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Macroeconomic Effects of Taxes on Banking

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Abstract

This paper evaluates the macroeconomic effects of taxes on banking in a small open economy in a currency union for three tax alternatives: an additional tax on profits, on deposits, and on loans. We propose a DSGE model with a rich detail of taxes and a banking sector and show that these three taxes are equivalent in their effects on macroeconomic variables. Banks react to higher taxes by increasing their markups and by transferring part of the fiscal cost to households and firms through higher interest rates on loans. The increase in government revenues comes at a cost of a long-run decrease of GDP, an increase in loans interest rates, and a reduction in the volume of credit, deposits and bank capital. Our simulation exercises show that the trade-off between government revenues and economic activity is well captured by an elasticity of GDP to ex post government revenue close to -0.9, which is virtually independent of the tax rate.

Keywords: banking taxes, DSGE, capital, loans, deposits.

JEL Classification: E44, E62, G21.

1. Introduction

Tax increases in the banking sector have been under intense scrutiny since the 2007 international financial crisis. To the extent that the crisis was initially identified within the financial sector, various arguments have been put forward in recent years to justify the desirability of introducing additional taxes into the banking system. Thus, the European Commission (2010) provides three reasons for backing taxation. First, together with regulation, banking taxes can indirectly contribute to increasing the stability of the financial sector, discouraging certain riskier activities (see, e.g., Freixas and Rochet, 2013). Like Pigouvian taxes, taxation on banks would thus seek to correct a potentially negative externality by reducing banking activity as financial costs become more expensive. Secondly, banking taxes can contribute to the recovery of public financial aids provided to banks during the crisis. Alternatively, in-

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stead of retrospective compensation, taxes can be utilized prospectively to finance funds for future bank restructuring. Thirdly, taxation can ensure that the financial sector makes a fair, substantial and comparable contribution to public finances as in the case of other economic activities (see, e.g., Claessens, Keen and Pazarbasioglu, 2010).

In this paper we evaluate the macroeconomic effects of banking taxes using a dynamic general equilibrium model of a small open economy in a currency union. In particular, we extend the DSGE model of Boscá et al. (2018) to include a rich detail of taxes in the banking sector. Conveniently calibrated, the model is able to procure interesting quantitative results for EMU members of the effects of banking taxes on economic activity. As an illustration of its capabilities, the model has been calibrated in this paper for the Spanish economy, where the recent debate has focused on the macroeconomic consequences of introducing an extraordinary tax on banking.

From our simulation results we get three main findings. First, the three types of banking taxes have similar negative effects on economic activity. Secondly, the general equilibrium elasticity of GDP to ex post government revenues is close to -0.9. This elasticity is relatively robust to changes in structural parameters. Thirdly, the increase of banking taxes to obtain an ex ante increment in public revenues equivalent to 0.1 percentage point of GDP leads to an interest rate increase on loans of close to 15 basis points.

Our results are in line with most of the empirical evidence available for other countries on the economic effects of taxes on the banking sector. As demonstrated by Capelle-Blancard and Havrylchyk (2017) in their review of the literature, part of the research has focused on the effects of corporate income tax on banking activity. For example, Caminal (2003) and Albertazzi and Gambacorta (2010) show that this type of banking taxes increase loan interest rates by increasing capital costs. The empirical evidence for large samples of countries favors this hypothesis, i.e., a higher corporate tax translates into higher net interest margins. Demirgüç-Kunt and Huizinga (1999 and 2001) find that this tax is fully passed on to the consumer. For their part, Chiorazzo and Milani (2011) estimate that in the short run European banks shift 45 percent of this tax burden to consumers and 80 percent in the long term, a percentage that Albertazzi and Gambacorta (2010) estimate at 90 percent. However, Capelle-Blancard and Havrylchyk (2017) show that the robustness of these results depends on how potential endogeneity problems are addressed. Considering possible endogenous regressors, their results indicate that there is hardly any transfer of the corporate tax to banks' interest rate margins.

De Nicolo (2010) has assessed the potential impact on the growth of bank assets, the probability of default and GDP of a Financial Stability Contribution tax (FSC) by taxing bank liabilities net of own resources, together with an additional Financial Activity Tax (FAT), which taxes pre-tax profits. In general, the estimated effects are negative and small, although in some scenarios they could reduce GDP growth by 0.26 percentage points if the tax on financial activity were accompanied by a 100 bp tax on net liabilities.

Using a sample of 2,987 banks in 23 EU countries from 2007 to 2013, Kogler (2016) has evaluated the effects of introducing different bank taxes, demonstrating that European banks have increased interest rates on loans between 20 and 24 basis points. To the extent that in some cases deposits are partially exempt from taxes compared to other bank resources (as own resources and debt), there is an increase in deposits demand (and in their interest rates) relative to other types of financing. The final effect of bank taxes is an increase in net interest income because the increase of interest rate of loans is the dominant effect. These effects are greater in banks that operate in more concentrated markets.

Buch, Hilberg and Tonzer (2016) have analyzed how the tax introduced in the German banking system in 2011 has affected the composition and size of banks' balance sheets and interest rates. This tax is mainly levied on bank liabilities net of own resources and retail deposits. Using the method of differences in differences (before and after the introduction of the tax, distinguishing between banks affected and not affected by the tax), these authors find that banks affected by the tax respond with lower growth of loans and higher interest rates on new deposits than banks not affected. The latter effect aims at shifting the sources of financing from the resources affected by the tax to those not taxed, such as deposits. These results have been more recently corroborated by Haskamp (2018), finding that taxed banks have increased the interest rates on their loans by about 0.14 percentage points.

Using a similar methodology, Capelle-Blancard and Havrylchyk (2017) quantify the effects of the tax introduced in the Hungarian banking system in 2010. Again, using differences in differences, these authors show that the bank tax is fully transferred to the interest rates on bank loans and commissions, and that it falls much more heavily on loans for households than for firms. Their results also show that returns on assets are not affected, indicating that the increase of interest rates on loans fully compensates for the cost of the tax to banks.[2]

Similar results have been obtained by Banerji et al. (2017), who have analyzed the impact of the 2000 tax imposed on gross profits of large Japanese banks operating in Tokyo. These authors have found that affected banks increased their net interest income and commissions and reduced the volume of loans compared to unaffected banks.

As we have seen in the preceding review of the literature, the analysis of the effects of taxes on banking activity is relatively abundant, while the analysis of their macroeconomic effects is more scarce, particularly when using dynamic general equilibrium models. The research more closely related to our approach is by Lendvai, Raciborski and Vogel (2013). However, as their objective is to study the impact of an equity transaction tax on financial and real

[2] Other studies have shown that the introduction of taxes affects the return on equity (ROE). For example, Chronopoulos, Sobiech and Wilson (2018) find that the introduction of the Australian banking tax meant a 5.2 percent fall in the stock market valuation of those banks affected by the tax.

variables, they consider a DSGE model with financial frictions but without a banking sector.[3] Therefore, our paper contributes to fill the existing gap as it proposes a general equilibrium model with banks that allows us not only to analyze the reaction of financial variables to banking taxes, but also their effects on main economic aggregates, such as GDP, investment, private consumption or public revenues, using a DSGE model where the banking sector is explicitly defined.

The structure of this paper is as follows. Section 2 describes the main characteristics of the dynamic general equilibrium model used to evaluate the potential effects of banking taxes. Section 3 discusses the main quantitative results of the simulations for different tax alternatives and their macroeconomic effects. Finally, section 4 presents the main conclusions.

2. The Model

In this section we model a small open economy that belongs to a monetary union, such as EMU, with a supra-national central bank (the ECB) that sets the policy interest rate according to a Taylor rule and supplies full-allotment refinancing to banks. The objectives of the policy rule are aggregate inflation and output growth at the union level. As in Monacelli (2004) and Galí and Monacelli (2005), we take the part of the inflation rate and output growth that depends on the rest of the union as exogenous to the model.

There are four types of consumers in the home economy. First, patient households get utility from the consumption goods and housing services. They receive a wage income for the differentiated labor supplied to labor unions and they save part of this income in bank deposits. Second, impatient households behave similarly, except that they take bank loans to finance their purchases. Third, hand-to-mouth households do not have access to financial markets and earn utility only from the consumption goods on which they spend their disposable income. Finally, entrepreneurs are similar to patient consumers, except that they finance consumption goods with the income they obtain renting capital to intermediate good producers.

Labor unions buy and bundle labor from the different households and re-sell it, under monopolistic competition, to intermediate good producers. For their part, intermediate good producers combine labor with the capital rented from entrepreneurs and public capital (freely available) to produce differentiated intermediate goods that are sold to retailers. Retailers re-label and re-sell these differentiated intermediate goods to monopolistic packagers that

[3] Their results indicate that an equity transaction tax that collects 0.1 percent of GDP has a limited impact on the volatility of real variables, but results in a 0.2 percent decline in GDP in the long run. The tax generates an increase in the cost of capital which results in a decrease in investment similar to that caused by an increase in corporate income tax.

bundle them into a single homogeneous type of final good. These monopolistic packagers resell final goods to consumers and capital producers, who transform them into capital goods that are sold to entrepreneurs under perfect competition.

Following Gerali et al. (2010), banks are comprised of wholesale and retail banking units, which offer deposits to savers (patient consumers) and loans to impatient households and entrepreneurs. Through the purchase of public debt, retail banking also lends to the government. In the retail savings and credit markets, deposits and loans offered by different entities are imperfect substitutes, so banks also operate under monopolistic competition. The substitution elasticities of banks' deposits and loans may be subject to disturbances that alter the market power of banks in setting interest rates for their clients. In particular, interest rates on retail deposits are determined at a spread vis-à-vis the interest rate at which ECB funding can be obtained. Interest rates on retail loans are set at a spread vis-à-vis the interest rate at which the retail units are financed from the wholesale branch. Both retail deposit and loan spreads depend on the market power of the banks. The interest rate on loans granted by wholesale banks to their retail units is determined by a spread set against the interest rate on external debt, which includes a country risk premium and also a cost incurred by banks if they deviate from the regulatory asset-to-capital ratio. Banks are also exposed to disturbances in the evolution of their capital, resulting in deviations from the restriction in the capital ratio to bank assets they have to satisfy. Following Schmitt-Grohe and Uribe (2003), to ensure the stationarity of equilibrium we assume that the country risk premium increases with the country's net foreign asset position.

