below) and ε_t^b represents an exogenous spread shock, which may captures tensions in the international financial markets, unrelated to the domestic economic conditions.

Banks

Letting NW_t be the (real) amount of equity capital —or net worth— that a representative banker has at the end of period t, the bank's balance sheet is given by

$$Q_t K_t + \frac{B_t + B_t^*}{P_t} = NW_t + \frac{D_t}{P_t}. \tag{18}$$

Net worth is accumulated through retained earnings. It is thus the difference between the gross return on assets and the cost of liabilities

$$NW_t = R_t^\ell Q_{t-1} K_{t-1} + \Pi_t^{-1} \left(R_{t-1}^b \frac{B_{t-1}}{P_{t-1}} + R_{t-1}^* \Phi_{t-1} \frac{B_{t-1}^*}{P_{t-1}} - R_{t-1}^d \frac{D_{t-1}}{P_{t-1}} \right). \tag{19}$$

The banker's objective is to maximize the discounted stream of payouts back to the household, where the relevant discount rate is the household's intertemporal marginal rate of substitution $\beta \Lambda_{t+1}/\Lambda_t$.[9] Under frictionless capital markets the timing of the payouts is irrelevant. To the extent the intermediary faces a financing constraint that depends on its net worth, it is optimal for the banker to retain earnings over time. In order to insure that over time banks do not retain earnings to the point where they can fund all investments from their own capital, we introduce a finite planning horizon for bankers. In particular, it is assumed that at each point in time a fraction $1 - s_b$ of banks randomly exit the market, and the corresponding net worth is distributed lump-sum to the households. An equivalent number of banks enter the market, with an initial net worth NW^e financed lump-sum by households. Accordingly, the banker's objective is to maximize the present value of expected net-worth, accounting for the probability of (random) exit

$$\mathcal{V}_0^b \equiv \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^{t+1} \frac{\Lambda_{t+1}}{\Lambda_0} \left[\left(1 - s^b\right) \left(s^b\right)^t NW_{t+1} \right]. \tag{20}$$

To motivate a limit on the bank's ability to obtain deposits, we introduce the following moral hazard/costly enforcement problem. At the beginning of the period, the banker can choose to divert an exogenous time-varying fraction Ψ_t^b of the funds from the loans it holds and transfer the proceeds to the household.[10] It is also assumed that funds allocated to government bonds or to international investors cannot be diverted. A possible justification for this assumption is that in practice it might be difficult to monitor the actual returns received from loans to the non-financial sector, while it is easier to monitor the assets held into publicly traded market (such government bonds or international securities). The cost to the banker of diverting part of its assets is that the depositors can force the intermediary into bankruptcy and recover the remaining value of assets $\mathcal{V}_t^b$. Accordingly, for depositors to be willing to

[9] We assume that the discount factor of the financial intermediary coincides with the discount factor of Ricardian households. A possible justification for this assumption is that Ricardian households fully control the management of financial intermediaries, without necessarily holding their ownership (which could be partially held by HtM households).

[10] As in Gertler and Karadi (2013), we are implicitly assuming that each banker is a member of a specific household, so that the remaining depositors do not get any benefit from the diverted funds.

supply funds to the bank, the following incentive compatibility constraint must be satisfied

$$\mathcal{V}_t^b \geq \Psi_t^b Q_t K_t. \tag{21}$$

The left-hand side of eq. (21) is what the banker would lose by diverting a fraction of the bank's assets. The right-hand side is the gain from doing so.

The banker's maximization problem is to choose the sequence $\{B_t, Q_t K_t, B_t^*\}_{t=0}^{\infty}$ to maximize (20) subject to (19) and (21). The associated optimality conditions give

$$R_t^d = R_t^b = R_t^* \Phi_t \equiv R_t \tag{22}$$

$$Lev_t = \frac{\beta \mathbb{E}_t \left\{ \Lambda_{t,t+1}^b \Pi_{t+1}^{-1} R_t^d \right\}}{\Psi_t^b - \beta \mathbb{E}_t \left\{ \Lambda_{t,t+1}^b \left(R_{t+1}^l - \Pi_{t+1}^{-1} R_t^d \right) \right\}} \tag{23}$$

where we have defined the bank's adjusted discount factor

$$\Lambda_{t,t+1}^b \equiv \frac{\Lambda_{t+1}}{\Lambda_t} \left[\left(1 - s^b\right) + \left(s^b\right) \Psi_t^b Lev_{t+1} \right] \tag{24}$$

and the "risk-adjusted" leverage ratio

$$Lev_t = Q_t K_t / NW_t. \tag{25}$$

Notice that eq. (22) constitutes a no-arbitrage condition, and implies that the return on deposits and government bonds is equalized, and equal the interest rate at which financial intermediaries can borrow (or save) in the internationally financial markets. Thus, holding constant the monetary policy rate R_t^*, a change in the country spread Φ_t would lead to a one-to-one change in all domestic interest rates. Eq. (23) indicates instead the presence of an endogenous spread between the return on loans and the return on bonds, that depends on the bank's leverage.[11]

Aggregating across banks, we have that aggregate net worth evolves according to

$$NW_t = s^b \left[\left(R_t^l - \Pi_t^{-1} R_{t-1} \right) Lev_{t-1} + \Pi_t^{-1} R_{t-1} \right] NW_{t-1} + NW^e. \tag{26}$$

Also, the financial income transferred to the households in any period t is given by

$$F_t \equiv \left(1 - s^b\right) NW_t - NW^e + \left(1 - \tau_t^p\right) \mathcal{P}_t \tag{27}$$

which is the sum of the (net) payout from the banking sector, and the after-tax profits of intermediate good producers $\left(1 - \tau_t^p\right) \mathcal{P}_t$.

[11] In fact, if loans could not be diverted —i.e. if $\Psi^b = 0$—, then we would have $\Lambda_{t,t+1}^b = 1$, and thus the return on loans must equal the deposit rate $R_{t+1}^l = \Pi_{t+1}^{-1} R_t^d$, and the leverage ratio would be indeterminate.

Capital Producers

There is a continuum of perfectly competitive capital producers. In each period, a capital producer buys the existing capital (net of depreciation), makes new investment, and sells the new capital stock to firms. The evolution of the capital stock is given by

$$K_t = (1-\delta) K_{t-1} + \varepsilon_t^i \left(1 - a\left(\frac{I_t}{I_{t-1}}\right)\right) I_t \tag{28}$$

where I_t denotes investment, ε_t^i denotes an exogenous shock to investment, and $a\left(\frac{I_t}{I_{t-1}}\right)$ is adjustment cost function satisfying $a(1) = a'(1) = 0$.

The optimality condition of the capital producers is given by

$$1 - Q_t \varepsilon_t^i \left[1 - a\left(\frac{I_t}{I_{t-1}}\right) - a'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] = \beta \mathbb{E}_t \left\{\frac{\Lambda_{t+1}}{\Lambda_t} \varepsilon_{t+1}^i Q_{t+1} a'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\} \tag{29}$$

The optimal investment decision (29) implicitly determines the value of the cost of capital Q_t —often referred to as (marginal) Tobin's Q.

2.4 Firms

Production in the domestic economy takes place into three layers. In a first layer, an infinite number of monopolistically competing intermediate producers produce differentiated intermediate goods $Y_t(i)$, with $i \in [0,1]$, and set prices subject to nominal rigidities, modeled following the formalism of Calvo (1983). In the second layer, final good producers combine the differentiated intermediate domestic goods and sell them in competitive markets, both domestically and abroad. In the third layer, a continuum of domestic retailers combine the final domestic good and imports of foreign goods and sell the resulting bundle to satisfy domestic consumption and investment needs. Next, we characterize the decision problems faced by retailers, final good producers and intermediate goods producers, respectively.

Retailers

A continuum of perfectly competitive domestic retailers produce the composite good bundle $\mathcal{Y}_t$ according to the production function

$$\mathcal{Y}_t = \left[(1-\omega)^{\frac{1}{\varepsilon^x}} (Y_{d,t})^{\frac{\varepsilon^x - 1}{\varepsilon^x}} + \omega^{\frac{1}{\varepsilon^x}} (Y_{im,t})^{\frac{\varepsilon^x - 1}{\varepsilon^x}}\right]^{\frac{\varepsilon^x}{\varepsilon^x - 1}}$$

where $Y_{d,t}$ denotes the demand for domestic good, $Y_{im,t}$ are imports of foreign final goods, the parameter $\omega \in [0,1]$ can be interpreted as a measure of openness, and ε^x is the elasticity of substitution between domestic and imported goods. The cost minimization problem of a representative domestic retailer gives the demand for imported final goods

$$Y_{im,t} = \left(\frac{\omega}{1-\omega}\right) S_t^{-\varepsilon^x} Y_{d,t} \tag{30}$$

where $S_t \equiv P_t^*/P_{d,t}$ denote the terms-of-trade, and namely the ratio between the price of foreign and domestic goods, all expressed in the common currency of the monetary union (the Euro). In turn, the consumer price index (CPI) is given by $P_t = P_{d,t}\left[(1-\omega) + \omega\,(S_t)^{1-\varepsilon^x}\right]^{\frac{1}{1-\varepsilon^x}}$ which implies that the PPI-to-CPI ratio $p_{d,t} \equiv P_{d,t}/P_t$ must satisfy

$$(p_{d,t})^{\varepsilon^x - 1} = (1-\omega) + \omega\,(S_t)^{1-\varepsilon^x} \tag{31}$$

while CPI inflation satisfies

$$\Pi_t^{1-\varepsilon^x} = \Pi_{d,t}^{1-\varepsilon^x}\left[\frac{(1-\omega) + \omega\,(S_t)^{1-\varepsilon^x}}{(1-\omega) + \omega\,(S_{t-1})^{1-\varepsilon^x}}\right]. \tag{32}$$

Final good producers

The final domestic good is produced by a continuum of perfectly competitive producers, according to the production function

$$Y_t \equiv \left[\int_0^1 Y_t\,(i)^{\frac{\varepsilon^p - 1}{\varepsilon^p}}\,di\right]^{\frac{\varepsilon^p}{\varepsilon^p - 1}}$$

where $\varepsilon^p > 1$ denotes the elasticity of substitution between varieties produced domestically. The final good is then sold in both the domestic market (Y_{dt}) or exported to foreign countries (EX_t).

Cost minimization of final good producers implies that the demand for a specific domestic good variety at any given point in time t is given by

$$Y_t\,(i) = \left(\frac{P_{d,t}\,(i)}{P_{d,t}}\right)^{-\varepsilon^p} Y_t \tag{33}$$

where $P_{d,t} \equiv \left[\int_0^1 P_{d,t}\,(i)^{1-\varepsilon^p}\,di\right]^{\frac{1}{1-\varepsilon^p}}$ is the *domestic* producer price index (or PPI).

Intermediate Good Producers

Each intermediate good is produced by a monopolistically competitive firm $i \in [0,1]$ according to the production function

$$Y_t\,(i) = \varepsilon_t^a \left(K_{t-1}^g\right)^{\alpha_g} \left[\tilde{K}_t\,(i)\right]^{\alpha} \left[N_t^f\,(i)\right]^{1-\alpha} \tag{34}$$

where $N_t^f\,(i)$ denotes employment by the specific firm i, and ε_t^a is an exogenous productivity shock. The variable $\tilde{K}_t\,(i)$ denotes a composite between capital services $K_t^f\,(i) \equiv K_{t-1}\,(i)$ and energy $E_t\,(i)$, according to the aggregator

$$\tilde{K}_t(i) \equiv \left[(1-\nu^e)^{\frac{1}{\eta}} \left[K_t^f(i)\right]^{1-\frac{1}{\eta}} + (\nu^e)^{\frac{1}{\eta}} \left[E_t(i)\right]^{1-\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}} \tag{35}$$

where parameter $\nu^e \in [0,1]$ can be interpreted as a measure of energy dependence, while parameter $\eta > 0$ measures the substitutability between capital services and energy. Throughout, we assume that E_t is an input of production that is fully imported from abroad, and possibly from outside the monetary union, at an exogenously given price P_t^e.[12] Parameter $\alpha \in [0,1]$ determines instead the factor share of the capital-energy composite relative to labor. The term K_{t-1}^g indicates the public capital stock, which is assumed to be productivity enhancing, and α_g measures how influential public capital is on private production.

As explained earlier, at the beginning of each period a firm owns a stock of capital $K_{t-1}(i)$, purchased in the previous period at a price $Q_{t-1}$and financed with loans from financial intermediaries at (state contingent) interest rate R_t^ℓ. Firms choose how intensively to use the capital in production, which can be traded at the end of the period at a price Q_t. They also purchase energy at a price P_t^e, and purchase labor from labor intermediaries at the wage W_t^f. For convenience, we can separate their problem into two stages.