Finally, we assume a fiscal authority that consumes, invests, borrows (selling bonds to domestic banks, domestic households and the rest of the world), sets lump-sum transfers, and taxes consumption, housing services, labor earnings, capital earnings, bond holdings, and banks' deposits, loans and profit.

2..1 Patient households

There is a continuum of patient households indexed by j, with mass γ_p, who choose $c^p_{j,t}$, $d^p_{j,t}$, $h^p_{j,t}$ in order to maximize utility subject to the budget constraint. Their utility depends on consumption, $c^p_{j,t}$; housing services, $h^p_{j,t}$; and hours worked, $\ell^p_{j,t}$ and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \left[(1-a_{cp})\varepsilon_t^z log(c^p_{j,t} - a_{cp}c^p_{t-1}) + a_{hp}\varepsilon_t^h log(h^p_{j,t}) - \frac{a_{\ell p}{\ell^p_{j,t}}^{1+\phi}}{1+\phi} \right],$$

where c^p_t denotes the average patient household's consumption, $c^p_t = \gamma_p^{-1}\left(\int_0^{\gamma_p} c^p_{j,t} dj\right)$, ε_t^z is a shock to the consumption preferences of all households and ε_t^h is a shock to the housing preferences of all household.

The jth patient household is subject to the following budget constraint:

$$(1+\tau_t^c)c_{j,t}^p + (1+\tau_t^h)q_t^h \Delta h_{j,t}^p + d_{j,t}^p + \frac{\alpha_{RW}(1-\alpha_{B_g})Bg_t}{\gamma_p} - \frac{(1-\alpha_{ED})B_t^*}{\gamma_p} = (1-\tau_t^w)w_{j,t}^p \ell_{j,t}^p + \frac{1+r_{t-1}^d}{\pi_t} d_{j,t-1}^p + \frac{(1-\omega_b)(1-\tau_t^{Jb})}{\gamma_p} J_{t-1}^b - \frac{T_t^{up}}{\gamma_p} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m} + \frac{\alpha_{RW}(1-\alpha_{B_g})(1+r_t^d)Bg_{t-1}}{\gamma_p} - \frac{(1-\alpha_{ED})(1+r_t^d)B_{t-1}^*}{\gamma_p}, \quad (1)$$

where $\pi_t = \frac{P_t}{P_{t-1}}$ is gross inflation of the consumption good, with P_t denoting the price of the consumption good and the variables, τ_t^w, τ_t^c, τ_t^h and τ_t^{Jb} denoting taxes on labor income, consumption, accumulation of housing services and banks' dividends; q_t^h is the price of housing services in terms of the consumption good; $w_{j,t}^p$ is the real wage in terms of the consumption good; and r_{t-1}^d is the nominal interest rate on deposits.

The flow of expenses comprises consumption, $(1+\tau_t^c)c_{j,t}^p$, accumulation of housing services, $(1+\tau_t^h)q_t^h\Delta h_{j,t}^p$, current deposits, $d_{j,t}^p$, government bonds $\frac{\alpha_{RW}(1-\alpha_{B_g})Bg_t}{\gamma_p}$, and international bonds $\frac{(1-\alpha_{ED})B_t^*}{\gamma_p}$. Income resources include after-tax labor income, $(1-\tau_t^w)w_{j,t}^p\ell_{j,t}^p$, after-tax deposits gross return from the previous period, $\left[\frac{1+r_{t-1}^d}{\pi_t}\right] d_{j,t-1}^p$, dividends from the banking sector, $\frac{(1-\omega_b)(1-\tau_t^{Jb})}{\gamma_p} J_{t-1}^b$ (where ω_b is the share of benefits that the banking sector does not distribute as dividends), the cost paid to unions, $\frac{T_t^{up}}{\gamma_p}$, lump-sum taxes paid to the government, $\frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m}$, payments on government bonds $\frac{\alpha_{RW}(1-\alpha_{B_g})(1+r_t^d)Bg_{t-1}}{\gamma_p}$ and payments on international bonds $\frac{(1-\alpha_{ED})(1+r_t^d)B_{t-1}^*}{\gamma_p}$, where γ_i, γ_e, and γ_m represent the mass of the rest of consumers, α_{RW} is the share of public debt in the hands of resident agents, α_{B_g} the share in the hands of banks and $(1-\alpha_{B_g})$ in the hands of patient households. Finally, q_t^h is the price of housing services in terms of consumption goods.

2..2 Impatient households

There is a continuum of impatient households in the economy indexed by j, with mass γ_i, who choose $c_{j,t}^i$, $b_{j,t}^i$ and $h_{j,t}^i$ in order to maximize utility subject to the budget constraint. Utility depends on consumption $c_{j,t}^i$, housing services $h_{j,t}^i$ and hours worked $\ell_{j,t}^i$, and has the following form:

$$E_0 \sum_{t=0}^{+\infty} \beta_i^t \left[(1-a_{ci})\varepsilon_t^z log(c_{j,t}^i - a_{ci}c_{t-1}^i) + a_{hi}\varepsilon_t^h log(h_{j,t}^i) - \frac{a_{\ell i}\ell_{j,t}^{i\,1+\phi}}{1+\phi} \right]$$

where c_t^i denotes the average patient household's consumption, $c_t^i = \gamma_i^{-1}\left(\int_0^{\gamma_i} c_{j,t}^i dj\right)$ and ε_t^z and ε_t^h are defined as in the patient household's problem above. The jth impatient household budget constraint, expressed in terms of final goods, is given by:

$$(1+\tau_t^c)c_{j,t}^i + (1+\tau_t^h)q_t^h\Delta h_{j,t}^i + \left(\frac{1+r_{t-1}^{bi}}{\pi_t}\right)b_{j,t-1}^i =$$

$$(1-\tau_t^w)w_{j,t}^i\ell_{j,t}^i + b_{j,t}^i - \frac{T_t^{ui}}{\gamma_i} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m}, \tag{2}$$

where $w_{j,t}^i$ is the real wage in term of the consumption good, and r_{t-1}^{bi} is the nominal interest rate on loans.

Although expenses and incomes are similar to the ones described for patient households, the main difference is $b_{j,t}^i$, which represents bank loans. In addition, impatient households face a borrowing constraint. In terms of final goods, they cannot borrow more than a certain proportion of the expected value in period t of the value in period $t+1$ of their housing stock at period t discounted by $(1+r_t^{bi})$:

$$(1+r_t^{bi})b_{j,t}^i \leq m_t^i E_t\left\{q_{t+1}^h h_{j,t}^i \pi_{t+1}\right\},$$

where m_t^i is the stochastic loan-to-value ratio for all impatient households' mortgages. We assume that the shocks in the model are small enough so that we can solve the model imposing the condition that the borrowing constraint always binds.

2..3 Hand-to-mouth households

There is a continuum of hand-to-mouth households in the economy indexed by j, with mass γ_m, who choose $c_{j,t}^m$ in order to maximize utility subject to the budget constraint. Utility depends on consumption $c_{j,t}^m$ and hours worked $\ell_{j,t}^i$, and has the following form:

$$E_0\sum_{t=0}^{+\infty}\beta_m^t\left[(1-a_{cm})\varepsilon_t^z log(c_{j,t}^m - a_{cm}c_{t-1}^m) - \frac{a_{\ell m}{\ell_{j,t}^m}^{1+\phi}}{1+\phi}\right].$$

where c_t^m denotes the average hand-to-mouth household's consumption, $c_t^m = \gamma_m^{-1}\left(\int_0^{\gamma_m} c_{j,t}^m dj\right)$ and ε_t^z and ε_t^h are defined as in the patient household's problem above. The jth hand-to-mouth household budget constraint is given by:

$$(1+\tau_t^c)c_{j,t}^m = (1-\tau_t^w)w_{j,t}^m\ell_{j,t}^m - \frac{T_t^{um}}{\gamma_m} - \frac{T_t^g}{\gamma_p+\gamma_i+\gamma_e+\gamma_m} \tag{3}$$

where $w_{j,t}^m$ is the real wage in terms of the consumption good.

The only expense of hand-to-mouth households is after-tax consumption. The sources of income are labor income net of the cost of participating in the labor union and the lump-sum transfers received from the government. Hand-to-mouth households do not have bank deposits or bank loans.

2..4 Labor unions and labor packers

There are three types of labor unions and three types of "labor packers," one for each type of household. Each household delegates the labor decision to its labor union. The labor unions sell labor in a monopolistically competitive market to the "labor packer". The labor packer sells bundled labor in a competitive market to intermediate good producers and uses the following function to bundle labor:

$$\ell_t^s = \left(\int_0^{\gamma_s} \left(\ell_{j,t}^s \right)^{\frac{\varepsilon_t^\ell - 1}{\varepsilon_t^\ell}} dj \right)^{\frac{\varepsilon_t^\ell}{\varepsilon_t^\ell - 1}},$$

where ℓ_t^s is labor from households of type s and ε_t^ℓ is the elasticity of substitution among different types of labor, which is stochastic.