In a first stage, for given input prices and desired production level, cost minimization determines the optimal input choices. Due to the constant returns to scale technology, this implies that all firms choose the same factor input ratios and an identical marginal cost of production given by

$$\frac{K_t^f}{E_t} = \frac{1-\nu^e}{\nu^e}\left(\frac{P_t^e}{r_t^k}\right)^\eta \tag{36}$$

$$\frac{\tilde{K}_t}{N_t^f} = \left[\frac{W_t^f}{(1-\alpha)\,\varepsilon_t^a\left(K_{t-1}^g\right)^{\alpha_g}}\right]^{\frac{1}{\alpha}} [MC_t]^{-\frac{1}{\alpha}} \tag{37}$$

$$MC_t = \frac{1}{\varepsilon_t^a\left(K_{t-1}^g\right)^{\alpha_g}} \frac{\left(W_t^f\right)^{1-\alpha}}{\alpha^\alpha(1-\alpha)^{1-\alpha}} \left[(1-\nu^e)\left(R_t^k\right)^{1-\eta} + \nu^e\left(P_t^e\right)^{1-\eta}\right]^{\frac{\alpha}{1-\eta}} \tag{38}$$

which are independent from the individual firm level of production.

In a second stage firms optimally set prices, subject to the demand equation (33). Analogously to what described for the case of unions, the optimality condition of a generic domestic firm resetting its price $P_{d,t}^r$ in a given period t is given by

$$\mathbb{E}_t \sum_{k=0}^{\infty} (\beta\theta_p)^k \frac{Y_{t+k|t}}{P_{t+k}} \left[P_{d,t}^r X_{t,t+k}^d - \frac{\varepsilon^p}{\varepsilon^p - 1} MC_{t+k}\right] = 0. \tag{39}$$

[12]This specification is flexible, as it nests different possibilities as special cases. For instance, the limiting case with $\eta = 1$ corresponds to the standard Cobb-Douglas case, and thus labor, capital and energy will have a unitary elasticity of substitution. Instead, if $\eta < 1$ capital and energy are complements, thus meaning that energy become a more essential factor of production, in the sense that the elasticity of substitution between capital and energy is lower than the elasticity of substitution between the capital-energy composite and labor.

where $\mathcal{M}^p \equiv \frac{\varepsilon^p}{\varepsilon^p - 1} > 1$, $\theta_p \in [0,1]$ is a parameter determining the degree of price stickiness, while the term $X^p_{t,t+k} \equiv \left(\Pi^d_{t,t+k}\right)^{\iota_p} \left(\Pi^d\right)^{k(1-\iota_p)}$ denotes price-indexation to *domestic* producer price inflation (PPI) given by $\Pi^d_t \equiv \frac{P_{d,t}}{P_{d,t-1}}$, where the parameter $\iota_p \in [0,1]$ indicates the degree of inflation indexation.

Eq. (39) indicates that new prices are set as a markup over a weighted average of current and future the marginal costs. Using the definition of the PPI index, we then have that PPI inflation must satisfy

$$1 - \theta_p \left(\frac{\Pi^d}{\Pi^d_t}\right)^{(1-\iota_p)(1-\epsilon^p)} = (1-\theta_p)\left(\frac{P^r_{d,t}}{P_{d.t}}\right)^{1-\epsilon^p} \tag{40}$$

Also, integrating across all intermediate producers (who face the same marginal cost) we have that aggregate profits are given by

$$\mathcal{P}_t = \frac{P_{d,t}}{P_t}\left(1 - \frac{MC_t}{P_{d,t}}\right) Y_t. \tag{41}$$

2.5 Foreign Sector

The small open economy assumption implies that all foreign variables are exogenous relative to the domestic economy.

In particular, it is assumed that exports of the domestic economy (EX_t) are given by a constant price-elasticitity of demand function

$$EX_t = \left[\left(\frac{P_{d,t}}{P^*_t}\right)^{-\epsilon^*_p} \left(\alpha^* Y^*_t\right)\right] = \left(S_t\right)^{\epsilon^*_p} \left(\alpha^* Y^*_t\right) \tag{42}$$

where Y^*_t and P^*_t denote the foreign aggregate demand and the foreign price index, both of which evolve exogeneously, and the parameter α^* captures the impact of factors other than prices that may affect exports, while $\epsilon^*_p > 0$ captures the price elasticity of foreign demand.

Imports of the domestic economy are given by the sum of imports of foreign final goods $Y_{im,t}$ and energy E_t (which can be thought as a good imported from countries outside the EMU) at the corresponding (exogenous) prices P^*_t and P^e_t, respectively. Formally, total imports are given by

$$IM_t = \left(\frac{P^*_t}{P_t} Y_{im,t} + \frac{P^e_t}{P_t} E_t\right) = \frac{P_{d,t}}{P_t}\left(S_t Y_{im,t} + S^e_t E_t\right) \tag{43}$$

where $S^e_t \equiv P^e_t / P_{d,t}$ is the terms-of-trade for energy goods.

Defining net exports (expressed in terms of the CPI index) as

$$NX_t \equiv \frac{P_{d,t}}{P_t} EX_t - IM_t = \frac{P_{d,t}}{P_t}\left[\left(S_t\right)^{\epsilon^*_p}\left(\alpha^* Y^*_t\right) - \left(S_t Y_{im,t} + S^e_t E_t\right)\right] \tag{44}$$

and denoting with $b^*_t \equiv \frac{B^*_t}{P_t}$, the evolution of the real net foreign asset position (expressed in terms of the CPI index) is given by

$$b^*_t = \frac{R^d_{t-1}}{\Pi_t} b^*_{t-1} + NX_t. \tag{45}$$

Foreign output, foreign inflation and energy prices are assumed to evolve according to AR(2) process. Instead, the foreign interest rate is assumed to be adjusted according to the Taylor rule

$$R_t^* = \left(\bar{R}^*\right)^{\rho_{rr}} \left[(\Pi_t^*)^{\rho_{rp}} \left(Y_t^*/Y_{t-1}^*\right)^{\rho_{ry}}\right]^{1-\rho_{rr}} \exp\left(\epsilon_t^{r*}\right)$$

where $\rho_{rr} \in [0, 1)$, $\rho_{rp} > 1$ and $\rho_{ry} > 0$ are policy parameters, and ϵ_t^{r*} is an exogenous disturbance.

2.6 Fiscal Policy

The government provides transfers to both types of households $\left(T_t^H \text{and } T_t^R\right)$, and government spending (G_t), which is the sum of public consumption (C_t^g), public investment (I_t^g), and public employment expenditures. Following standard practices, we assume full home-bias in goverment purchases of goods and services, so that their nominal price equals the domestic PPI index $P_{d,t}$. We then have that real government spending —expressed in terms of the CPI index– is given by

$$G_t = \frac{P_{d,t}}{P_t}\left(C_t^g + I_t^g\right) + \frac{\hat{W}_t}{P_t} N_t^g \tag{46}$$

where N_t^g denotes public employment. The public capital stock at the end-of-period t is then given by

$$K_t^g = \left(1 - \delta^g\right) K_{t-1}^g + I_t^g. \tag{47}$$

The above expenditures are financed with direct taxes (on labor, profits, and financial income) and indirect taxes (on consumption) and social security contributions. Total tax revenues are then given by

$$\mathcal{T}_t = \tau_t^c C_t + \left(\tau_t^s + \tau_t^w\right) \frac{W_t}{P_t} N_t + \tau_t^p \mathcal{P}_t + \tau_t^y \left[F_t + \frac{\left(R_{t-1}^d - 1\right)}{\Pi_t} D_{t-1}\right] \tag{48}$$

where C_t, N_t and D_t denotes aggregate consumption, labor and savings, respectively.

The government primary balance is then given by

$$PB_t = \mathcal{T}_t - \left[G_t + \lambda^H T_t^H + \left(1 - \lambda^H\right) T_t^R\right] \tag{49}$$

Letting $b_t \equiv B_t/P_t$ denote the real government debt, the (period-by-period) government budget constraint is then given by

$$b_t = \frac{R_{t-1}^d}{\Pi_t} b_{t-1} - PB_t. \tag{50}$$

Dynamic sustainability of public debt requires the introduction of a debt rule that makes one or more fiscal instument to be adjusted in order to enforce the government's intertemporal budget constraint. Throughout, we assume that each fiscal instrument is adjusted in response to deviations of the debt-GDP ratio b_{t-1}/GDP_{t-1} in period $t-1$ to its long-run target $\bar{b}_y$, according to the following scheme

$$x_t = \bar{x} + \rho_x (x_{t-1} - \bar{x}) + (1-\rho_x)\phi_x \left(\frac{b_{t-1}}{GDP_{t-1}} - \bar{b}_y\right) + \varepsilon_t^x \tag{51}$$

where $x_t \in \left\{\tau_t^c, \tau_t^y, \tau_t^s, \tau_t^{sh}, \tau_t^p, \log C_t^g, \log I_t^g, \log N_t^g\right\}$, and $\bar{x}$ denotes the corresponding long-run target (or steady state value), $\rho_x \in [0,1)$ is the smoothing parameter, the parameter ϕ_x measures the responsiveness of the tax instrument to deviations of the debt-GDP ratio from target, and ε_t^x is an i.i.d. shock.

A similar fiscal rule is also assumed for lump-sum transfers, which however are also assumed to respond endogenously to economic fluctuations —a form of "automatic" stabilizers. Formally, for transfers T_t^x with $x \in \{H, R\}$ we assume the fiscal rule

$$\log T_t^x = \log \bar{T}^x + \rho_x \left(T_{t-1}^x - \log \bar{T}^x\right) + (1-\rho_x)\phi_x \left(\frac{b_{t-1}}{GDP_{t-1}} - \bar{b}_y\right) + \phi_{xU}\left(U_t^x - \bar{U}^x\right) + \varepsilon_t^x \tag{52}$$

where the parameter ϕ_{xU} measures the responsiveness of transfers to deviations of the unemployment rate U_t^x in deviations from its long-run target $\bar{U}^x$. In order to guarantee stability of the debt ratio, it suffices that the coefficient ϕ_x is non-zero (positive for tax instruments, and negative for expenditure instruments) for at least one instrument.[13]Public wages W_t^g are instead assumed to be constant in real terms, i.e. $W_t^g/P_t = \bar{w}^g$.

2.7 Market Clearing

In a competitive equilibrium, the following market clearing conditions should be satisfied. First, domestic demand must equal production of domestic retailers

$$(C_t + I_t) + \frac{P_{d,t}}{P_t}\left(C_t^g + I_t^g\right) = \mathcal{Y}_t = \frac{P_{d,t}}{P_t} Y_{d,t} + \frac{P_t^*}{P_t} Y_{im,t}. \tag{53}$$

Also, demand for domestic goods (from domestic or foreign agents) must equal domestic production of final goods

$$Y_t = Y_{d,t} + EX_t. \tag{54}$$

A definition of gross domestic product consistent with national accounting is then given by[14]

$$GDP_t = Y_t + (1+\tau_t^s)\frac{P_t}{P_{d,t}}\frac{W_t^g}{P_t}N_t^g + \delta^g K_{t-1}^g - \frac{P_t^e}{P_t}\frac{P_t}{P_{d,t}}E_t = \frac{P_t}{P_{d,t}}\left[C_t + I_t + G_t + \delta^g K_{t-1}^g + NX_t\right]. \tag{55}$$

Also, market clearing in the market for intermediate goods implies that

$$\int_0^1 Y_t(i)\, di = \varepsilon_t^a \left(K_{t-1}^g\right)^{\alpha_g} \int_0^1 \left[N_t^f(i)\right]^{1-\alpha} \left[\tilde{K}_t(i)\right]^{\alpha} di$$

[13]In practice, it suffices to assume a small responsiveness, consistently with standard results in the optimal fiscal policy literature, suggesting that the costs of (distortionary) fiscal adjustments should be smoothed over time.

[14]According to national accountings, government value added and government spending include public capital consumption δK_{t-1}^g.

or equivalently

$$Y_t \simeq \varepsilon_t^a \left(K_{t-1}^g\right)^{\alpha_g} \left[\frac{\tilde{K}_t}{N_t^f}\right]^{\alpha} N_t^f \tag{56}$$

where the last expression follows from the fact that $N_t^f = \int_0^1 N_t^f(i)\, di$, and $\int_0^1 Y_t(i)\, di = Y_t \Delta_t^p$, and where $\Delta_t^p \simeq \int_0^1 \left(\frac{P_{d,t}(i)}{P_{d,t}}\right)^{-\varepsilon^p} di$ is an index of price dispersion which equals 1 up to a first-order approximation around a steady state with constant inflation.

In the financial markets, market clearing for deposits requires

$$\frac{D_t}{P_t} = \left(1-\lambda^H\right)\frac{D_t^R}{P_t} + \lambda^H \underline{D}. \tag{57}$$

while market clearing for firms' capital requires

$$K_t^f \equiv \int_0^1 K_t^f(i)\, di = K_{t-1}. \tag{58}$$

Finally, market clearing in the labor markets requires that

$$N_t^H = N_t^R \equiv \tilde{N}_t = \int_0^1 N_t(\ell)\, d\ell = N_t \Delta_t^w \simeq N_t^f + N_t^g \tag{59}$$

where $\Delta_t^w \equiv \int \left(\frac{W_t(\ell)}{W_t}\right)^{-\varepsilon^w} d\ell$ is an index of price dispersion, which equals 1 up to a first-order approximation around a steady state with constant inflation.

3 Calibration and Estimation

We calibrate the model to quarterly frequency. Most structural parameters are calibrated so that the model deterministic steady-state replicates a number of targets for the Spanish economy calculated over the period 1995-2004, as summarized in Table 1.

As explained in more details in Appendix A.1, for given targets for GDP, the bank's leverage ratio, the unemployment rate, and the trade balance, the steady-state of the model can be obtained analytically, and recover the model parameters $\{\epsilon_n, \Theta^N, NW^e, \alpha^*\}$ to match those targets. The values of the resulting parameters are summarized in Table 2.

In particular, we normalize per-capita GDP to one both in the foreign and domestic economy ($Y^* = G\bar{D}P = 1$), which implies a labor disutility parameter $\varepsilon^n = 2.65$. Also, foreign (EMU) steady CPI steady-state inflation to 2% in annual terms, which implies that CPI and PPI inflation are equal both in the domestic and foreign economy, and given by $\Pi = \Pi^d = \Pi^* = (1.02)^{1/4}$ in our quarterly calibration. Furthermore, we set the net foreign assets positions $b^* = 0$, which implies that net exports $NX = 0$, and consequently that there is no spread between the domestic and foreign nominal interest rate, i.e. $R = R^* = \frac{1}{\beta}\Pi$ and $\log \Phi = 0$.

We set the capital income share parameter $\alpha = 0.4$ and the price elasticity parameter $\epsilon^p = 7$ so that labor income WN equals 38% of GDP, and profits equal 23% of GDP, which are very close to the corresponding ratios in Spain over the period 1995-2024. We also set the depreciation rate $\delta = 0.025$ and the discount factor $\beta = 0.9951$ so that private investment corresponds to about 18% GDP, as in the Spanish data, and the annualized real interest rate equals 2% per year. Also, we set the openness parameter $\omega = 0.33$ and the importance of energy $\nu^e = 0.07$ so that in steady state imports (and exports) equal 30% of GDP, with energy being 4.4% of GDP. We also set the elasticity of production to public capital $\alpha^g = 0.015$, and the elasticity of substitution between capital and energy $\eta = 0.7$.

Regarding Hand-to-Mouth households, we set their fraction to be $\lambda = 0.55$. We also set $\bar{d} = 0$, $\Xi_H = 1$ and $\Theta_H = 1$ which implies that Hand-to-Mouth households cannot borrow, do not receive any financial income, and their labor productivity is equal to those of Ricardian households.[15]

Regarding the labor market, as is standard in the literature, we set the (inverse) Frisch elasticity $\phi = 1$, the wage elasticity of labor demand $\epsilon^w = 8$, and the quarterly separation rate $s = 0.03$. We then set the matching efficiency parameter $\Theta_N = 1.1139$ so that the aggregate unemployment rate equals 12.5% in steady state.

Regarding financial markets, following Gertler and Karadi (2013), we set the banks' survival rate to $s_b = 0.975$, which implies an average life for a bank of 10 years. We then calibrate the financial constraint parameter $\Psi_b = 0.9194$ and the net worth of new banks $NW^e = 0.0103$ so that in steady the "risk adjusted" leverage equals 3, and the average deposit lending spread equals 2 percent per year.

Table 1: Steady State Ratios – Data vs Model

Variable (GDP shares)	**Data Spain (1995-2024)**	**Model**	**Description**
C	0.58	0.61	Consumption
I	0.18	0.18	Investment
NX	-0.001	0	Net Exports
WN	0.37	0.38	Labor Income
$\tau^c C$	0.085	0.088	Revenues from Consumption Taxes
$\tau^s WN$	0.093	0.096	Social Security Contributions (firms)
$\tau^{sh} WN$	0.034	0.035	Social Security Contributions (households)
$\tau^y (Y - \mathcal{P})$	0.077	0.077	Revenues from Personal Income Taxes
$\tau^p \mathcal{P}$	0.025	0.025	Revenues from Corporate Profits Taxes
C^g	0.076	0.076	Gov't Purchases
I^g	0.049	0.049	Gov't Investment
WN^g	0.070	0.072	Gov't Employment Expenditure
T	0.116	0.098	Transfers

The steady-state values of fiscal variables are calibrated so that each item matches the sample average of its counterpart in the data. To do, we assign each revenue and expenditure item in the classification of the Spanish administration (Intervención General de la Administración del Estado (IGAE)) is assigned to a corresponding variable in the model, as summarized in Table 4, so that the sum of revenues and expenditures provides a complete description of the government finances. Thus, we set the government

[15] In future work, we plan to calibrate these parameters based on household level data on consumption, income and wealth from the Bank of Spain (Encuesta Financiera de las Familias).

debt equal $\bar{b}$ to 74 percent of (annual) GDP, government consumption $\bar{C}^g = 0.0758$, government investment $\bar{I}^g = 0.0485$, and the share of public employment to total employment $\nu^g = N^g/N = 18.8$ percent, which corresponds to the ratio of Public Labor Income over Total Labor income. Transfers to Hand-to-Mouth households are set to $T^H = 0.0725$, and transfers to Ricardian households T^R are calculated residually so that the government budget constraint is satisfied given the values for the remaining fiscal variables. As a result, total transfers amount to about 6.6 percent of GDP.

Regarding tax rates, we set the consumption tax rate $\tau^c = 14.5\%$ so that consumption tax revenues equals 8.5% of GDP, personal income tax rate $\tau^y = 10.75\%$ so that the corresponding revenues $\tau^y (Y - \mathcal{P}) = 7.7\%$ of GDP, the corporate profit tax rate $\tau^p = 9.8\%$ so that the revenues $\tau^p \mathcal{P} = 2.5\%$, and the social security contribution rate of households and firms to be $\tau^{sh} = 9.19\%$ and $\tau^s = 25.12\%$ so that the corresponding revenues equal 3.5% and 9.6% of GDP, respectively.

Regarding the foreign sector, in line with Schmitt-Grohe and Uribe (2003), we specify the price elasticity of foreign demand $\epsilon_p^* = 0.5$, and and the sensitivity of the spread to the external debt $\phi_{\bar{d}} = 0.001$.

3.1 Estimated Parameters

We estimate the model over the 1995:Q1-2024:Q2 sample, considering as driving processes 9 fiscal shocks (on $\tau_t^c, \tau_t^y, \tau_t^s, \tau_t^{sh}, \tau_t^p, \log C_t^g, \log I_t^g, \log N_t^g$ and a shock to transfers T_t which is common for both type of households), 4 foreign shocks (to foreign output growth, inflation, energy prices, and interest rates), and 6 domestic macro shocks (technology ε_t^a, labor supply ε_t^n, wage markup ε_t^w, price markup ε_t^p, investment adjustment ε_t^i and discount factor ε_t^d).

As observables, we use the 9 fiscal variables and the 4 foreign variables described above, as well as Spanish data on GDP, consumption, investment (all in per capita terms, deflated using CPI deflator, and expressed in growth rates), the unemployment rate, wage inflation and price inflation. All variables are expressed in deviation from their sample mean.

The estimation exercise is conducted in two steps. In a first step, we estimate a VAR(2) model for the three (exogenous) foreign variables (GDP, inflation and energy prices) using standard methods. In a second step, we performed a Bayesian estimation of the DSGE model to estimate all the parameters related to the exogenous processes (standard deviations and persistence), all the parameters of the fiscal rules (51) and (52, as well as key parameters determining the response of macro variables to macro shocks like the capital adjustment cost, the degree of habits persistence, the degree of price and wage stickiness, and the elasticity of the matching function.

The values of the prior and the posteriors estimates are summarized in the Table 3.

The estimated parameters reveal systematic yet heterogeneous fiscal reactions to debt dynamics and the business cycle, providing quantitative evidence on the stabilizing role of fiscal responses in Spain. Notably, we find that government consumption and investment respond substantially to economic fluctuations and play an important role for stabilizing the Debt/GDP ratio. But an important stabilizing role is also played taxes, especially social security contributions.

Table 2: Calibrated Parameters

Text	**Value**	**Description**
Households & Financial Intermediaries		
β	0.9951	Discount factor
λ_H	0.55	Fraction of Hand-to-Mouth households
ϕ	1.0	Inverse Frisch Elasticity of Labor Supply
ε_n	2.65	Disutility of Labor
$\bar{d}$	0	Borrowing Limit for HtM households
δ	0.025	Depreciation Rate of Private Capital
Ξ_H	1	Productivity of HtM households
Ξ_R	1	Productivity of Ricardian households
Θ_H	0	Fraction of Financial Income given to HtM households
Θ_R	$\frac{1}{1-\lambda_H}$	Fraction of Financial Income given to Ricardian households
Supply Side: Labor Unions and Firms		
Θ_N	1.1139	Matching efficiency
s	0.03	Labor Separation rate
ϵ^w	8	Wage Elasticity of Labor Demand
ϵ^p	7	Price Elasticity of Demand
ι_p	0.5	Price indexation to past inflation
ι_w	0.5	Wage indexation to past inflation
ν^e	0.07	Importance of energy in production
η	0.7	Elasticity of substitution between capital and energy
α^g	0.015	Influence of public capital in production
α	0.4	Production share of capital-energy composite
External Sector		
$\phi_{\bar{d}}$	0.001	Sensitivity of spread to NFA position
ω	0.33	Openness of domestic economy
ϵ^x	0.85	Elasticity of Substitution between foreign and domestic goods
ϵ_p^*	0.5	Price elasticity of foreign demand
Tax rates		
τ^c	0.1450	Average consumption tax rate
τ^y	0.1075	Average personal income tax rate
τ^{sh}	0.0919	Average social security tax rate (households)
τ^s	0.2512	Average social security tax rate (firms)
τ^p	0.098	Average corporate profits tax rate
Government Expenditures and Debt		
c^g	0.0758	Average government consumption
i^g	0.0485	Average government investment
ν^g	0.1881	Average share of public employment over total employment
T^H	0.0725	Average transfers to HtM households
T^R	0.0586	Average transfers to Ricardian households
δ^g	0.016	Depreciation rate of government capital
$\bar{b}$	0.74×4	Average debt/GDP ratio (quarterly)

Table 3: Estimated parameters

Parameters	Post. Mean	90% HPD Interval	Prior	Prior Mean	Pstdev
Shocks Persistence					
ρ_{τ^c}	0.8483	[0.8430, 0.8528]	Beta	0.800	0.1000
ρ_{τ^s}	0.8558	[0.8504, 0.8610]	Beta	0.800	0.1000
$\rho_{\tau^{sh}}$	0.8491	[0.8444, 0.8546]	Beta	0.800	0.1000
ρ_{τ^p}	0.8615	[0.8551, 0.8683]	Beta	0.800	0.1000
ρ_{τ^y}	0.6449	[0.6370, 0.6549]	Beta	0.500	0.1000
ρ_{c^g}	0.9079	[0.9035, 0.9119]	Beta	0.800	0.1000
ρ_{i^g}	0.6404	[0.6338, 0.6480]	Beta	0.500	0.1000
ρ_{n^g}	0.8993	[0.8924, 0.9060]	Beta	0.800	0.1000
ρ_{TH}	0.9031	[0.8955, 0.9106]	Beta	0.800	0.1000
ρ_d	0.3920	[0.3899, 0.3940]	Beta	0.500	0.1000
ρ_n	0.8997	[0.8959, 0.9025]	Beta	0.800	0.1000
ρ_i	0.4117	[0.4067, 0.4150]	Beta	0.500	0.1000
ρ_a	0.4029	[0.4003, 0.4059]	Beta	0.400	0.1000
ρ_w	0.7944	[0.7914, 0.7974]	Beta	0.800	0.1000
ρ_p	0.8619	[0.8527, 0.8711]	Beta	0.800	0.1000
Shocks Standard Deviations					
ϵ_{τ^c}	0.0093	[0.0083, 0.0103]	Inv. Gamma	0.010	2.0000
ϵ_{τ^y}	0.0289	[0.0252, 0.0323]	Inv. Gamma	0.010	2.0000
ϵ_{τ^p}	0.1394	[0.1277, 0.1544]	Inv. Gamma	0.050	2.0000
ϵ_{τ^s}	0.0064	[0.0059, 0.0068]	Inv. Gamma	0.050	2.0000
$\epsilon_{\tau^{sh}}$	0.0060	[0.0059, 0.0061]	Inv. Gamma	0.050	2.0000
ϵ_{c^g}	0.0185	[0.0163, 0.0206]	Inv. Gamma	0.050	2.0000
ϵ_{i^g}	0.1571	[0.1403, 0.1759]	Inv. Gamma	0.100	2.0000
ϵ_{n^g}	0.0256	[0.0231, 0.0280]	Inv. Gamma	0.050	2.0000
ϵ_T	0.0511	[0.0511, 0.0458]	Inv. Gamma	0.050	2.0000
ε^d	0.1701	[0.1509, 0.1911]	Inv. Gamma	0.050	2.0000
ε^i	0.5923	[0.5435, 0.6491]	Inv. Gamma	0.050	2.0000
ε^n	0.0795	[0.0717, 0.0865]	Inv. Gamma	0.050	2.0000
ε^a	0.1160	[0.1003, 0.1302]	Inv. Gamma	0.050	2.0000
ε^w	0.0428	[0.0387, 0.0468]	Inv. Gamma	0.050	2.0000
ε^p	0.0752	[0.0674, 0.0845]	Inv. Gamma	0.050	2.0000
Fiscal Responses to Debt/GDP ratio					
ϕ_{τ^c}	0.0167	[0.0158, 0.0173]	Norm	0.000	1.0000
ϕ_{τ^s}	0.0381	[0.0373, 0.0388]	Norm	0.000	1.0000
$\phi_{\tau^{sh}}$	0.0185	[0.0176, 0.0195]	Norm	0.000	1.0000
ϕ_{τ^y}	0.0221	[0.0214, 0.0229]	Norm	0.000	1.0000
ϕ_{τ^p}	0.0195	[0.0187, 0.0203]	Norm	0.000	1.0000
ϕ_{c^g}	-0.0466	[-0.0477, -0.0456]	Norm	0.000	1.0000
ϕ_{i^g}	-0.0259	[-0.0271, -0.0249]	Norm	0.000	1.0000
ϕ_{n^g}	0.0193	[0.0179, 0.0209]	Norm	0.000	1.0000
ϕ_{TH}	-0.0079	[-0.0090, -0.0066]	Norm	0.000	1.0000
ϕ_{TH_U}	-0.0161	[-0.0168, -0.0155]	Norm	0.000	1.0000
Macro Parameters					
$c_{adjcost}$	5.1490	[5.0793, 5.2099]	Norm	3.500	1.5000
θ_w	0.7480	[0.7477, 0.7484]	Beta	0.700	0.0200
θ_p	0.7499	[0.7491, 0.7505]	Beta	0.700	0.0200
θ_N	0.3093	[0.3012, 0.3156]	Beta	0.500	0.1500
$\mathcal{H}$	0.2083	[0.2007, 0.2151]	Beta	0.500	0.1500