The labor packer chooses $l_{j,t}^s$ for all household (j) in order to maximize:

$$w_t^s \ell_t^s - \int_0^{\gamma_s} w_{j,t}^s \ell_{j,t}^s dj.$$

subject to the production function and taking as given all wages. Both, $w_{j,t}^s$ and w_t^s refer to real wages in terms of the consumption good. Using the zero profits condition of labor packers implied by perfect competition and the FOCs, we obtain the following labor demand functions:

$$\ell_{j,t}^s = \left(\frac{w_{j,t}^s}{w_t^s} \right)^{-\varepsilon_t^\ell} \ell_t^s.$$

To find the aggregate real wage for each type of labor we use again the zero profit condition and the demand functions to obtain:

$$w_t^s = \left(\int_0^{\gamma_s} w_{j,t}^{1-\varepsilon_t^\ell} dj \right)^{\frac{1}{1-\varepsilon_t^\ell}}.$$

The labor union sets the nominal wage $W_{j,t}^s$ to maximize the following objective function, which represents the utility of the household supplying the labor from the resulting wage income net of a quadratic cost for adjusting the nominal wage:

$$E_0 \sum_{t=0}^{+\infty} \beta_s^t \left\{ U_{c,j,t}^s \theta_t^{wc} \left[w_{j,t}^s \ell_{j,t}^s - \frac{\eta_w}{2} \left(\pi_{j,t}^{ws} \theta_t^w - \pi_{t-1}^{\iota_w} \pi^{1-\iota_w} \theta_{t-1}^c \right)^2 w_t^s \right] - \frac{a_{\ell^s} \ell_{j,t}^{s\,1+\phi}}{1+\phi} \right\}$$

subject to:

$$\ell_{j,t}^s = \left(\frac{w_{j,t}^s}{w_t^s} \right)^{-\varepsilon_t^\ell} \ell_t^s, \text{ and } w_{j,t}^s \equiv \frac{W_{j,t}^s}{P_t}$$

where:

$$\pi^{ws}_{j,t} \equiv \left(\frac{w^s_{j,t}}{w^s_{j,t-1}} \right) \pi_t, \tag{4}$$

and $\theta^{wc}_t \equiv \left(\frac{1-\tau^w_t}{1+\tau^c_t}\right), \theta^w_t \equiv \left(\frac{1-\tau^w_t}{1-\tau^w_{t-1}}\right)$ and $\theta^c_t \equiv \left(\frac{1+\tau^c_t}{1+\tau^c_{t-1}}\right)$. $U^s_{c,j,t}$ is the instantaneous marginal utility of households taken as given by unions.

Assuming a symmetric equilibrium, the FOCs of each labor union of type $s = p, i, m$ imply that:

$$\ell^s_t = \left(\int_0^{\gamma_s} \left(\ell^s_{j,t}\right)^{\frac{\varepsilon^\ell_t - 1}{\varepsilon^\ell_t}} dj \right)^{\frac{\varepsilon^\ell_t}{\varepsilon^\ell_t - 1}} = \ell^s_{j,t}$$

Finally, the cost of participating in the labor union is equal to the quadratic cost of changing the wage:

$$T^{us}_t = \gamma_p \frac{\eta_w}{2} \left(\pi^{ws}_t \theta^w_t - \pi^{\iota_w}_{t-1} \pi^{1-\iota_w} \theta^c_{t-1} \right)^2 w^s_t \tag{5}$$

for all types of households.

2..5 Entrepreneurs

There is a continuum of entrepreneurs in the economy indexed by j, with mass γ_e, who choose $c^e_{j,t}$, $k^e_{j,t}$, and $b^e_{j,t}$, in order to maximize the following utility function:

$$E_0 \sum_{t=0}^{+\infty} \beta^t_e (1 - a_{ce}) log(c^e_{j,t} - a_{ce} c^e_{t-1}).$$

where c^e_t denotes the average entrepreneur's consumption, $c^e_t = \gamma_e^{-1} \left(\int_0^{\gamma_e} c^e_{j,t} dj \right)$. The jth entrepreneur's budget constraint is given by:

$$\begin{aligned} &(1 + \tau^c_t) c^e_{j,t} + \frac{1 + r^{be}_{t-1}}{\pi_t} b^e_{j,t-1} + q^k_t k^e_{j,t} = \\ &(1 - \tau^k_t) r^k_t k^e_{j,t} + q^k_t (1 - \delta) k^e_{j,t-1} + b^e_{j,t} + \frac{J^R_t}{\gamma_e} + \frac{J^x_t}{\gamma_e} + \frac{J^k_t}{\gamma_e} - \frac{T^g_t}{\gamma_p + \gamma_i + \gamma_e + \gamma_m}. \end{aligned} \tag{6}$$

where τ^k_t denotes taxes on returns on capital, q^k_t is the price of the capital good in terms of the consumption good, r^k_t is the return on capital in terms of the consumption good, and r^{be}_{t-1} is the nominal interest rate on loans.

Entrepreneurs buy the capital good from the capital good producers and rent it to the intermediate good producers. They also own the intermediate good producers' firms and the capital good producers' firms and have bank loans. The flow of expenses of entrepreneurs is given by consumption (plus consumption taxes) $(1 + \tau^c_t) c^e_{j,t}$, capital purchases $q^k_t k^e_{j,t}$, and interest plus principal of loans taken out during the previous period $\frac{1+r^{be}_{t-1}}{\pi_t} b^e_{j,t-1}$. The sources of income are rental capital (minus capital taxes), $(1-\tau_t^k)r_t^k k_{j,t}^e$, loans , $b_{j,t}^e$, capital from the previous period $q_t^k(1-\delta)k_{j,t-1}^e$, dividends from the retail firms, $\frac{J_t^R}{\gamma_e}$, dividends from intermediate good producers $\frac{J_t^x}{\gamma_e}$, and dividends from capital good producers, $\frac{J_t^k}{\gamma_e}$, net of lump-sum taxes paid to the government, $\frac{T_t^g}{\gamma_p+\gamma_i+\gamma_p}$.

In addition, impatient entrepreneurs face a borrowing constraint. In terms of final goods, they cannot borrow more than a certain proportion of the expected value in period t of the value in period $t+1$ of their capital stock in period $t+1$ discounted by $(1+r_t^{be})$:

$$(1+r_t^{be})b_{j,t}^e \leq m_t^e E_t\left\{q_{t+1}^k \pi_{t+1}(1-\delta)k_{j,t}^e\right\},$$

where m_t^e is the stochastic loan-to-value ratio.

2..6 Intermediate good producers

There is a continuum of competitive intermediate good producers in the economy indexed by j, with mass γ_x. Intermediate good producers sell intermediate goods in a competitive market to retailers.

The jth intermediate good producer has access to a technology represented by a production function:

$$y_{j,t}^x = A_t\left(k_{j,t-1}^{ee}u_j\right)^\alpha\left[\left(\ell_{j,t}^{pp}\right)^{\mu_p}\left(\ell_{j,t}^{ii}\right)^{\mu_i}\left(\ell_{j,t}^{mm}\right)^{\mu_m}\right]^{1-\alpha}\left(\frac{K_{t-1}^g}{\gamma_x}\right)^{\alpha_g},$$

where $k_{j,t-1}^{ee}$ is the capital rented by the firm from entrepreneurs, u_j is the capital utilization rate that we consider exogenous, $\ell_{j,t}^{pp}$ is the amount of "packed" patient labor input rented by the firm, $\ell_{j,t}^{ii}$ is the amount of "packed" impatient labor input rented by the firm, $\ell_{j,t}^{mm}$ is the amount of "packed" hand-to-mouth labor input rented by the firm, and K_{t-1}^g is the amount of public capital controlled by the government. A_t denotes an aggregate productivity shock.

In addition to the cost of the inputs required for production, the intermediate good producers face a fixed cost of production, Φ_x, which guarantees that the economic profits are roughly equal to zero in the steady-state, to be consistent with the additional assumption of no entry and exit of intermediate good producers and a cost of utilization of capital equal to:

$$\left[\psi_{u_1}\left(u_j-1\right)+\frac{\psi_{u_1}}{2}\left(u_j-1\right)^2\right]k_{j,t-1}^{ee}.$$

Intermediate good producers take all prices as given and choose $k_{j,t-1}^{ee}$, $\ell_{j,t}^{pp}$, $\ell_{j,t}^{ii}$, and $\ell_{j,t}^{mm}$ to maximize profits:

$$\frac{J_t^x}{\gamma_x} = \frac{y_t^x}{x_t} - w_t^p\ell_t^{pp} - w_t^i\ell_t^{ii} - w_t^m\ell_t^{mm} - r_t^k k_{t-1}^{ee} - \Phi_x - \left[\psi_{u_1}\left(u_j-1\right)+\frac{\psi_{u_1}}{2}\left(u_j-1\right)^2\right]k_{j,t-1}^{ee} \quad (7)$$

2..7 Capital good producers

There is a continuum of capital goods producers in the economy indexed by j, with mass γ_k. Capital goods producers sell new capital goods, $k_{j,t}$, in a competitive market to entrepreneurs.

The jth capital goods producer produces these new capital goods out of the non-depreciated portion of old capital goods, $(1-\delta)k_{j,t-1}$, bought from entrepreneurs at price q_t^k, and of gross investment goods, $i^z_{j,t}$, bought from investment good packers at price p_t^I. Old non-depreciated capital goods can be converted one to one to new capital. However, gross investment goods are subject to non-linear adjustment costs. The amount of new capital goods evolves according to the following law of motion,

$$k_{j,t} = (1-\delta)k_{j,t-1} + i_{j,t}\varepsilon_t^k.$$

where $i_{j,t}$ is *effective* investment, which is related to investment (*gross of adjustment costs*) through the following expression,

$$i^z_{j,t} = i_{j,t}\left[1 + \frac{\eta_i}{2}\frac{i_{j,t}}{k_{j,t-1}}\right] \tag{8}$$

so that $i_{j,t} \le i^z_{j,t}$, and ε_t^k is an investment-specific productivity shock.

Each capital good producer chooses $k_{j,t}$ and $i_{j,t}$ in order to maximize profits:

$$\frac{J_t^k}{\gamma_k} = \left[q_t^k\varepsilon_t^k - p_t^I\left(1 + \frac{\eta_i}{2}\frac{ß_t}{k_{t-1}}\right)\right] i_t. \tag{9}$$

2..8 Retailers

There is a continuum of retailers indexed by j, with mass γ. Each retailer buys the intermediate good from intermediate goods producers, differentiates it and sells the resulting varieties of intermediate goods, in a monopolistically competitive market, to goods packers.

We assume that retail prices are indexed by a combination of past and steady-state inflation of retail prices with relative weights parameterized by ι_p. In addition, retailers are subject to quadratic price adjustment costs, where η_p controls the size of these costs.

Then, each retailer chooses the nominal price for its differentiated good, $P^H_{j,t}$ to maximize:

$$E_0\sum_{t=0}^{+\infty}\beta_p^t\lambda_{j,t}^p\left[p_t^H\frac{P^H_{j,t}y_{j,t}}{P_t^H} - \frac{y^{xx}_{j,t}}{x_t} - \frac{\eta_p}{2}\left(\frac{P^H_{j,t}}{P^H_{j,t-1}} - \left(\pi^H_{t-1}\right)^{\iota_p}\left(\pi^H_{ss}\right)^{1-\iota_p}\right)^2 y_t\right]$$

subject to:

$$\begin{aligned} y_{j,t} &= y^{xx}_{j,t} \\ y_{j,t} &= \left(\frac{P^H_{j,t}}{P^H_t}\right)^{-\varepsilon_t^y} y_t, \end{aligned}$$

where $p_t^H = \frac{P_t^H}{P_t}$, $\pi_t^H = \frac{P_t^H}{P_{t-1}^H}$, and ε_t^y is the elasticity of substitution.