4 Main Applications

The purpose of this section is to illustrate several potential applications of the MEGAIReF model. Specifically, we use it to analyze the effects of macroeconomic shocks, to assess the determinants of fiscal multipliers, and to compute Laffer curves for the Spanish economy.

4.1 The Effects of Macro Shocks

We start by analyzing the effects of transitory macroeconomic shocks on our main variable of interests over a 10-year (40 quarters) horizon.

4.1.1 A 1% increase in technological capacity

Figure 2 shows the effects of a transitory increase in total factor productivity by 1 percent. As illustrated, the effect on GDP is expansionary and persistent. In the short-run, this is mainly driven by the improvement in net exports, while at longer horizons it is sustained by an increase in domestic demand (consumption and investment).

Specifically, higher productivity reduces firms' marginal costs of production. In a flexible price economy, this would induce firms to reduce prices, thereby stimulating both domestic and foreign demand, and increasing output. In contrast, in our economy, nominal rigidities prevent firms from fully adjusting their prices in the short-run. As a result, demand is weaker than in the flexible price case. Consequently, labor demand is also weaker, exerting downward pressures on wages and further dampening domestic demand. This mechanism is reinforced by the rise in the real interest rate: as domestic prices fall, the nominal interest rate remains unchanged because the central bank targets the entire monetary union, leading to a higher real rate that further depresses consumption.

In the medium-run, as prices gradually adjust to reflect lower marginal costs, domestic demand increases. Moreover, the higher marginal productivity of labor leads to an increase in real wages.

The technology shock also improves public finances, reducing the debt ratio and raising the primary balance. However, the debt-to-GDP ratio may temporarily rise on impact, as the higher real interest rate increases the value of the outstanding debt burden. By contrast, and as shown in details in Figure 3, the primary balance —net of interest payments— improves. One the one hand, higher productivity expands the tax base, thus leading to higher tax revenues. This is mainly driven by higher revenue from personal income taxes and corporate profit taxes, which more than offsets the drop in social-security contributions due to the (temporary) decline in employment. On the other hand, public expenditures decline in terms of GDP, due both to the increase in GDP and to the reduction of domestic prices (given the assumed home-bias in government purchases).

As prices and quantities adjust, the primary balance gradually returns toward its steady state, while the debt-to-GDP ratio continues to decline, reflecting the higher level of potential output.

4.1.2 A 1% increase in the interest rate spread

Figure 4 reports the effects of a negative demand shock, modeled as a 1% increase in the interest rate spread between the domestic and Euro-area interest rate. As illustrated, GDP falls persistently, driven by a sharp contraction in investment and a milder decline in consumption. The increase in the spread raises the real interest rate, which dampens both consumption and investment. In turn, this reduces

Figure 2: Impulse Responses to a 1% Technology Shock

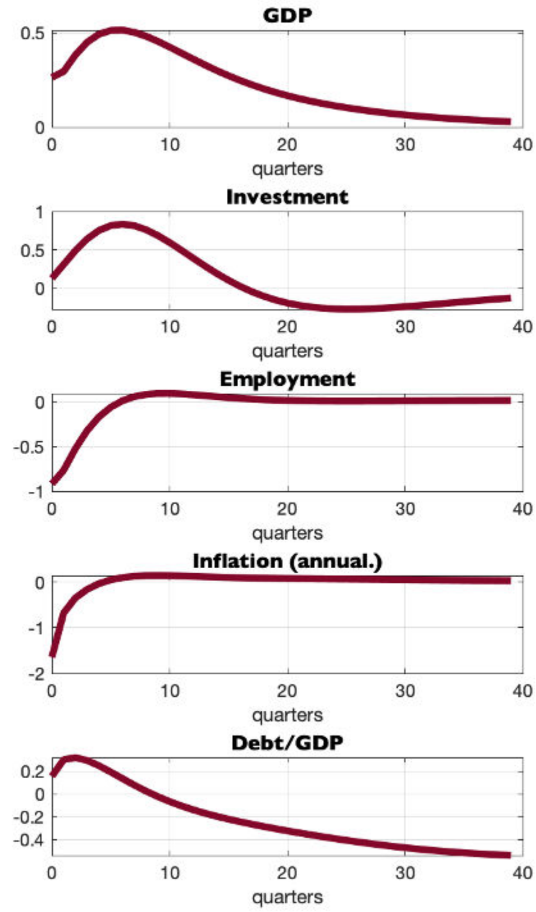
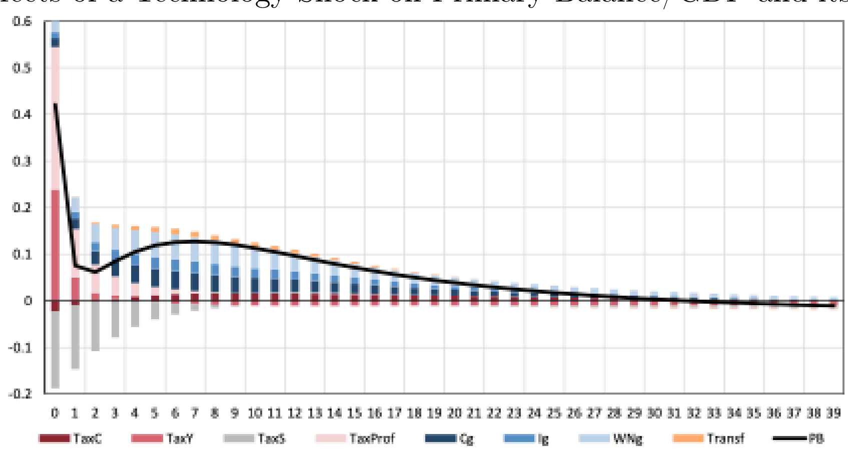


Figure 3: Effects of a Technology Shock on Primary Balance/GDP and its components



firms' demand for labor, leading to lower real wages and employment, which further depresses aggregate demand and amplifies the downturn.

The fiscal implications of this shock are adverse. The debt-to-GDP ratio rises persistently, while the primary balance slightly decreases. Both the higher spread and the accompanying decline in inflation

Figure 4: Impulse Responses to a 1% Interest Rate Shock

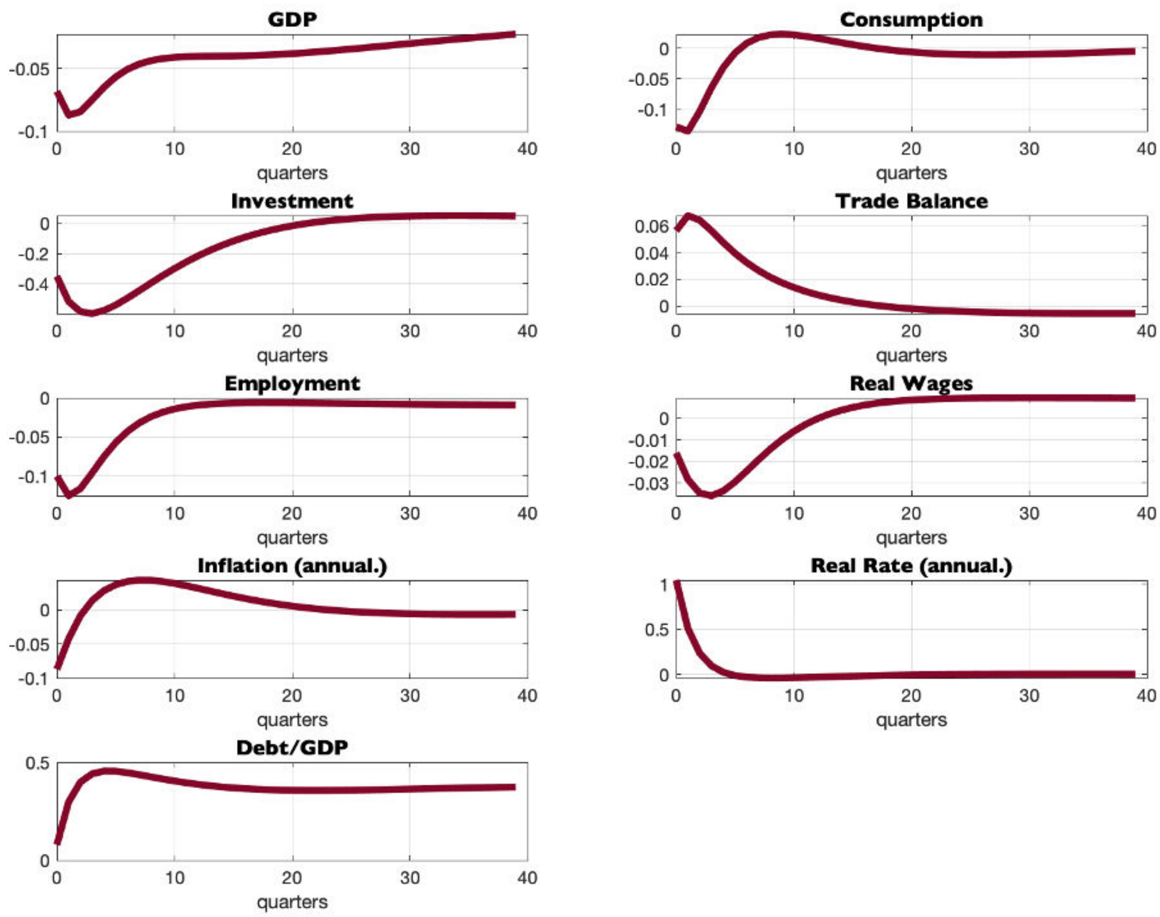
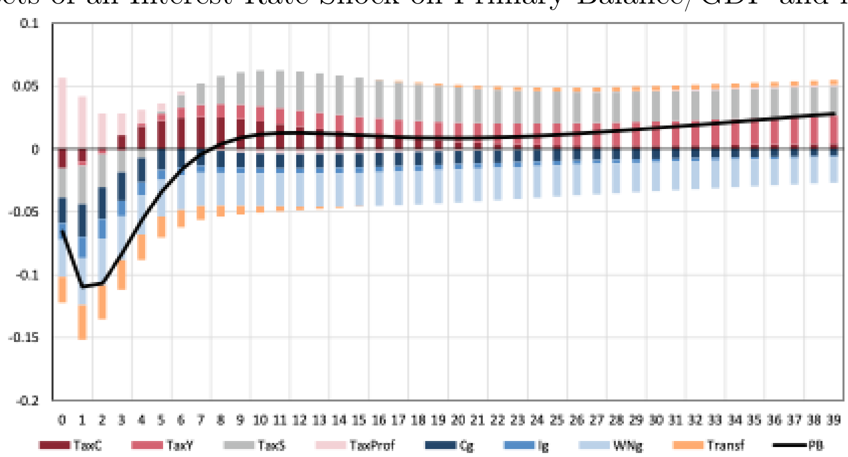


Figure 5: Effects of an Interest Rate Shock on Primary Balance/GDP and its components



contribute to raise the real interest rate and, consequently, the real value of the public debt burden. Additionally, the fall in GDP contributes mechanically to the increase in the debt/GDP ratio.

Figure 5 decomposes the change in the primary balance (relative to GDP) following the negative spread shock. As shown, in the first quarters the primary balance deteriorates slightly, as a result of the increase in transfers to Hand-to-Mouth households, aimed at offsetting the reduction in their income. Similarly, there is also a notable negative contribution from public employment expenditure: since public employment and wages are fixed, a decline in inflation leads to an increase in the real wage of public employees, which in turn raises total expenditure. However, the deterioration of the primary balance is modest. As the economy recovers and adjusts to its new equilibrium, transfers decrease and the primary balance improves.

4.2 Determinants of the Fiscal Multiplier

The MEGAIReF model features a granular representation of fiscal policy, including a detailed disaggregation of government expenditure into its main components: purchases of goods and services, compensation of public employees, public investment, and transfers to households. A key dimension in evaluating the macroeconomic effects of fiscal policy is the estimation of fiscal multipliers.

From an empirical standpoint, a large body of literature has examined the response of output to government spending shocks, employing a wide range of identification strategies (see e.g. Ramey, (2014)). Batini et al. (2014) provide a synthesis of the main structural and cyclical factors shaping the size of fiscal multipliers.

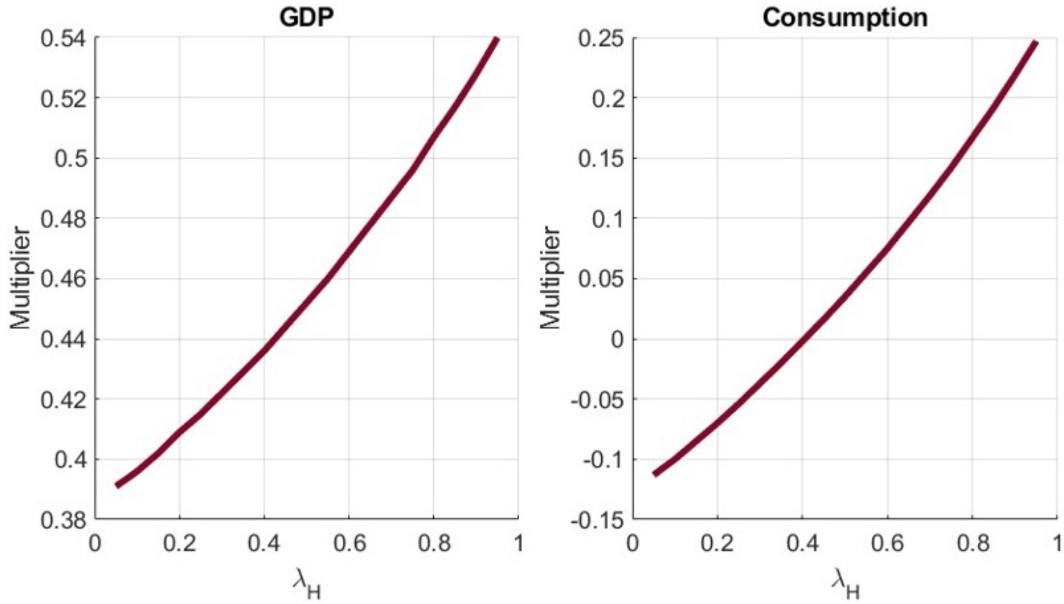
Structural determinants include the degree of trade openness (countries that are less open to trade, or larger economies with low import propensity, tend to exhibit higher multipliers), the extent of labor market rigidities (limited wage flexibility amplifies the output response to demand shocks), the size of automatic stabilizers (large automatic stabilizers, whose countercyclical effects offset part of the fiscal impulse, tend to reduce multipliers), the exchange rate regime (flexible exchange rate regimes are associated with smaller multipliers, as exchange rate movements can partly neutralize the effects of fiscal policy on output), and the level of public debt (high-debt countries usually experience lower multipliers).

Regarding cyclical determinants, both the position in the business cycle (multipliers tend to be larger during downturns, as unused resources and credit constraints amplify the effects of government expenditure) and the degree of monetary accommodation have a significant impact on the size of fiscal multipliers.

Recent theoretical work highlights the role of agent heterogeneity as a key determinant of the government expenditure multiplier. The MEGAIReF model, which is a TANK DSGE model for Spain, incorporates household heterogeneity, nominal and real frictions, and a rich fiscal structure. This allows for an in-depth comprehensive assessment of the mechanisms underlying the size of government spending multipliers.

The main results of our analysis are summarized in Figure 6 which shows the values of government spending multipliers on GDP and consumption, over a 1-year horizon, and for different values of the share of HtM households (λ_H). Firstly, in the baseline calibration with $\lambda_H = 0.55$, the MEGAIReF

Figure 6: Heterogeneity and Fiscal Multipliers (1-year horizon)



model yields a value of 0.46. This estimate is in line with the result reported by Stahler and Thomas (2021) using the FiMOD model (0.6).[16]

The value obtained in MEGAIReF fall within the empirical range of values found for Spain. For instance, De Castro and Hernández de Cos (2006) estimate a government consumption multiplier of about 0.6 after four quarters. Similarly, Hernández de Cos and Moral-Benito (2013) find the government consumption multiplier varies significantly across the cycle (0.2 in expansionary, 2.07 during recessions).

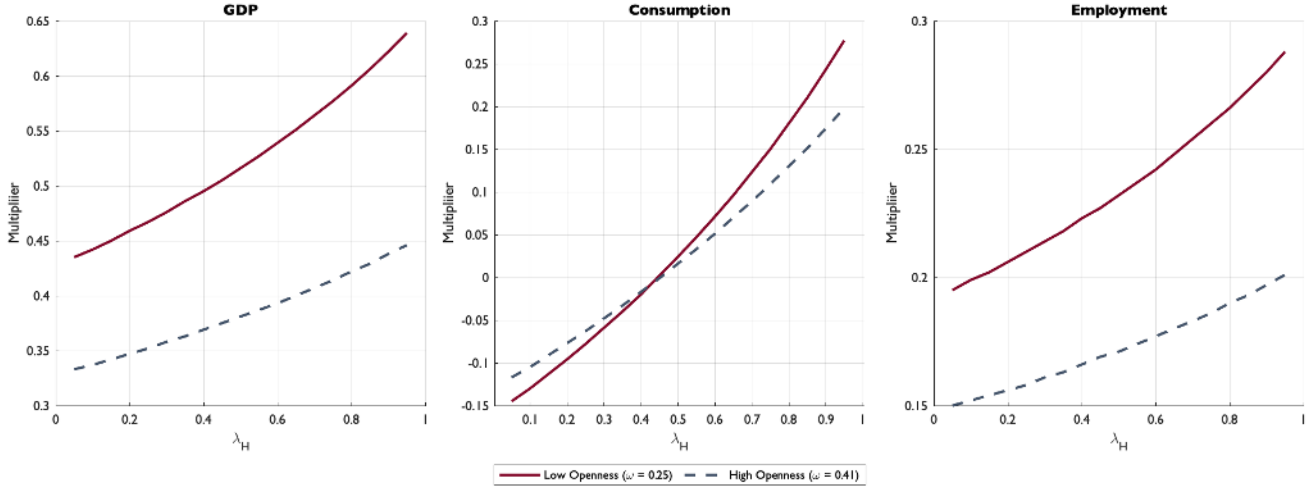
Secondly, the degree of agent heterogeneity, measured by the share of hand-to-mouth households, also affects the size of the government spending multiplier. The multiplier for GDP after 4 quarters increases monotonically with the share of HtM households, as liquidity constraints amplify the consumption response to fiscal expansions. However, the overall effect remains relatively moderate: the multiplier rises only from 0.38 when the share of HtM households is at its minimum to 0.54 when the economy is almost entirely composed of HtM households. Nevertheless, the sensitivity of the private consumption multiplier is even greater: when HtM households are few, public spending crowds out private consumption, leading to a negative consumption multiplier.

The limited sensitivity of the government spending multiplier to the share of hand-to-mouth households in MEGAIReF may reflect several offsetting mechanisms.For instance, the open-economy structure, implies that part of the fiscal impulse leaks via imports. Second, the spread on sovereign debt increases with external indebtedness, raising financing costs and dampening the fiscal impulse.

To study the interaction between openness and household heterogeneity, we consider two possible scenarios: a more closed economy ($\omega = 0.2475$) and a more open economy ($\omega = 0.4125$), compared to the base calibration of the model ($\omega = 0.33$), and simulate a 1% increases in government purchases of good and services. As shown in Figure 7, the government consumption multiplier on GDP is higher

[16]On impact, the fiscal multiplier in MEGAIReF is 0.52, which is lower than the impact multiplier of approximately 1 obtained by Boscá et al. (2010) with the REMS model.

Figure 7: Fiscal Multipliers, Heterogeneity and Openness

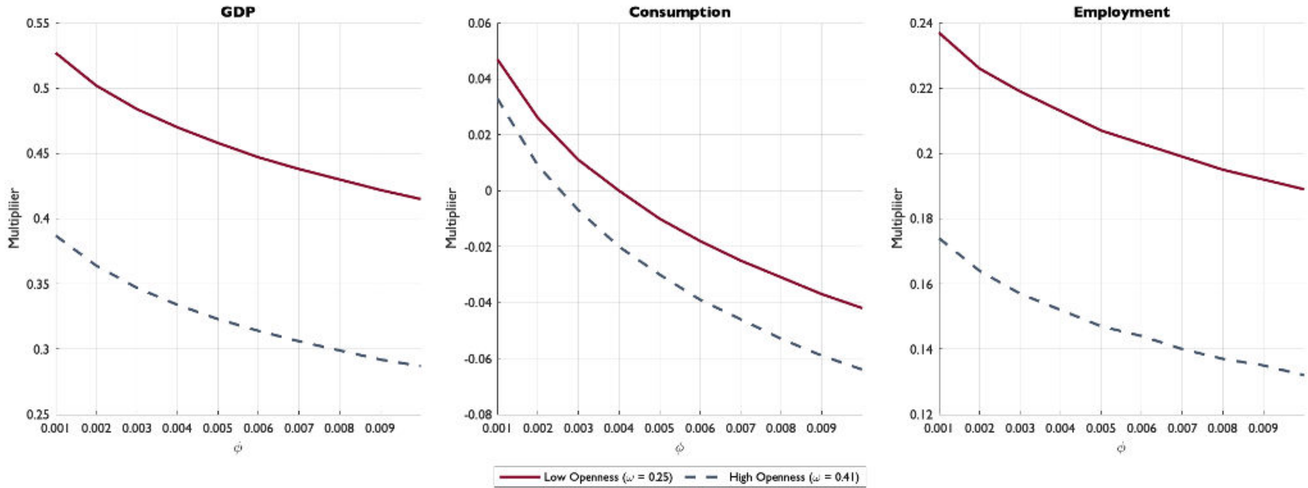


in the more closed economy for all values of the HtM share. This is consistent with standard theory and empirical evidence: in more open economies, the fiscal impulse is partially leaked to the rest of the world, through imports. More interestingly, the slope of the multiplier-HtM curve is steeper in the relatively more closed economy, indicating a stronger amplification effect of liquidity constraints in closed economies. The underlying mechanism is that higher consumption by HtM households is more likely to be met by domestic production, rather than by imports, hence generating a larger output response.

The employment multiplier exhibits a pattern similar to that of GDP. For private consumption, the open-economy curve intersects the closed economy curve at levels of the share of HtM households for which the consumption multiplier is negative. This intersection highlights the stronger effectiveness of fiscal policy in the closed economy setting. When the share of HtM households is low, public consumption tends to crowd out private consumption. However, in the open economy, part of this contraction is absorbed through imports, resulting in a more muted decline in total consumption relative to the closed economy.

To assess the role of financial constraints in shaping the expansionary effects of fiscal policy in the Spanish economy we examine the sensitivity of the sovereign spread to the stock of external debt ($\phi = 0.001$ in the base calibration) under the same two openness scenarios as before. Results are summarized in Figure 8. A higher sensitivity of the spread dampens the multiplier: as the fiscal impulse unfolds, import demand also rises, leading to a deterioration of the trade balance and an accumulation of external debt. The resulting increase in external debt raises the sovereign spread, which in turn leads to higher domestic interest rates, thereby crowding out domestic demand. This mechanism is more pronounced in the open economy, where imports respond more strongly to the fiscal impulse, amplifying both the trade deficit and the accumulation of external liabilities. Notably, the fiscal multiplier becomes highly sensitive to the spread parameter, particularly in the open economy, where the multiplier curve declines rapidly, displaying a steep negative slope.