Assuming complete markets and a symmetric equilibrium, we have that:

$$y_t = \left(\int_0^\gamma y_{j,t}^{\frac{\varepsilon_t^y}{1-\varepsilon_t^y}} dj \right)^{\frac{1-\varepsilon_t^y}{\varepsilon_t^y}} = y_{j,t}.$$

Finally, the individual retailer's profits are given by:

$$\frac{J_t^R}{\gamma} = y_t \left[1 - \frac{1}{x_t} - \frac{\eta_p}{2} \left(\pi_t^H - \left(\pi_{t-1}^H\right)^{\iota_p} \left(\pi_{ss}^H\right)^{1-\iota_p} \right)^2 \right]. \tag{10}$$

2..9 Banks

There is a continuum of banks with mass γ_b. Each bank comprises of three units: a wholesale unit and two retail units. The two retail units are responsible for selling differentiated loans and differentiated deposits, in monopolistically competitive markets, to loan and deposit packers. The wholesale unit manages the capital position of the bank, receives loans from abroad, and raises wholesale domestic loans and deposits. The loan-retailing unit also gives loans to the government in a competitive market.

2..9.1 Wholesale unit

The wholesale unit of branch j combines bank capital, $k_{j,t}^b$, wholesale deposits, $d_{j,t}^b$, and foreign borrowing, $-\frac{B_{j,t}^*}{\gamma_b}$, in order to issue wholesale domestic loans, $b_{j,t}^b$, in a competitive market. The balance sheet of the wholesale unit of branch j is:

$$b_{j,t}^b = d_{j,t}^b - \frac{B_{j,t}^*}{\gamma_b} + k_{j,t}^b.$$

The wholesale units pay a quadratic cost whenever the capital-to-assets ratio $\frac{k_{j,t}^b}{b_{j,t}^b}$ deviates from an exogenously given target, ν_b. Finally, bank capital, in nominal terms, $\hat{k}_j^b$ evolves according to the following law of motion:

$$k_{j,t}^b = \frac{(1-\delta_b)}{\varepsilon_t^{kb}} k_{j,t-1}^b + (1-\tau_t^{Jb}) \omega_b J_{j,t-1}^b,$$

where ε_t^{kb} is a shock to the bank capital management and $J_{j,t}^b$ represents the profits of the bank in nominal terms.

The problem of the wholesale unit of branch j is to choose the amount of wholesale loans, $b_{j,t}^b$, and wholesale deposits, $d_{j,t}^b$, and foreign borrowing, B_t^*, in order to maximize cash flows:

$$\max_{b^b_{j,t}, d^b_{j,t}, B^*_{j,t}} r^b_t b^b_{j,t} - r_t d^b_{j,t} + r^*_t \frac{B^*_{j,t}}{\gamma_b} - \frac{\eta_b}{2} \left(\frac{k^b_{j,t}}{b^b_{j,t}} - \nu_b \right)^2 k^b_{j,t},$$

where r^b_t, r_t, and r^*_t are the gross real interest rates for wholesale lending, wholesale deposits, and foreign borrowing respectively, all of them taken as given and in terms of consumption goods. Parameter η_b determines the cost of deviating from the regulatory capital ratio, ν_b. The rate r_t is the monetary policy rate that follows from the assumption that wholesale units can obtain funds from the monetary authority at that rate. The FOC displays the following results:

$$(r^b_t - r^*_t) = -\eta_b \left(\frac{k^b_t}{b^b_t} - \nu_b \right) \left(\frac{k^b_t}{b^b_t} \right)^2. \tag{11}$$

We can drop the sub-index j from the FOCs because the focus is on a symmetric equilibrium where each wholesale bank unit decides its optimal capital-to-loans ratio, taking as given the capital-to-loans ratios of other banks. Accordingly, we can drop the sub-index from the law of motion for bank capital:

$$\pi_t k^b_t = \frac{(1-\delta_b)}{\varepsilon^{kb}_t} k^b_{t-1} + \omega_b \left(\frac{\pi_t J^b_{t-1}}{\gamma_b} \right), \tag{12}$$

and the balance-sheet equation of each wholesale unit:

$$b^b_t = d^b_t - \frac{B^*_t}{\gamma_b} + k^b_t. \tag{13}$$

Following Schmitt-Grohe and Uribe (2003), to ensure the stationarity of equilibrium we assume that:

$$r^*_t = \phi_t r_t, \tag{14}$$

where the risk premium ϕ_t increases with the external debt according to the expression:

$$\log \phi_t = -\widetilde{\phi} \left(\exp\left(B^*_t \right) - 1 \right) + \theta^{rp}_t \tag{15}$$

where θ^{rp}_t is a exogenous shock to the risk premium.

2..9.2 Deposit-retailing unit

The deposit-retailing unit of branch j combines bank capital and sells a differentiated type of deposit, $d^{pp}_{j,t}$, in a monopolistically competitive market, to deposit packers, who bundle the varieties together and sell the packed deposits, in a competitive market, to patient households, d^{pp}_t. Finally, each deposit-retailing unit uses its resources to buy $d^b_{j,t}$ from the wholesale banks.

The deposit-retailing unit of branch j chooses the real gross interest rate paid by its type of deposit, $r^d_{j,t}$ in order to maximize:

$$E_0 \sum_{t=0}^{+\infty} \beta_p^t \lambda_t^p \left[r_t d^b_{j,t} - r^d_{j,t} d^{pp}_{j,t} - \frac{\eta_d}{2} \left(\frac{r^d_{j,t}}{r^d_{j,t-1}} - 1 \right)^2 r^d_t d^{pp}_t \right]$$

subject to:

$$\begin{aligned} d^b_{j,t} &= d^{pp}_{j,t}, \\ d^{pp}_{j,t} &= \left(\frac{r^d_{j,t}}{r^d_t} \right)^{-\varepsilon^d_t} d^{pp}_t, \end{aligned}$$

where ε^d_t is the elasticity of substitution between different types of deposits and η_d determines the costs associated to changes in the interest rate of deposits.

The demand faced by deposit-retailing units is derived from the optimization problem solved by deposits packer. The FOCs of deposit-retailing units are:

$$\begin{aligned} & 1 + \frac{r_t}{r^d_t} \left(\frac{\theta^d_t}{\theta^d_t - 1} \right) - \left(\frac{\theta^d_t}{\theta^d_t - 1} \right) + \eta_d \left(\frac{r^d_t}{r^d_{t-1}} - 1 \right) \frac{r^d_t}{r^d_{t-1}} \\ & -\beta_p E_t \left\{ \frac{\lambda^p_{t+1}}{\lambda^p_t} \left[\eta_d \left(\frac{r^d_{t+1}}{r^d_t} - 1 \right) \left(\frac{r^d_{t+1}}{r^d_t} \right)^2 \frac{d^{pp}_{t+1}}{d^{pp}_t} \right] \right\} = 0, \end{aligned} \tag{16}$$

where we have omitted the subindexes j in the FOC because of complete markets and the construction of a symmetric equilibrium. Hence we have that:

$$d^{pp}_t = \left(\int_0^\gamma \left(d^{pp}_{j,t} \right)^{\frac{\varepsilon^d_t}{1-\varepsilon^d_t}} dj \right)^{\frac{1-\varepsilon^d_t}{\varepsilon^d_t}} = d^{pp}_{j,t}$$

and:

$$d^b_t = d^{pp}_t. \tag{17}$$

2..9.3 Loan-retailing unit

The loan-retailing unit of branch j borrows from the wholesale unit, $b^b_{j,t}$, creates differentiated loans and sells the resulting loan, in a monopolistically competitive market, to loan packers, who sell the packed loans to impatient households, $b^{ii}_{j,t}$ and entrepreneurs, $b^{ee}_{j,t}$. Each loan-retailing unit also lends to the government, B^g_t, in a competitive market at a rate $\theta^g_{ss} r^b_t$, i.e., charging a mark-up over the cost of the funds, but taking both the mark-up and the cost of the funds as given.

The loan-retailing unit of branch j chooses the real gross interest rates for its loans to impatient households, $r^{bi}_{j,t}$, and entrepreneurs, $r^{be}_{j,t}$, in order to maximize profits subject to:

$$b^{ii}_{j,t} + b^{ee}_{j,t} + \frac{\alpha_{B_g}\alpha_{RW}B^g_t}{\gamma_b} = b^b_{j,t}, \tag{18}$$

$$b^{ii}_{j,t} = \left(\frac{r^{bi}_{j,t}}{r^{bi}_t}\right)^{-\varepsilon^{bi}_t} b^{ii}_t, \tag{19}$$

$$b^{ee}_{j,t} = \left(\frac{r^{be}_{j,t}}{r^{be}_t}\right)^{-\varepsilon^{be}_t} b^{ee}_t, \tag{20}$$

where we have used $\lambda^p_{j,t}$ because capital good producers are owned by patient households, ε^{bi}_t and ε^{be}_t are the elasticities of substitution between types of loans for impatient households and for entrepreneurs, respectively.