Figure 8: Fiscal Multipliers and Sovereign Spread Sensitivity



4.3 Laffer Curves

In this section we examine the relationship between steady state public revenues and tax rates on personal income, employee social security contribution, and VAT rate. In each case, we consider a permanent changes in a single tax rates, and calculate the corresponding change in total public revenues while leaving unchanged the remaining model parameters.

Figure 9 illustrates the effects of varying the personal income tax rate (excluding social security contributions), ranging from 0 to 80%. As expected, there is highly nonlinear relationship between the tax rate and tax revenues, known as the Laffer curve. For low levels of the income tax rate, an increase in tax rates leads to an increase in tax revenues —even though less-than-proportional to the resulting decline in GDP. But beyond a certain level, tax revenues decrease: according to our analysis, the peak of the Laffer curve is reached when the (effective) personal income tax rate is about 60%, which is substantially higher than the current value in the Spanish economy (10.65 % in our baseline calibration).

Similarly, Figure 10 shows the effect on public revenues of permanent changes in employee social security contributions. As can be seen, the relationship between the two variables is also nonlinear, although in this case the distortionary effect of the tax is stronger than for personal income taxes —i.e. tax increases are associated with larger declines in GDP. In this respect, it should be noted that in MEGAIReF social contributions are levied exclusively on labor income, while personal income tax also applies to capital income. Yet, also in this case the peak of the Laffer curve is reached at an (effective) rate of about 60%, which is well above the current rate in the Spanish economy (9.2% in our baseline calibration).

Finally, Figure 11 examines the relationship between the consumption tax rate and public revenues. In this case, the relationship between the two variables is slightly nonlinear and the slope remains positive for the range of values considered (a maximum tax rate of 80 %), meaning that fiscal revenue does not reach a maximum. This result suggests that, to achieve the same level of public revenues, a consumption tax is less distortionary than an income tax. This outcome is due to the theoretical

Figure 9: Personal Income Tax Laffer Curve

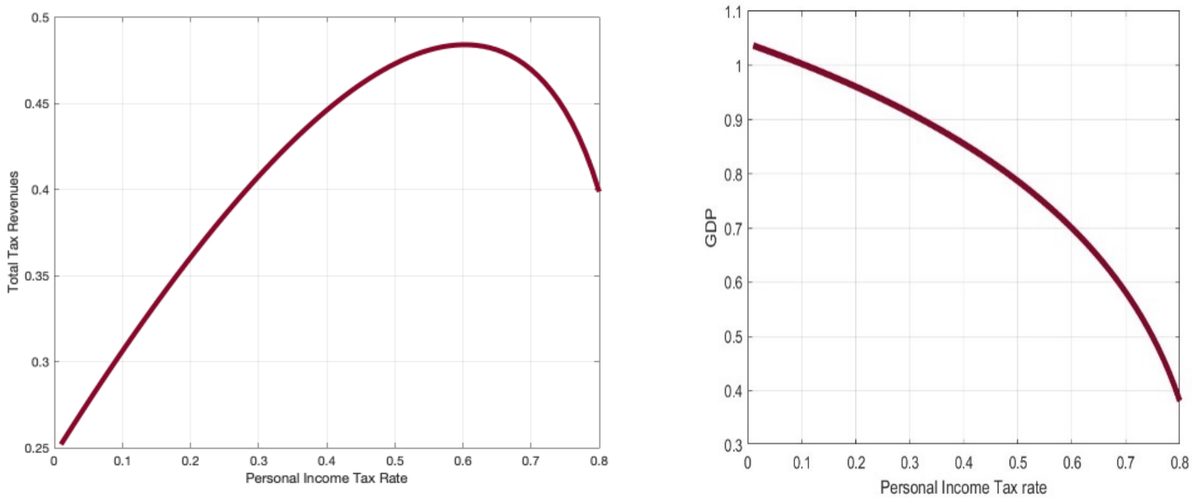
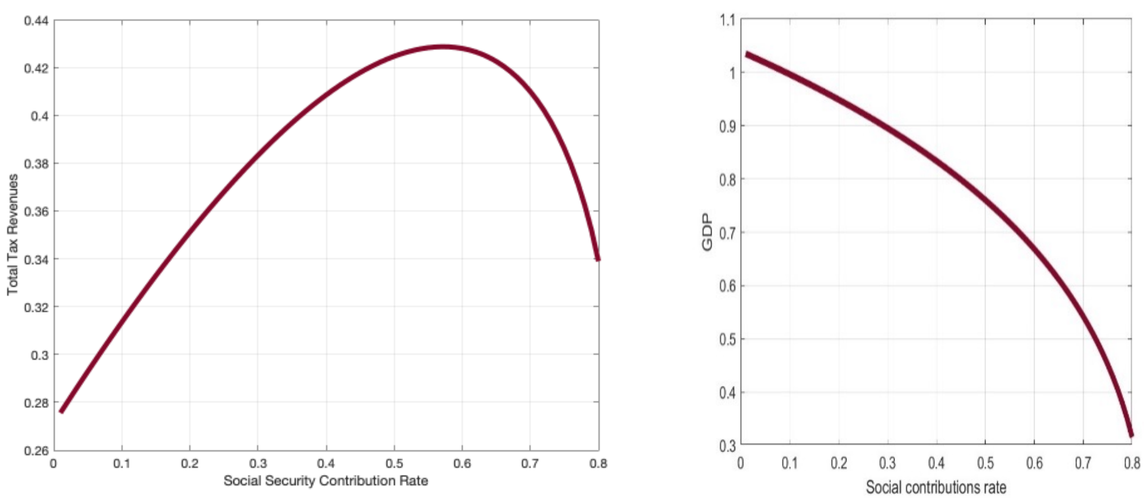
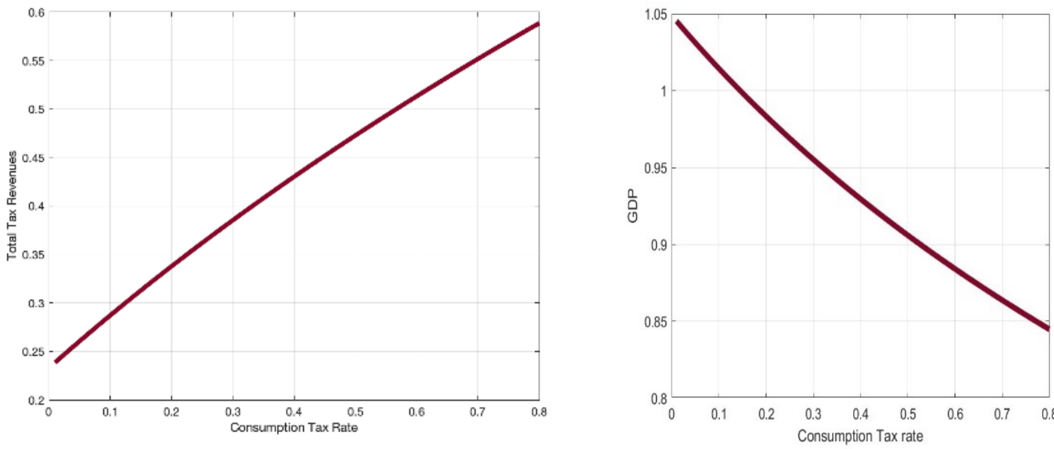


Figure 10: (Employee) Social Security Contributions Laffer Curve



possibility of setting a consumption tax above 100%, so that the revenue-maximizing rate would lie beyond this range.[17] These results are consistent with other analysis of the Laffer curve for both the Eurozone (e.g., Vogel (2014) and Trabandt and Uhlig (2010)), and Spain (Boscá et al., 2017).

Figure 11: Consumption Tax Laffer Curve



5 Conclusions

MEGAIReF offers a coherent framework to evaluate the effectiveness of fiscal policy in a small open economy with household heterogeneity, real and nominal rigidities, and an active fiscal sector. Its results confirm key theoretical predictions and align with empirical findings, while also emphasizing the importance of structural features –such as openness and liquidity constraints– in shaping fiscal multipliers.

Our applications show how MEGAIReF can provide useful insights on the determinants of fiscal multipliers and the macroeconomic impact of fiscal policy. The analysis could be extended to disentangle the effects across different types of public spending (consumption, investment, employment). Additionally, further analysis could explore the distributional impacts of fiscal shocks, as well as their effects on inflation, and the fiscal balance and its composition, particularly in light of MEGAIReF's endogenous fiscal rules and financial frictions. Finally, through the lens of the estimated model, it would be possible to identify the role of macro shocks in driving fluctuations in the primary balance and government debt over the past decades.

[17] Clearly, for the case of personal income tax and social security contributions, a rate above 100 is not feasible, as it would imply that the tax base would also go to zero.

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Appendix

A.1 The Steady State

The steady state of the model can be obtained as follows. First, let's normalize $GDP = 1$ and fix $NX = 0$, $\Pi = \Pi^* = \Pi_d = (1.02)^{1/4}$. Also we set $p_d = p^e = 1$ which from (31) implies that the terms of trade $S = 1$, and thus and thus from the definition of terms of trade $S_t \equiv P^*_t/P_{d,t}$ it follows that

$$p^* = S = S^e = 1.$$

Then, equation (45) and the fact that $NX = 0$ implies that the net-foreign-assets position $b^* = 0$. Also, we target a real rate 2% per year, which implies a (gross) nominal interest of $R = (1.02)^{1/4}\,\Pi$, and set all fiscal variables to their average values over our sample. Using the household Euler equation (3), this implies that the discount factor should be set to

$$\beta = \left[R - \tau^y\left(R^d_t - 1\right)\right]^{-1}\Pi$$

The steady state can then be obtained analytically as follows.

- From the optimality condition of capital producers (29) we get $Q = 1$. Then, from the banks' decisions —eqs. (16) - (26), and for fixed targets for the equilibrium credit spread $SpreadK$ we have

$$\begin{aligned}
\log\Phi &= 0 \\
R &= R^* \\
R^l &= R + SpreadK \\
r^k &= R^l - (1-\delta)
\end{aligned}$$

- On the **Supply Side** we get from the firms' price setting decision (39) that the real marginal cost is

$$mc = p_d\left(\mathcal{M}^p\right)^{-1}.$$

  Using (38) we can then solve for the real labor cost paid by firms

$$w^f = \left\{\frac{mc\left(K^g\right)^{\alpha_g}\left[\alpha^\alpha\left(1-\alpha\right)^{1-\alpha}\right]}{\left[\left(1-\nu^e\right)\left(r^k\right)^{1-\eta} + \nu^e\left(p^e\right)^{1-\eta}\right]^{\frac{\alpha}{1-\eta}}}\right\}^{\frac{1}{1-\alpha}}$$

  Also, from (35)-(37) we have the ratios

$$\frac{K^f}{E} = \frac{1-\nu^e}{\nu^e}\left(\frac{p^e}{r^k}\right)^{\eta}$$
$$\frac{\tilde{K}}{E} \equiv \left[(1-\nu^e)^{\frac{1}{\eta}}\left[\frac{K^f}{E}\right]^{1-\frac{1}{\eta}} + (\nu^e)^{\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$$
$$\frac{\tilde{K}}{N^f} = \left[\frac{w^f}{(1-\alpha)(K^g)^{\alpha_g}}\right]^{-\frac{1}{\alpha}}[mc]^{\frac{1}{\alpha}}$$

Using the production function (56) we get the ratio

$$\frac{N^f}{Y} = \left[(K^g)^{\alpha_g}\left[\frac{\tilde{K}}{N^f}\right]^{\alpha}\right]^{-1}$$

and since we have fixed steady state government employment to be a fixed proportion ν^g of total empoyment we have that

$$\frac{N}{Y} = \frac{N^f+N^g}{Y} = \frac{N^f+\nu^g N}{Y}$$
$$\Rightarrow \frac{N}{Y} = \frac{1}{1-\nu^g}\frac{N^f}{Y}$$
$$\Rightarrow \frac{N^g}{Y} = \nu^g \frac{N}{Y}$$

From the above capital ratios we can also calculate $\frac{\tilde{K}}{Y} = \frac{\tilde{K}}{N^f}\frac{N^f}{Y}$, $\frac{E}{Y} = \frac{\tilde{K}}{Y}\left(\frac{\tilde{K}}{E}\right)^{-1}$ and $\frac{K^f}{Y} = \frac{K}{Y} = \frac{K^f}{E}\frac{E}{Y}$, and eq. (28) implies that $\frac{I}{Y} = \delta\frac{K}{Y}$.

- From the **market clearing** conditions (55) we can obtain the level of gross output

$$Y = \left[p_d + w^g(1+\tau^s)\frac{N^g}{Y} - p^e\frac{E}{Y}\right]^{-1}\left(\underbrace{GDP}_{1} - \delta^g K^g\right)$$

which can be combined with the previous ratios to obtain the levels of production factors $\tilde{K}$, N, N^f,N^g, and thus aggregate investment and consumption

$$I = \delta K$$
$$C = GDP - I - G - \delta^g K^g.$$

- Now, from the Labor Supply equations (7), (8) and (11), and for given given the exogenous public wages w^g it must be that

$$\hat{w} = \frac{N^f w^f + N^g(1+\tau^s)w^g}{N_t}$$

$$w = \frac{\hat{w} - [1 - \beta(1-s)] \frac{1}{\Theta^N} \left(\frac{sN}{U}\right)^{\frac{\theta^N}{1-\theta^N}}}{1+\tau^s}$$

and

$$w = \mathcal{M}^w \varepsilon_n \frac{1+\tau^c}{1-\tau^w} \bar{\Xi} (N)^{\varphi}.$$

Given a target value for the steady state hiring costs $\Theta^N \left(\frac{sN}{U}\right)^{\theta^N}$ and the separation rate, the second equation can be used to get the real wage, and the last equation can be used to calibrate the disutility of labor parameter ε_n. The remaining supply side variables can be obtained from the firm's optimality conditions.

- From eqs. (25) it is then possible to obtain net worth $NW = K/Lev$, and use (26) to calibrate the parameters NW^e. Then combinining (23) and (24) it is possible to solve for the parameter Ψ_b and the bank's adjusted discount factor $\Lambda^b = \left[\left(1 - s^b\right) + \left(s^b\right) \Psi_b Lev\right]$. Then, using the bank's balance sheet constraint (18) one can obtain the steady state value of deposits

$$d = K + \bar{b} \times GDP + b^* - NW$$

and from (27) we get

$$F = (1 - s_b)\, NW + (1 - \tau^p)\, \mathcal{P} - NW^e.$$

- From the **households' decisions** —eq. (1)-5)— we can calculate individual consumption C^H, C^R, the marginal utility Λ and savings d^R of Ricardian households. Also, from eqs. (14)-(15) can be used to obtain the unemployment rates, both individual and aggregate, i.e. U^H, U^R and U.

- Regarding the **fiscal sector**, given the target debt $b = \bar{b}$, eq. (50) implies that the primary balance must given by

$$PB = \left(\frac{R}{\Pi} - 1\right) \bar{b} = \left(\frac{1}{\beta} - 1\right) \bar{b}$$

and thus eq. (49) can be used to determine the size of transfers needed to balance the budget, given by

$$T^R = \frac{\mathcal{T} - \left[G + \lambda^H T^H\right] - PB}{(1 - \lambda^H)} = \bar{T}^R$$

- Regarding the **external sector**, according to (30) and (54), and using the fact the terms of trade $S = S^e = 1.$ we have that imports are given by

$$Y_{im} = \frac{\omega}{1-\omega} Y_d = \frac{\omega}{1-\omega} \left(Y - \alpha^* Y^*\right).$$

Also, since Net Exports equal zero, eq. (44) exports must be equal to imports, i.e.

$$\alpha^* Y^* = Y_{im} + S^e E.$$

Thus, combining the last two equations we get that

$$(\alpha^* Y^*)\left(1 + \frac{\omega}{1-\omega}\right) = \frac{\omega}{1-\omega} Y + S^e E$$

or equivalently

$$\alpha^* = \frac{\omega Y + (1-\omega)\, S^e E}{Y^*}$$

which can be used to calibrate α^*.

A.2 Mapping between actual Fiscal Variables and Model counterparts

Table 4: Fiscal Variables: Data vs Model

	DATA	MODEL	Symbol
	RECURSOS NO FINANCIEROS		
	RECURSOS CORRIENTES		
P.11	Producción de mercado	Public Salaries (-)	W*N_g (-)
P.12	Producción para uso final propio	Public Salaries (-)	W*N_g (-)
P.131	Pagos por otra producción no de mercado	Public Salaries (-)	W*N_g (-)
D.211	Impuestos del tipo valor añadido IVA	VAT tax revenues	tau_c
D.212	Impuestos y derechos sobre las importaciones, excluido IVA	VAT tax revenues	tau_c
D.214	Impuestos sobre los productos, excluido IVA e importaciones	VAT tax revenues	tau_c
D.29	Otros impuestos sobre la producción	Transfers (-)	T (-)
D.39	Otras subvenciones a la producción	Transfers (-)	T (-)
D.41	Intereses	Transfers (-)	T (-)
D.42	Rentas de sociedades	Transfers (-)	T (-)
D.43+..+D.45	Otras rentas de la propiedad	Transfers (-)	T (-)
D.51	Impuestos sobre la renta	Income Tax	tau_y and tau_p
D.59	Otros impuestos corrientes	Income Tax	tau_y and tau_p
D.611	Cotizaciones sociales efectivas a cargo de los empleadores	SS tax (firms)	tau_s
D.613	Cotizaciones sociales efectivas a cargo de los hogares	SS tax (households)	tau_sh
D.612	Cotizaciones sociales imputadas	SS tax (firms)	tau_s
D.71	Primas netas seguro no vida	Transfers (-)	T (-)
D.72	Indemnizaciones de seguro no vida	Transfers (-)	T (-)
D.73	Transferencias corrientes entre administraciones públicas	Transfers (-)	T (-)
D.74	Cooperación internacional corriente	Transfers (-)	T (-)
D.75	Transferencias corrientes diversas	Transfers (-)	T (-)
	RECURSOS DE CAPITAL		
D.91	Impuestos sobre el capital	Transfers (-)	T (-)
D.9_S.13	Transferencias de capital entre administraciones públicas	Transfers (-)	T (-)
D.92 (exc. D.9_S.13)	Ayudas a la inversión	Transfers (-)	T (-)
D.99 (exc. D.9_S.13)	Otras transferencias de capital	Transfers (-)	T (-)
	EMPLEOS NO FINANCIEROS		
	EMPLEOS CORRIENTES		
D.1	Remuneración de asalariados	Public Salaries	W*N_g
P.2	Consumos intermedios	Public Cons.	C_g
D.29	Otros impuestos sobre la producción	Public Cons.	C_g
D.31	Subvenciones a los productos	VAT tax revenues (-)	tau_c (-)
D.39	Otras subvenciones a la producción	VAT tax revenues (-)	tau_c (-)
D.41	Intereses	Interest Payments	r*b
D.42+..+D.45	Otras rentas de la propiedad	Interest Payments	r*b
D.51	Impuestos sobre la renta… a pagar	Income Tax (-)	tau_y and tau_p (-)
D.62	Prestaciones sociales distintas de las transferencias sociales en especie	Transfers	T
D.632	Transferencias sociales en especie: producción adquirida en el mercado	Public Cons.	C_g
D.71	Primas netas seguro no vida	VAT tax revenues (-)	T
D.72	Indemnizaciones de seguro no vida	Transfers	T
D.73	Transferencias corrientes entre administraciones públicas	Transfers	T
D.74	Cooperación internacional corriente	Transfers	T
D.75	Transferencias corrientes diversas	Transfers	T
D.76	Recursos propios de la UE basados en el IVA y la RNB	Transfers	T
D.8	Ajustes por la variación de los derechos por pensiones	Transfers	T
	EMPLEOS DE CAPITAL		
P.51g	Formación bruta de capital fijo	Public Investment	I_g
P.52+P.53	Variación de existencias y adquisiciones menos cesiones de objetos valiosos	Public Investment	I_g
NP	Adquisiciones menos cesiones de activos no financieros no producidos	Public Investment	I_g
D.9_S.13	Transferencias de capital entre administraciones públicas	Public Investment	I_g
D.92 (exc. D.9_S.13)	Ayudas a la inversión	Public Investment	I_g
D.99 (exc. D.9_S.13)	Otras transferencias de capital	Public Investment	I_g

A.3 Summary of Equations

This section summarizes the model equations needed to characterize the equilibrium. Nominal variables (e.g. bonds, prices, wages) are transformed into real variables (CPI based) and denoted with a lower case letter.

Description	#text	
Households Consumption		
Budget Constraint HtM	1	$(1+\tau_t^c)\,C_t^H = \frac{1}{P_t}\left[(1-\tau_t^w)\,\Xi^H exp\left(\mu_t^H\right) W_t N_t^H\right] + (1-\tau_t^y)\,\Theta^H F_t + \left(\frac{R_{t-1}^d}{\Pi_t} - 1\right)\underline{d} - \tau_t^y \frac{\left(R_{t-1}^d - 1\right)}{\Pi_t}\underline{d} + T_t^H$
Budget Constraint Ricardian (* redundant by Walras Law)	2	$(1+\tau_t^c)\,C_t^R + \frac{D_t^R}{P_t} = \frac{1}{P_t}\left[(1-\tau_t^w)\,exp\left(\mu_t^R\right)\Xi^R W_t N_t^R\right] + (1-\tau_t^y)\,\Theta^R F_t + \frac{R_{t-1}^d}{\Pi_t}\frac{D_{t-1}^R}{P_{t-1}} - \tau_t^y \frac{\left(R_{t-1}^d - 1\right)}{\Pi_t}\frac{D_{t-1}^R}{P_{t-1}} + T_t^R$
Ricardian Intertemp. FOC	3	$\Lambda_t = \beta \mathbb{E}_t \left\{\left[R_t^d - \tau_{t+1}^y\left(R_t^d - 1\right)\right]\Lambda_{t+1}\Pi_{t+1}^{-1}\right\}$
Ricardian Intratemp. FOC	4	$\Lambda_t = \frac{1}{1+\tau_t^c}\frac{1}{\left[C_t^R - \mathcal{H}C_{t-1}^R\right]}\varepsilon_t^d$
Aggregate Consumption	5	$C_t \equiv \lambda^H C_t^H + \left(1-\lambda^H\right) C_t^R$
Labor Supply		
Labor cost	7	$\hat{w}_t = \frac{N_t^f w_t^f + N_t^g (1+\tau_t^s) w_t^g}{N_t}$
Reservation Wage	11	$\tilde{w}_t \equiv \varepsilon_t^n \frac{1+\tau_t^c}{1-\tau_t^w}\left(\frac{exp\left(\mu_t^h\right)\lambda^H}{\Xi^H} + \frac{1-\lambda^H}{\Xi^R}\right)\tilde{N}_t^{\varphi}$
Opt. Labor. Interm.	8	$\hat{w}_t = (1+\tau_t^s)\,w_t + a_t^N(\cdot) - \beta(1-s)\,\mathbb{E}_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t} a_{t+1}^N(\cdot)\right\}$
Wage Setting	10	$w_t^r \Gamma_{1,t}^w = \mathcal{M}^w \Gamma_{2,t}^w \varepsilon_t^{\mu w}$
Wage Setting aux 1	10	$\Gamma_{1,t}^w = (w_t)^{\varepsilon^w} N_t + (\beta\theta_w)\,\mathbb{E}_t\left(\frac{X_{t,t+1}^w}{\Pi_{t,t+1}}\right)^{1-\varepsilon^w}\Gamma_{1,t+1}^w$
Wage Setting aux 2	10	$\Gamma_{2,t}^w = (w_t)^{\varepsilon^w} N_t \tilde{w}_t + (\beta\theta_w)\,\mathbb{E}_t\left(\frac{X_{t,t+1}^w}{\Pi_{t,t+1}}\right)^{-\varepsilon^w}\Gamma_{2,t+1}^w$
Real Wage Dynamics	12	$w_t^{1-\epsilon^w} = (1-\theta_w)\,(w_t^r)^{1-\epsilon^w} + \theta_w\left[\left(\frac{\Pi}{\Pi_t}\right)^{1-\iota_w} w_{t-1}\right]^{1-\epsilon^w}$
Unemployment HtM	13 & 14	$U_t^H \equiv 1 - \tilde{N}_t\left(w_t \frac{\Xi^H}{C_t^H - \mathcal{H}C_{t-1}^H}\frac{exp\left(\mu_t^H\right)}{\varepsilon_t^n}\frac{1-\tau_t^w}{1+\tau_t^c}\right)^{-\frac{1}{\varphi}}$
Unemployment Ricardian	13 & 14	$U_t^R \equiv 1 - \tilde{N}_t\left(w_t \frac{\Xi^R}{C_t^R - \mathcal{H}C_{t-1}^R}\frac{1}{\varepsilon_t^n}\frac{1-\tau_t^w}{1+\tau_t^c}\right)^{-\frac{1}{\varphi}}$
Total Unemployment	15	$U_t = \lambda^H U_t^H + \left(1-\lambda^H\right) U_t^R$
Labor Adjustment Function		$a_t^N(\cdot) = \frac{1}{\Theta_t^N}\left(\left(N_t - (1-s_t)\,N_{t-1}\right)/U_t\right)^{\frac{\theta^N}{1-\theta^N}}$
Financial Intermediaries' Investment		
Law of Motion for Capital	28	$K_t = (1-\delta)\,K_{t-1} + \varepsilon_t^i\left[1 - a\left(\frac{I_t}{I_{t-1}}\right)\right] I_t$
Spread	17	$\log\Phi_t = -\bar{\phi}\left(\exp\left(B_t^*/GDP_t\right) - 1\right) + \varepsilon_t^b$
Domestic Interest Rate	22	$R_t = R_t^* \Phi_t$
Optimal Spread	23	$Lev_t = \frac{\beta\mathbb{E}_t\left\{\Lambda_{t,t+1}^b \Pi_{t+1}^{-1} R_t^d\right\}}{\Psi_t^b - \beta\mathbb{E}_t\left\{\Lambda_{t,t+1}^b\left(R_{t+1}^l - \Pi_{t+1}^{-1} R_t^d\right)\right\}}$
Bank's discount factor	24	$\Lambda_{t,t+1}^b \equiv \frac{\Lambda_{t+1}}{\Lambda_t}\left[\left(1-s^b\right) + \left(s^b\right)\Psi_t^b Lev_{t+1}\right]$
Bank's Leverage	25	$Lev_t = Q_t K_t / NW_t.$
Lending rate	16	$R_{t+1}^{\ell} = \frac{r_{t+1}^k + (1-\delta) Q_{t+1}}{Q_t}$
Banks' Net Worth	26	$NW_t = s^b\left[\left(R_t^l - \Pi_t^{-1} R_{t-1}\right) Lev_{t-1} + \Pi_t^{-1} R_{t-1}\right] NW_{t-1} + NW^e$
Financial Transfer	27	$F_t \equiv \left(1-s^b\right) NW_t - NW^e + \left(1-\tau_t^p\right)\mathcal{P}_t$
Optimal Investment	29	$1 - Q_t\varepsilon_t^i\left[1 - a\left(\frac{I_t}{I_{t-1}}\right) - a'\left(\frac{I_t}{I_{t-1}}\right)\frac{I_t}{I_{t-1}}\right] = \beta\mathbb{E}_t\left\{\frac{\Lambda_{t+1}}{\Lambda_t}\varepsilon_{t+1}^i Q_{t+1} a'\left(\frac{I_{t+1}}{I_t}\right)\left(\frac{I_{t+1}}{I_t}\right)^2\right\}$
Inv. Adj. Function		$cadjcost/2 * (I_t/I_{t-1} - 1)^2$
Deriv. of Inv. Adj. Function		$cadjcost/ * (I_t/I_{t-1} - 1)$
Supply Side: Production and Price Setting		
Retailers Imports	30	$Y_{im,t} = \frac{\omega}{1-\omega} S_t^{-\varepsilon^x} Y_{d,t}$
PPI over CPI ratio	31	$\left(p_{d,t}\right)^{\varepsilon^x - 1} = (1-\omega) + \omega\,(S_t)^{1-\varepsilon^x}$
CPI Inflation	32	$\Pi_t^{1-\varepsilon^x} = \Pi_{d,t}^{1-\varepsilon^x}\left[\frac{(1-\omega)+\omega(S_t)^{1-\varepsilon^x}}{(1-\omega)+\omega\left(S_{t-1}\right)^{1-\varepsilon^x}}\right]$
Capital Energy Composite	35	$\tilde{K}_t \equiv \left[(1-\nu^e)^{\frac{1}{\eta}}\left[\frac{K_t^f}{E_t}\right]^{1-\frac{1}{\eta}} + (\nu^e)^{\frac{1}{\eta}}\right]^{\frac{\eta}{\eta-1}} E_t$
Equil. K/E ratio	36	$\frac{K_t^f}{E_t} = \frac{1-\nu^e}{\nu^e}\left(\frac{S_t^e p_{d,t}}{r_t^k}\right)^{\eta}$