The demand faced by the loan-retailing unit in Equations (19) and (20) is derived from the optimization problem solved by loan packers. The FOCs for this problem are:

$$\begin{aligned} &1 + \frac{r^b_t}{r^{bi}_t}\left(\frac{\theta^{bi}_t}{\theta^{bi}_t - 1}\right) - \left(\frac{\theta^{bi}_t}{\theta^{bi}_t - 1}\right) - \eta_{bi}\left(\frac{r^{bi}_t}{r^{bi}_{t-1}} - 1\right)\frac{r^{bi}_t}{r^{bi}_{t-1}} + \\ &\beta_p E_t\left\{\frac{\lambda^p_{t+1}}{\lambda^p_t}\left[\eta_{bi}\left(\frac{r^{bi}_{t+1}}{r^{bi}_t} - 1\right)\left(\frac{r^{bi}_{t+1}}{r^{bi}_t}\right)^2 \frac{b^{ii}_{t+1}}{b^{ii}_t}\right]\right\} = 0 \text{ and} \end{aligned} \tag{21}$$

$$\begin{aligned} &1 + \frac{r^b_t}{r^{be}_t}\left(\frac{\theta^{be}_t}{\theta^{be}_t - 1}\right) - \left(\frac{\theta^{be}_t}{\theta^{be}_t - 1}\right) - \eta_{be}\left(\frac{r^{be}_t}{r^{be}_{t-1}} - 1\right)\frac{r^{be}_t}{r^{be}_{t-1}} + \\ &\beta_p E_t\left\{\frac{\lambda^p_{t+1}}{\lambda^p_t}\left[\eta_{be}\left(\frac{r^{be}_{t+1}}{r^{be}_t} - 1\right)\left(\frac{r^{be}_{t+1}}{r^{be}_t}\right)^2 \frac{b^{ee}_{t+1}}{b^{ee}_t}\right]\right\} = 0 \end{aligned} \tag{22}$$

where η_{bi} and η_{be} determine the costs associated to changes in the interest rates of loans. Hence we have that:

$$b^{ii}_t = \left(\int_0^\gamma \left(b^{ii}_{j,t}\right)^{\frac{\varepsilon^{bi}_t}{1-\varepsilon^{bi}_t}} dj\right)^{\frac{1-\varepsilon^{bi}_t}{\varepsilon^{bi}_t}} = b^{ii}_{j,t} \text{ and}$$

$$b^{ee}_t = \left(\int_0^\gamma \left(b^{ee}_{j,t}\right)^{\frac{\varepsilon^{be}_t}{1-\varepsilon^{be}_t}} dj\right)^{\frac{1-\varepsilon^{be}_t}{\varepsilon^{be}_t}} = b^{ee}_{j,t}.$$

2..9.4 Profits

The profit of the bank branch j in terms of consumption good units is given by:

$$J_t^b = (r_t^{bi} - \tau_t^b)b_t^{ii} + (r_t^{be} - \tau_t^b)b_t^{ee} + \theta_{ss}^g r_t^b \left(\alpha_{RW} \frac{B_t^g}{\gamma_b}\right) - (r_t^d + \tau_t^d)d_t^{pp} + r_t^* \frac{B_t^*}{\gamma_b} -$$
$$\frac{\eta_b}{2}\left(\frac{k_t^b}{b_t^b} - \nu_b\right)^2 k_t^b - \frac{\eta_d}{2}\left(\frac{r_t^d}{r_{t-1}^d} - 1\right)^2 (r_t^d + \tau_t^d)d_t - \frac{\eta_{bi}}{2}\left(\frac{r_t^{bi}}{r_{t-1}^{bi}} - 1\right)^2 (r_t^{bi} - \tau_t^b)b_t^{ii}$$
$$-\frac{\eta_{be}}{2}\left(\frac{r_t^{be}}{r_{t-1}^{be}} - 1\right)^2 (r_t^{be} - \tau_t^b)b_t^{ee}, \qquad (23)$$

where again we drop the sub-index j under complete markets and symmetric equilibrium.

2..10 External sector

We consider that the home country is small relative to the rest of the world, taken as exogenous (see Monacelli, 2004, and Gali and Monacelli, 2005).

2..10.1 Imports

A continuum of consumption good packers in the economy indexed by j with mass γ_c buy domestic goods from good packers, $c_{j,t}^h$, and import foreign goods, $c_{j,t}^f$, pack them and sell the bundle for consumption in a competitive market to households and entrepreneurs. The packing technology is expressed by the following CES composite baskets of home- and foreign-produced goods:

$$c_{j,t}^c = \left((1 - \omega^c \varepsilon_t^{\omega d})^{\frac{1}{\sigma_c}} \left(c_{j,t}^h\right)^{\frac{\sigma_c - 1}{\sigma_c}} + (\omega^c \varepsilon_t^{\omega d})^{\frac{1}{\sigma_c}} \left(c_{j,t}^f\right)^{\frac{\sigma_c - 1}{\sigma_c}}\right)^{\frac{\sigma_c}{\sigma_c - 1}}.$$

There is also a continuum of investment good packers in the economy indexed by j with mass γ_z that buy domestic goods from good packers, $i_{j,t}^h$, and import foreign goods, $i_{j,t}^f$, pack them and sell the bundle, in a competitive market, to capital producers. The technology is given by

$$i_{j,t}^z = \left((1 - \omega^i \varepsilon_t^{\omega d})^{\frac{1}{\sigma_i}} \left(i_{j,t}^h\right)^{\frac{\sigma_i - 1}{\sigma_i}} + (\omega^i \varepsilon_t^{\omega d})^{\frac{1}{\sigma_i}} \left(i_{j,t}^f\right)^{\frac{\sigma_i - 1}{\sigma_i}}\right)^{\frac{\sigma_i}{\sigma_i - 1}},$$

where σ_c and σ_i are the consumption and investment elasticities of substitution between domestic and foreign goods and, ω^c and ω^i, are inversely related to the degree of home bias and, therefore, directly with openness. These parameters are assumed to be affected by the same shock, $\varepsilon_t^{\omega d}$.

Each period, the consumption goods packer chooses $c_{j,t}^h$ and $c_{j,t}^f$ to minimize production costs subject to the technological constraint.

By assuming a symmetric equilibrium, from FOCs we can obtain the following expressions:

$$c_t^h = (1 - \omega^c \varepsilon_t^{\omega d}) \left(p_t^H\right)^{-\sigma_c} c_t^c, \tag{24}$$

$$c_t^f = (\omega^c \varepsilon_t^{\omega d}) \left(p_t^M\right)^{-\sigma_c} c_t^c, \tag{25}$$

$$i_t^h = (1 - \omega^i \varepsilon_t^{\omega d}) \left(\frac{p_t^H}{p_t^I}\right)^{-\sigma_i} i_t^z, \tag{26}$$

$$i_t^f = (\omega^i \varepsilon_t^{\omega d}) \left(\frac{p_t^M}{p_t^I}\right)^{-\sigma_i} i_t^z. \tag{27}$$

Because profits have to be zero, we have the following relationships:

$$1 = \left((1 - \omega^c \varepsilon_t^{\omega d}) \left(p_t^H\right)^{1-\sigma_c} + (\omega^c \varepsilon_t^{\omega d}) \left(p_t^M\right)^{1-\sigma_c}\right)^{\frac{1}{1-\sigma_c}}, \tag{28}$$

$$p_t^I = \left((1 - \omega^i \varepsilon_t^{\omega d}) \left(p_t^H\right)^{1-\sigma_i} + (\omega^i \varepsilon_t^{\omega d}) \left(p_t^M\right)^{1-\sigma_i}\right)^{\frac{1}{1-\sigma_i}}. \tag{29}$$

Given the small open economy assumption, the price of imports in domestic currency is defined as:

$$p_t^M = er_t(1 + \tau_t^m), \tag{30}$$

where er_t is the real exchange rate (and ER_t the nominal exchange rate), i.e., $er_t = \frac{ER_t P_t^*}{P_t}$, τ_t^m represents the import tariff, and P_t^* stands for the exogenous world price index.

Some definitions follow from the previous equations:

$$C_t = \gamma_c c_t^c, \tag{31}$$

$$C_t^h = \gamma_c c_t^h, \tag{32}$$

$$I_t = \gamma_z i_t^z, \text{ and} \tag{33}$$

$$I_t^h = \gamma_z i_t^h, \tag{34}$$

where C_t is aggregate consumption and I_t is aggregate investment. Aggregate imports are:

$$IM_t = \gamma_c c_t^f + \gamma_z i_t^f = C_t^f + I_t^f. \tag{35}$$

Therefore, the following equations hold in aggregate:

$$C_t = \gamma_c c_t^c = p_t^H \gamma_c c_t^h + p_t^M \gamma_c c_t^f = \gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m,$$

$$I_t = \gamma_z i_t^z = \frac{p_t^H}{p_t^I} \gamma_z i_t^h + \frac{p_t^M}{p_t^I} \gamma_z i_t^f = \gamma_k i_t.$$

2..10.2 Exports

Good packers export under some degree of imperfect exchange rate pass-through. We assume a fraction $(1-ptm)$ of good packers' prices differ at home and abroad. The remaining fraction of good packers, ptm, sets a unified price across countries (i.e., the law of one price holds). Thus, the export price deflator relative to consumption goods, p_t^{EX}, is defined as:

$$p_t^{EX} = (1-\tau_t^x) p_t^{H(1-ptm)} (er_t)^{ptm}, \tag{36}$$

where τ_t^x are export subsidies and the parameter ptm determines the degree of pass through.

The continuum of foreign consumers and investors with mass γ^* demand domestic goods from good packers given by:

$$c_t^{*f} = \omega_t^f \left(\frac{p_t^{EX}}{er_t} \right)^{-\sigma_c^*} c_t^*, \tag{37}$$

$$i_t^{*f} = \omega_t^f \left(\frac{p_t^{EX}}{er_t} \right)^{-\sigma_c^*} i_t^*, \tag{38}$$

where c_t^* and i_t^* represent the (exogenous) aggregate consumption and investment demand in the rest of the world, and ω_t^f captures the impact of factors other than prices affecting exports.