Equil. K/N ratio	37	$\frac{\tilde{K}_t}{N_t^f} = \left[\frac{w_t^f}{(1-\alpha)\varepsilon_t^a \left(K_{t-1}^g\right)^{\alpha_g}} \right]^{\frac{1}{\alpha}} [mc_t]^{-\frac{1}{\alpha}}$
Equil. Marginal Cost	38	$mc_t = \frac{1}{\varepsilon_t^a \left(K_{t-1}^g\right)^{\alpha_g}} \frac{\left[w_t^f\right]^{1-\alpha}}{\alpha^\alpha (1-\alpha)^{1-\alpha}} \left[(1-\nu^e)\left(r_t^k\right)^{1-\eta} + \nu^e \left(S_t^e p_{d,t}\right)^{1-\eta}\right]^{\frac{\alpha}{1-\eta}}$
Equil. Profits	41	$\mathcal{P}_t = \left(p_{d,t} - mc_t\right) Y_t$
Price Setting	39	$\frac{p_{d,t}^r}{p_{d,t}} \Gamma_{1,t}^p = \mathcal{M}^p \Gamma_{2,t}^p$
Price Setting aux 1	39	$\Gamma_{1,t}^p = Y_t + (\beta\theta_p)\,\mathbb{E}_t \left\{ \left[\left(\frac{\Pi_{t+1}^d}{\Pi^d} \right)^{\iota^p - 1} \right]^{1-\varepsilon^p} \frac{\Pi_{t+1}^d}{\Pi_{t+1}} \Gamma_{1,t+1}^p \right\}$
Price Setting aux 2	39	$\Gamma_{2,t}^p = Y_t \frac{MC_t}{P_{d,t}} + (\beta\theta_p)\,\mathbb{E}_t \left\{ \left[\left(\frac{\Pi_{t+1}^d}{\Pi^d} \right)^{\iota^p - 1} \right]^{-\varepsilon^p} \frac{\Pi_{t+1}^d}{\Pi_{t+1}} \Gamma_{2,t+1}^p \right\}$
PPI inflation	40	$1 - \theta_p \left(\frac{\Pi^d}{\Pi_t^d} \right)^{(1-\iota_p)(1-\epsilon^p)} = (1-\theta_p) \left(\frac{p_{d,t}^r}{p_{d,t}} \right)^{1-\epsilon^p}$
External Sector		
Definition Terms of Trade		$S_t = p_t^* / p_{d,t} \Rightarrow \frac{S_t}{S_{t-1}} = \frac{\Pi_t^*}{\Pi_{dt}}$
Net Exports	44	$NX_t \equiv p_{d,t} \left[(S_t)^{\epsilon_p^*} (\alpha^* Y_t^*) - (S_t Y_{im,t} + S_t^e E_t) \right]$
Net Foreign Assets	45	$b_t^* = \frac{R_{t-1}}{\Pi_t} b_t^* + NX_t$
Fiscal Policy		
Gov't Expenditure	46	$G_t = p_{d,t} \left[(1+\tau_t^c) C_t^g + I_t^g \right] + w_t^g (1+\tau_t^s) N_t^g$
Public Capital	47	$K_t^g = (1-\delta^g) K_{t-1}^g + I_t^g$
Tax Revenues	48	$\mathcal{T}_t = \tau_t^c C_t + (\tau_t^s + \tau_t^w) \frac{W_t}{P_t} N_t + \tau_t^p \mathcal{P}_t + \tau_t^y F_t + \tau_t^y \frac{\left(R_{t-1}^d - 1\right)}{\Pi_t} d_{t-1}$
Primary Balance	49	$PB_t = \mathcal{T}_t - \left[G_t + \lambda^H T_t^H + \left(1-\lambda^H\right) T_t^R \right]$
Government Debt	50	$b_t = \frac{R_{t-1}}{\Pi_t} b_{t-1} - PB_t$
Fiscal Rule (8 instr.)	51	$x_t = \bar{x} + \rho_x (x_{t-1} - \bar{x}) + (1-\rho_x) \phi_x \left(\frac{b_{t-1}}{GDP_{t-1}} - \bar{b}_y \right) + \varepsilon_t^x$
Fiscal Rule Transfers (2 instr.)	52	$\log T_t^x = \log \bar{T} + \rho_x \left(T_{t-1}^h - \log \bar{T}\right) + (1-\rho_x) \phi_x \left(\frac{b_{t-1}}{GDP_{t-1}} - \bar{b}_y \right) + \phi_{xU} \left(U_t^x - \bar{U^x}\right) + \varepsilon_t^x$
Market Clearing		
Domestic Final Goods	54	$Y_t = Y_{d,t} + (S_t)^{\omega^*} (\alpha^* Y_t^*)$
Definition GDP	55	$GDP_t = Y_t + (1+\tau_t^s) \frac{w_t^g}{p_{d,t}} N_t^g + \delta^g K_{t-1}^g - \frac{p_t^e}{p_{d,t}} E_t$
		$p_{d,t} GDP_t = \left[C_t + I_t + G_t + NX_t + p_{d,t} \delta^g K_{t-1}^g \right]$
Aggregate Production	56	$Y_t = \varepsilon_t^a \left(K_{t-1}^g\right)^{\alpha_g} \left[\frac{\tilde{K}_t}{N_t^f} \right]^\alpha N_t^f$
Market for Deposits	57	$d_t = \left(1-\lambda^H\right) d_t^R + \lambda^H \underline{d}$
Capital Market	58	$K_t^f = K_{t-1}$
Labor Market	59	$N_t = N_t^f + N_t^g$

A.4 Summary of Endogenous Variables

In what follows we list the variables of the model. For each nominal variable (assets holdings and prices) we denote with a lower-case letter their real counterparts (i.e. the nominal variable deflated by CPI)

Text	Code	Description
Households (5 variables)		
C_t^H	c_H	Consumption HtM
C_t^R	c_R	Consumption Ricardian
Λ_t	Lambda	Marginal Utility of Consumption
$d_t^R \equiv \frac{D_t^R}{P_t}$	d_R	Ricardian Savings
C_t	C	Aggregate Consumption
Firms (14 variables)		
$Y_{im,t}$	Y_im	Imports of Final Goods
$Y_{d,t}$	Y_d	Domestic Demand for Domestic Goods
K_t^f	K_f	Demand for Capital

N_t^f	N_f	Demand for Labor
E_t	E	Demand for Energy
$\tilde{K}_t$	tilde_K	Capital - Energy Composite
$mc_t = MC_t/P_t$	mc	Real Marginal Cost
$\mathcal{P}_t$	Prof	Real Profits
$p_{d,t} = \frac{P_{d,t}}{P_t}$	p_d	Domestic PPI (relative to CPI)
Π_t	cpi	CPI inflation (Gross)
Π_t^d	ppi	PPI inflation (Gross)
$p_{d,t}^r = \frac{P_{d,t}^r}{P_{d.t}}$	pr_d	New Price Set by Intermediate Producers
$\Gamma_{1,t}^p$	Gamma1_p	Price Setting aux 1
$\Gamma_{2,t}^p$	Gamma2_p	Price Setting aux 2
External Sector (4 variables)		
NX_t	NX	Net Exports
S_t	S	Terms of Trade
S_t^e	S_e	Terms of Trade Energy
b_t^*	b_star	Net Foreign Assets
Y_t^*	Y_star	Foreign Output
R_t^*	R_star	Foreign Interest Rate
Π_t^*	ppi_star	Foreign Inflation
Labor Market (10 variables)		
$\tilde{w} = \frac{\tilde{W}_t}{P_t}$	tilde_w	Reservation Wage (real)
$\hat{w}_t = \frac{\hat{W}_t}{P_t}$	hat_w	Total Labor Cost (real)
$N_t = \tilde{N}_t$	N	Aggregate Employment
$w_t^r = \frac{W_t^r}{P_t}$	w_r	New Wage set by Unions
$\Gamma_{1,t}^w$	Gamma1_w	Auxiliary Variable for WS #1
$\Gamma_{2,t}^w$	Gamma2_w	Auxiliary Variable for WS #2
$w_t \equiv \frac{W_t}{P_t}$	w	Real Wages
U_t^H	U_H	Unemployment HtM
U_t^R	U_R	Unemployment Ricardian
U_t	U	Total Unemployment
Capital and Financial Market (13 variables)		
I_t	I	Private Investment
K_t	K	Private Capital (Supply)
Q_t	Q	Tobin's Q
R_t	R	Nominal Domestic Interest Rate (Gross)
Φ_t	Spread	Spread Domestic vs Foreign Rate
r_t^k	r_k	Return on Capital (Real)
R_t^l	R_l	Return on Loans (Gross, real)
Lev_t	Lev	Leverage Ratio
NW_t	NW	Banks' Net Worth
Λ_t^b	Lambda_b	Banks' Discount Factor
F_t	F	Households Net Financial Flows
$d_t \equiv D_t/P_t$	d	Demand for Deposits
Fiscal Policy (15 variables)		
τ_t^c	tau_c	Tax rate on consumption
τ_t^y	tau_w	Tax rate on income
τ_t^{sh}	tau_d	Social Security Contribution on Households

τ_t^s	tau_s	Social Security Contribution on Employers
τ_t^p	tau_p	Tax rate on Corporate Profits
C_t^g	C_g	Government Consumption
I_t^g	I_g	Government Investment
N_t^g	N_g	Public Employment
T_t^H	T_H	Transfers to HtM Households
T_t^R	T_R	Transfers to Ricardian
K_t^g	K_g	Public Capital
G_t	G	Total Gov. Expenditure (net of transfers)
$\mathcal{T}_t$	Tax	Total Tax Revenues
PB_t	PB	Primary Deficit
b_t	b	Government Debt
Market Clearing (2 variables)		
Y_t	Y	Gross Output
GDP_t	GDP	Gross Domestic Product