Therefore, exports of the home economy $ex_t = c_t^{*f} + i_t^{*f}$ can be written as:

$$ex_t = \omega_t^f \left(\frac{p_t^{EX}}{er_t} \right)^{-\sigma_c^*} (c_t^* + i_t^*). \tag{39}$$

Finally, we can define aggregate exports as:

$$EX_t = \gamma^* ex_t. \tag{40}$$

2..10.3 Accumulation of foreign assets

The net foreign asset position B_t^* evolves according to the following expression (denominated in the home currency):

$$B_t^* = \frac{(1+r_{t-1}^*)}{\pi_t} B_{t-1}^* + \left[p_t^{EX} \gamma^* ex_t - p_t^M \left(\gamma_c c_t^f + \gamma_z i_t^f \right) \right] \tag{41}$$

where a negative/positive sign for B_t^* implies a borrowing/lending position for the domestic economy with respect to the rest of the world and r_t^* stands for the interest rate paid/received for borrowing/lending abroad. Additionally, the trade balance TB_t is defined as:

$$TB_t = p_t^{EX} \gamma^* ex_t - p_t^M \left(\gamma_c c_t^f + \gamma_z i_t^f \right). \tag{42}$$

2..11 Prices

Prices in the model are written relative to before-consumption-tax CPI. Thus, the numeraire is P_t. In this subsection we establish some relationships between prices and inflation rates, where P_t^H is the (absolute) price of domestic-produced output and $p_t^H = \frac{P_t^H}{P_t}$ is the corresponding relative price. Also, π_t^H, the gross inflation rate that appears in the New Phillips curve, is defined as $\frac{P_t^H}{P_{t-1}^H}$. Correspondingly, the gross inflation rate for the relative price is:

$$\widetilde{\pi}_t^H = \frac{p_t^H}{p_{t-1}^H}. \tag{43}$$

Notice that both π_t^H and $\widetilde{\pi}_t^H$ are identified in the equations of the model, the former in the New Phillips curve and the latter because we write some equations in terms of p_t^H. However, we cannot identify P_t^H or P_t. The inflation rate considered by the central bank in the Taylor rule is π_t' (the post-consumption-tax gross inflation rate). We cannot obtain π_t' directly from P_t, because it is not identified, but we can recover it from π_t^H and $\widetilde{\pi}_t^H$ as

$$\pi_t' = \frac{P_t}{P_{t-1}} \frac{1+\tau_t^c}{1+\tau_{t-1}^c} = \frac{\frac{P_t}{P_t^H}}{\frac{P_{t-1}}{P_{t-1}^H}} \frac{P_t^H}{P_{t-1}^H} \frac{1+\tau_t^c}{1+\tau_{t-1}^c} = \frac{\pi_t^H}{\widetilde{\pi}_t^H} \frac{1+\tau_t^c}{1+\tau_{t-1}^c}, \tag{44}$$

and the before-consumption-tax inflation rate as

$$\pi_t = \frac{\pi_t^H}{\widetilde{\pi}_t^H}. \tag{45}$$

2..12 Monetary authority

The domestic economy belongs to a monetary union (say, EMU), and monetary policy is managed by the central bank (say, the ECB) through the following Taylor rule that sets the nominal interest rate allowing for some smoothness of the interest rate's response to the area-wide inflation rate and output growth:

$$(1+r_t) = (1+r_{ss})^{(1-\phi_r)}(1+r_{t-1})^{\phi_r} \left(\frac{\pi_t^{emu}}{\pi_{ss}^{emu}}\right)^{\phi_\pi(1-\phi_r)} \left(\frac{y_t^{emu}}{y_{t-1}^{emu}}\right)^{\phi_y(1-\phi_r)} (1+e_t^r), \tag{46}$$

where π_t^{emu} is EMU inflation as measured in terms of the consumption price deflator and $\frac{y_t^{emu}}{y_{t-1}^{emu}}$ measures the gross rate of growth of EMU output. We assume some inertia in setting the nominal interest rate, and the shock to the central bank interest rate is characterized by:

$$e_t^r \sim \mathcal{N}(0, \sigma_r) \tag{xvi}$$

The domestic economy contributes to EMU inflation and output growth according to its economic size in the Eurozone, ω_{Sp}:

$$\pi_t^{emu} = (1-\omega_{Sp})\left(\overline{\pi_t^{remu}}\right) + \omega_{Sp}\pi_t' \text{ and} \tag{47}$$

$$\frac{y_t^{emu}}{y_{t-1}^{emu}} = (1-\omega_{Sp})\left(\overline{\left(\frac{y_t^{remu}}{y_{t-1}^{remu}}\right)}\right) + \omega_{Sp}\frac{y_t}{y_{t-1}} \tag{48}$$

where $\overline{\pi_t^{remu}}$ and $\overline{\left(\frac{y_t^{remu}}{y_{t-1}^{remu}}\right)}$ are average (exogenous) inflation and output growth in the rest of the Eurozone.

The real exchange rate is given by the ratio of relative prices between the domestic economy and the remaining EMU members, so real appreciation/depreciation developments are driven by the inflation differential of the domestic economy vis-à-vis the euro area:

$$\frac{er_t}{er_{t-1}} = \frac{\overline{\pi_t^{remu}}}{\pi_t}. \tag{49}$$

2..13 Fiscal authority

The fiscal authority expends government consumption, government investment, and interest plus principal borrowed during the previous period. The fiscal authority collects revenues with new debt, lump-sum taxes, and distortionary taxation on consumption, housing services, labor income, loans, deposits and banks' profits:

$$\begin{aligned}
&C_t^g + I_t^g + \left(\frac{1+\theta_{ss}^b r_{t-1}^b}{\pi_t}\right) B_{t-1}^g = B_t^g + T_t^g + \tau_t^c\left(\gamma_p c_t^p + \gamma_i c_t^i + \gamma_e c_t^e + \gamma_m c_t^m\right) + \\
&\frac{\tau_t^m}{1+\tau_t^m} p_t^M IM_t - \frac{\tau_t^x}{1-\tau_t^x} p_t^{EX} EX_t + \\
&\tau_t^h q_t^h\left(\gamma_p \Delta h_{j,t}^p + \gamma_i \Delta h_{j,t}^i\right) + \tau_t^w\left(w_t^p \gamma_p \ell_t^p + w_t^i \gamma_i \ell_t^i + w_t^m \gamma_m \ell_t^m\right) + \tau_t^k r_t^k K_t + \\
&\tau_t^{Jb} J_{t-1}^b + \tau_t^d d_t^p + \tau_t^b (b_t^i + b_t^e).
\end{aligned} \tag{50}$$

Tax rates are constant:

$$\tau_t^s = \tau^s \text{ for } s = c, h, w, d, b, Jb, k, m, x.$$

Government consumption and investment are considered to be random shares of potential GDP:

$$C_t^g = \psi^{cg}\varepsilon_t^{cg} \tag{51}$$

$$I_t^g = \psi^{ig}\varepsilon_t^{ig} \tag{52}$$

where ψ^{cg} and ψ^{ig} are the parameters that represent GDP shares and both ε_t^{cg} and ε_t^{ig} are two stationary shocks.

Lump-sum taxes adjust to guarantee the non-explosiveness of government debt according to the following rule,

$$T_t^g = T_{t-1}^g + \rho_{tgb1}\left(\psi_t^{bg} - \psi_{ss}^{bg}\right) + \rho_{tgb2}\left(\psi_t^{bg} - \psi_{t-1}^{bg}\right), \tag{53}$$

where ψ_t^{bg} represents the proportion of public debt over aggregate output, namely,

$$\psi_t^{bg} = \frac{B_t^g}{Y_t} \tag{54}$$

and ψ_{ss}^{bg} refers to its steady-state objective value. In turn, public debt adjusts to satisfy the budget constraint given the above levels of C_t^g, I_t^g and T_t^g.

Finally, public capital evolves with investment according to the law of motion:

$$K_t^g = (1 - \delta_g)K_{t-1}^g + I_t^g. \tag{55}$$

3. Quantitative results

3..1 Main findings in the baseline scenario

In order to obtain quantitative results of the effects of banking taxes on economic activity, the model has been conveniently calibrated for the Spanish economy following Boscá et al (2018), although it can be alternatively estimated for any EMU member.

We solve numerically the model by changing, alternately, the specific tax rate on (a) banks' profits (τ^{Jb}); (b) deposits in banks from households (τ^D); and (c) loans from banks to mortgagors and entrepreneurs (τ^B). In all three cases, we depart from a situation in which this tax rate does not exist and then is introduced so that the *ex-ante* government revenues (i.e., the increase in revenues before the endogenous reaction in economic activity takes place) would increase by 0.1 percent points GDP. This metric favors a fair comparison among the three taxes of the macroeconomic reaction induced by any of them. In addition, we assume that the introduction of taxes are unanticipated and permanent, that is, there is no time for the agents to react in advance, and no specific date is proposed for tax expiration. Finally, we also consider that any additional government revenue coming from the new tax is used to finance a lump sum transfer, which is the same for all households in the economy.

Table 1 shows the main results. Because the effects may change over time, results are presented for two temporal horizons: at two years after the tax introduction, and in the very long run when the economy has reached a new steady state.

A first result worthy to note is that all the three taxes produce changes in the main macroeconomic variables of a similar magnitude. That means that taxes on profits, deposits or loans are equivalent in macroeconomic terms. The rationality behind this result is easy to understand by looking at two equations in the model: the one representing the interest rate reaction to deviations from the dictated capital-to-asset ratio (equation 11) and the banks' balance sheet constraint (equation 13). The first one implies that banks' capital and loans are tied by a constant relationship in the long run and move closely one each other in the short run. Hence, a tax levied on their assets triggers the same reaction by banks than a tax

Table 1: MACROECONOMIC EFFECTS OF TAXES ON BANKING

	Profits		Deposits		Loans	
	SS	2 years	SS	2 years	SS	2 years
GDP	-0.0828	-0.0307	-0.0776	-0.0272	-0.0774	-0.0272
Consumption	-0.0379	0.0338	-0.0355	0.0294	-0.0354	0.0294
Investment	-0.1116	-0.0885	-0.1046	-0.0718	-0.1043	-0.0717
Hours	0.0294	0.0060	0.0276	-0.0269	0.0275	-0.0268
Wage savers	-0.0235	-0.0136	-0.0220	-0.0160	-0.0220	-0.0160
Wage mortgagors	-0.0443	0.0433	-0.0415	0.0380	-0.0414	0.0380
Wage HtM	0.0264	0.0900	0.0248	0.1046	0.0247	0.1044
Deposits	-0.7915	-0.5540	-0.7425	-0.5267	-0.7405	-0.5256
Loans households	-1.9866	-1.3835	-1.8635	-1.2986	-1.8587	-1.2960
Loans firms	-0.1626	-0.0396	-0.1524	-0.0317	-0.1521	-0.0317
Rate deposits (bp)	0.0000	0.0334	0.0000	0.0310	0.0000	0.0309
Rate loans househ. (bp)	16.7424	10.3449	15.6855	8.5413	15.6439	8.5293
Rate loans firms. (bp)	14.7089	9.4056	13.7805	7.5617	13.7439	7.5514
Profits (before tax)	5.8733	3.6256	-1.4943	-4.2060	-1.4904	-4.1986
Profits (after tax)	-1.5943	-3.6835	-1.4943	-4.2060	-1.4904	-4.1986
Bank capital	-1.5943	-1.0472	-1.4943	-0.8949	-1.4904	-0.8933
Government revenues	0.0962	0.0760	0.0902	0.0626	0.0899	0.0625

Figures indicate percentage deviations with respect to the initial steady state, except for interest rates which are expressed in basis point deviations and government revenues which represent percent point GDP variation. The permanent increase in banking taxes is design to yield an ex ante increase in government revenues equivalent to 0.1 percentage point GDP in all cases.

on their capital, implemented through a charge on their profits. With respect to the second equation, the model includes a risk premium on deviations of external debt from their long run equilibrium. Therefore, the economy starts and ends in our simulations with a net foreign asset position equal to zero (see Schmitt-Grohe and Uribe, 2003). Imposing $B_t^* = 0$ and a constant capital-to-asset ratio (ν_b), the balance sheet constraint can be written as

$$d_t^b = (1 - \nu_b)\, b_t^b \tag{56}$$

demonstrating that taxing loans or deposits are equivalent when the fiscal shock does not provoke important movements in the external asset holdings. Given the macroeconomic equivalence of the three taxes in what follows we will just focus on the tax on banks profits.

Results in Table 1 also point out that the introduction of taxes triggers a response by banks that in the long run pushes loans rates up, approximately between 15 and 17 basis points, reducing the volume of credit (-0.15 percent to firms and -1.9 percent to households) and deposits (about -0.8 percent). The reaction of the financial variables harms aggregate consumption and investment, that fall by -0.04 and -0.11 percent, respectively, although consumption of those households without access to the financial market (hand-to-mouth consumers) rises, since they do not suffer the tighter banking conditions and benefit from the increase in government transfers. Prompted by the desire to compensate for the drop in consumption, lenders and borrowers augment working hours, leading to a reduction in their equilibrium wages. The negative effect on wages is also explained by the fall of the capital that follows lower private investment. Overall, the economic activity as measured by GDP is reduced by more than 0.08 percent. Although higher taxes on banking provokes a rise in the ex post banks markups that widens the tax base, the decline in real and financial activity causes a slowdown in the potential increase of public revenues.

In general, the negative effects on the economic activity increase over time: GDP, private consumption, and investment experience a larger decline in the long run than in the short run. The opposite is observed with profits before tax, which expand as banks translate the tax burden to households and firms, shrinking their balance sheets and making the credit more expensive, as they attempt to balance their after-tax profitability to the aggregate cost of capital for the rest of the sectors.

A more detailed representation of the dynamic response of the economy in the first ten years can be found in impulse-response functions in Figure 1, which confirms the equivalence between the three taxes. This figure shows that taxes prompt a smooth adjustment in the interest rates on loans that last for ten quarters before stabilizing to the new level. The dynamics of the interest rates are determined by the adjustment costs parameters η_d, η_{bi} and η_{be}. As we can also see in Figure 1, interest rates on deposits are virtually constant over time. This can be explained by the narrow relationship that interest rates on deposits have with the reference rate set by the ECB, given that both are tied in the long run by a constant markdown. Additionally, the monetary policy rate changes with EMU inflation, which is almost unaffected by the tax.

Deposits and loans to mortgagors experience a steep decline on impact, before continuing a smoother downturn. The results in Figure 1 display a high persistence of the effect that taxes on banking have on loans and deposits and that translates to consumption and GDP. Although close to it, ten years after the introduction of the tax, aggregate production has not still fully stabilized at its long-run equilibrium.

As discussed in the introduction, one argument in favor of higher taxes on banking activities has to do with increasing the participation of banks in public revenues. We investigate this aspect in Figure 2. More particularly, we let the tax rate on banks' profits to vary between 7 and 35 percentage point (meaning an ex ante government revenue increase between 0.1 and 0.5 GDP percentage point). The upper panel shows the long-run effect on GDP as percent deviation with respect to the initial equilibrium. The lower panel does the same for government

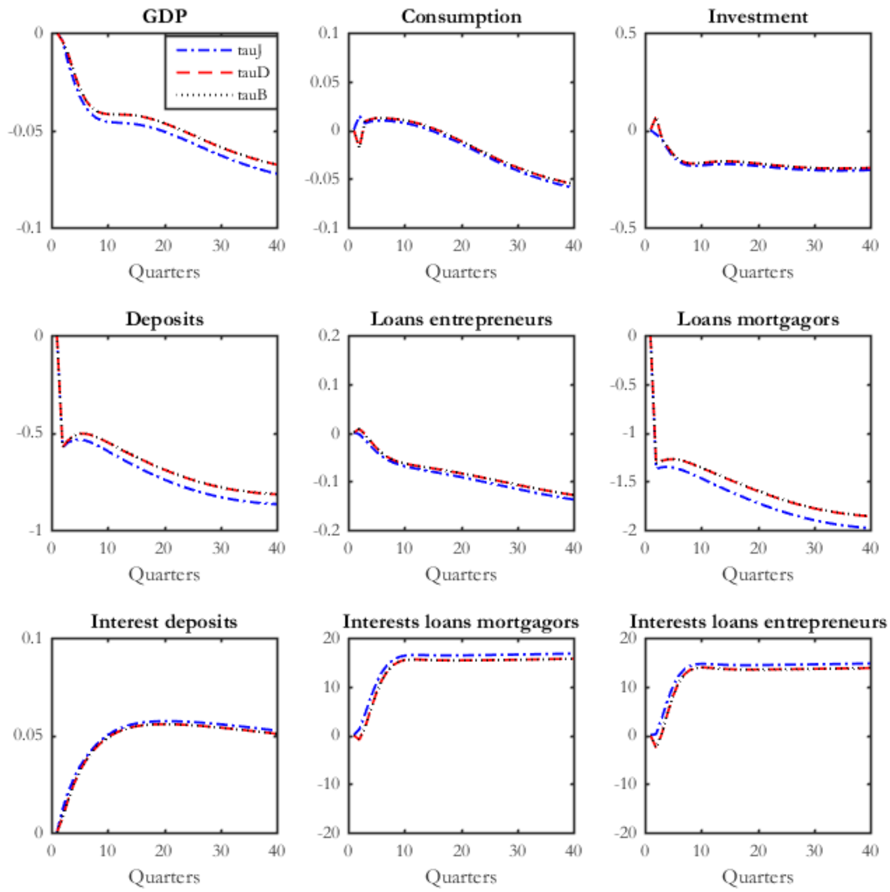


Figure 1: *Macroeconomic reaction to different taxes*

revenues expressed as percentage points of initial GDP. Thus, both figures are comparable in terms of GDP variation.

In our baseline scenario, government revenues increase slightly more than proportionally with respect to the tax rate. However, it comes at a cost of a more than proportionally decline in GDP. Banks react to taxes by increasing their markups and transferring part of the fiscal cost to households through higher interest rates on loans. The increase in the tax base (due to higher pre-tax profits) is not fully compensated by the negative effects on the tax base due to lower economic activity. According to our results, the trade-off between government revenue and GDP is captured by a general equilibrium elasticity of GDP to government revenues of -0.86, virtually independent of the tax rate.

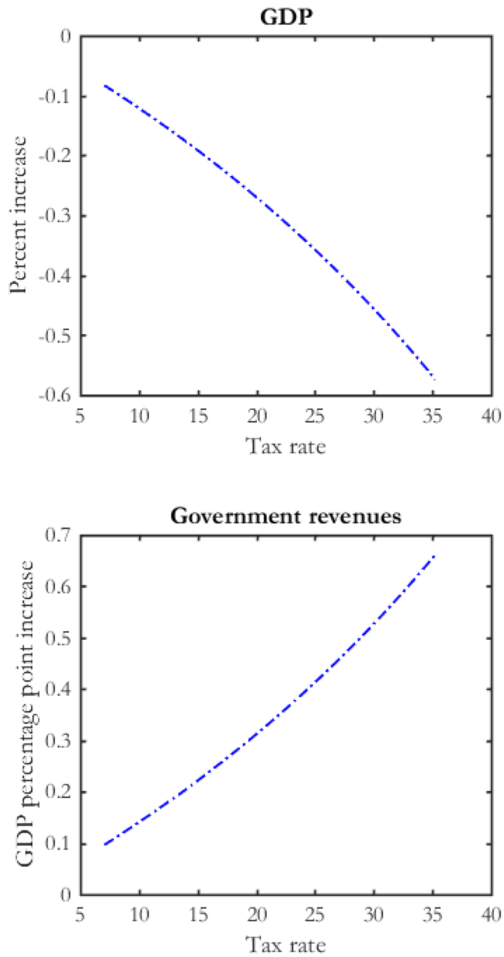


Figure 2: *Steady state GDP and government revenue reaction to the tax pressure on banks profits*

3..2 Robustness checks

To check the robustness of the results, we change the value of a set of structural parameters related to banks' decisions and their interaction with other economic agents. The results of this exercise are shown in Table 2, where each parameter is modified in both directions, lowering and increasing its value.

In most of the cases, the simulation results are not very sensitive to changes in the parameter values, despite the large range considered. Thus, the degree of competition in the banking sector (as capture by the markup parameters), the regulatory capital-to-assets ratio, or the cost for the banks of deviating from it, do not seem to play a relevant role.

Table 2: SENSITIVITY OF GDP ELASTICITY TO CHANGES IN DIFFERENT PARAMETERS
TAX ON BANKS' PROFITS. EFFECTS ON GDP

	Scenario	Parameters	SS	2 years
Baseline			-0.0828	-0.0307
Mortgagors' interest rate markups (θ^{bi}= 1.32)	Low	θ^{bi}= 1.15	-0.0848	-0.0296
	High	θ^{bi}= 1.60	-0.0802	-0.0325
Firms' interest rate markup (θ^{bi}= 1.16)	Low	θ^{be}= 1.07	-0.0806	-0.0301
	High	θ^{be}= 1.30	-0.0861	-0.0313
Deposits' interest rate markdown (θ^{d}= 0.61)	Low	θ^{d}= 0.80	-0.0848	-0.0313
	High	θ^{d}= 0.20	-0.0793	-0.0351
Government interest rate markup (θ^{g}= 1.00)	Low	θ^{g}= 1.00	-0.0828	-0.0307
	High	θ^{g}= 1.30	-0.0795	-0.0303
Interest rate reaction to capital deviation (η_b= 30)	Low	η_b= 30	-0.0743	-0.0239
	High	η_b= 120	-0.0876	-0.0369
Share of retained profits (ω_b= 0.8)	Low	ω_b= 0.5	-0.0820	-0.0253
	High	ω_b= 1.0	-0.0828	-0.0329
Interest rate rigidity (η_d= 2.5; η_{be}= 9.4; η_{bi}= 10.1)	Low	η_d= η_{be}= η_{bi}= 2	-0.0828	-0.0304
	High	η_d= η_{be}= η_{bi}= 500	-0.0828	-0.0291
Impatientness mortgagors (β_i= 0.98)	Low	β_i= 0.985	-0.0776	-0.0250
	High	β_i= 0.95	-0.1047	-0.0468
Impatientness entrepreneurs (β_e= 0.985)	Low	β_e= 0.989	-0.0898	-0.0330
	High	β_e= 0.97	-0.0639	-0.0245
Utility houses (a_{hp}= a_{hi}= 0.16)	Low	a_{hp}= a_{hi}= 0.10	-0.1042	-0.0401
	High	a_{hp}= a_{hi}= 0.26	-0.0629	-0.0222
Capital/assets ratio (ν_b= 0.09)	Low	ν_b= 0.06	-0.0717	-0.0243
	High	ν_b= 0.12	-0.0894	-0.0358
Capital utilization rate (u_j = 0.93)	Low	u_j= 0.8	-0.0942	-0.0340
	High	u_j= 1.0	-0.0773	-0.0290

Benchmark values of the parameters in brackets

We detect, however, that a higher degree of impatience for mortgagors can be associated with stronger negative effects of the tax. These households demand more credit when they are more impatient, but they have to buy houses to back up new loans. In equilibrium, when mortgagors have a higher discount rate, loans and the demand of homes fall by less after the increase of taxes on banks' profits, interest rates increase by more, and consumption and investment fall by more. As a result, GDP elasticity is -0.1042.

Interestingly, when we assume entrepreneurs with a higher impatience rate the result

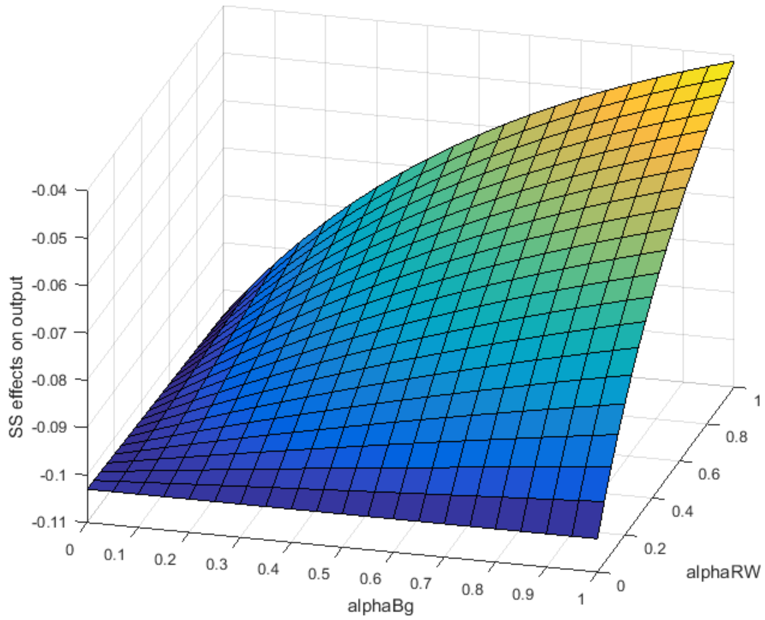
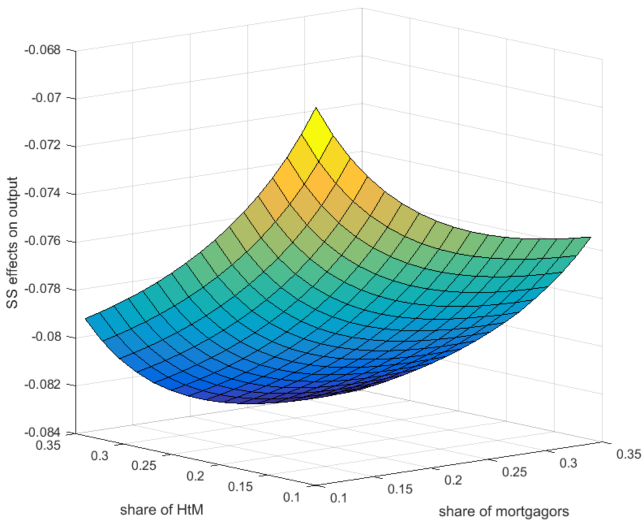


Figure 3: *GDP effect of taxes as a function of bank's government debt holdings*

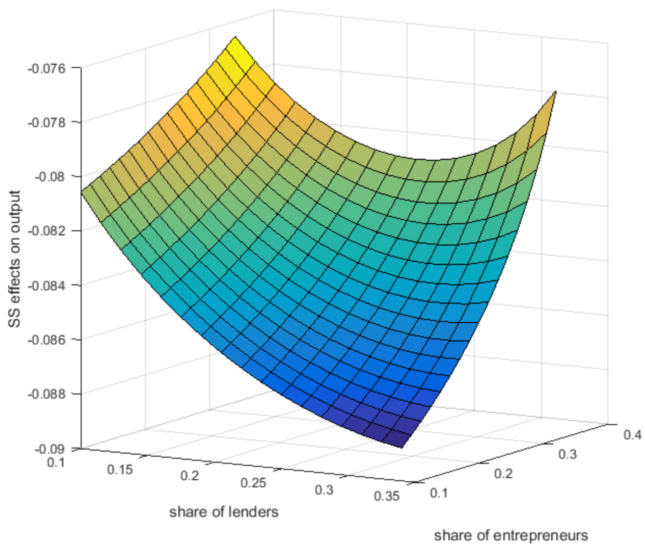
is quite different. In this case the banking tax is associated with weaker effects on economic activity. A higher discount rate implies that entrepreneurs increase current consumption and reduce capital investment, which is used as collateral for new loans and is rented to firms to produce intermediate goods. In a scenario of lower activity in the steady state, investment and output fall by less when the banking tax increases, and the GDP elasticity is -0.0639.

The value of the parameter for the weight of houses in utility also make a difference. When more utility is derived from houses (higher aggregate demand for houses), mortgagors' consumption is lower in the steady state. In this scenario, the banking tax induces a lower decline in their consumption and the GDP elasticity falls to -0.0629.

In Figure 3 we study how banks government bonds holdings can affect the long run macroeconomic impact. More specifically, we simultaneously change two parameters that, taken together, determine the share of total government debt in banks' balance sheets: the share of public debt held by residents (α_{RW}) and the share of government debt in resident hands held by banks (α_{Bg}). According to Figure 3, the banking tax will display a minimum impact (-0.04 against the benchmark -0.083) when $\alpha_{RW} = \alpha_{Bg} = 1$, that is, when all government debt is held by banks. In this case, the increase in government revenues and the subsequent reduction in government debt frees up bank resources that can be readdressed towards mortgagors and entrepreneurs. The negative effect becomes stronger the higher the amount of



(a) *Share of lenders held constant*



(b) *Share of mortgagors held constant*

Figure 4: *GDP effect of taxes as a function of household's shares*

government debt held by foreigners.

From the four categories of households in the model three interact directly with the banking sector, both supplying deposits (patient households) or demanding loans (impatient households and entrepreneurs). Even though the fourth category (hand-to-mouth households) does not interect directly with banks, its behavior is importantly affected by the introduction of the banking tax via the effect that it induces other variables, such as wages, hours and government transfers. Thus, the macroeconomic effects derived from the tax changes will depend on the weights that these four types of households have on the economy.

In Figure 4 we analyze the sensitivity of the long run effects on GDP to multiple combinations in the population shares of the different households. In the upper panel we keep constant the weight of patient households to the benchmark value (γ_p = 0.2) and let the share of mortgagors (γ_i) and hand-to-mouth (γ_m) vary between 10 and 35 percentage point. Under these circumstances the share of entrepreneurs is obtained as the residual (γ_e = 1 - γ_p - γ_i - γ_m). In the lower panel we proceed in a similar manner, but this time keeping the weight of mortgagors' constant to the benchmark value (γ_i = 0.25).

As can be seen In Figure 4, although very different combinations in the population contribution of the four categories of households can make some difference in the effect of the banking tax, these differences are not very pronounced: GDP elasticities range between -0.07 and -0.09. Given a reasonable constant share of lenders, the upper plot reproduces an minimum elasticity (-0.07) associated with a low share of impatient and hand-to-mouth households and a high share of entrepreneurs. Finally, the lower plot confirms that the elasticity is greater (-0.09) when the share of impatient households is high and the share of entrepreneurs is low.

Overall, these results confirm that the distortionary effects of banking taxes are robust to changes in the structural parameters of our model and, therefore, in quite different economic environments.

4. Conclusions

This paper has analyzed the effects that the introduction of three alternative banking taxes have on main macroeconomic variables. In particular, we have considered taxes on banking profits, loans, and deposits. To evaluate these effects, we have proposed a dynamic general equilibrium model specially designed for a small open economy in EMU. The model considers a rich detail of the tax structure and a banking sector characterized by its wholesale activity, which manages bank capital and obtains funding from the ECB and the rest of the world, and its retail activity, which obtains deposits and grants loans to impatient households, entrepreneurs, and the government.

Our results show that the three proposed taxes are equivalent in their macroeconomic effects. In order to maintain the return on capital (net of taxes) in line with the cost of capital of the economy, banks reduce their size in the long run, operating with a smaller volume of capital, credits and deposits, and increase loan interest rates. Taxes therefore negatively affect the real activity of the economy.

The higher the tax rate the more intensified is the reaction of banks in terms of translating part of the fiscal cost to households and firms. Although pre-tax bank profits widens with the tax rate, making it possible for government revenues to increase more than proportionately, distortionary effects on the supply side of the economy provoke a more than proportional GDP fall. Thus, the general equilibrium elasticity of GDP to ex post government revenues is close to -0.9, a macroeconomic trade-off that is virtually independent of the tax rate.

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