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Fiscal Devaluations in a Monetary Union and the Extensive Margin of Trade

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Abstract

We quantify the effects of fiscal devaluations within a monetary union model with endogenous entry and endogenous tradability. First, unilateral fiscal devaluations have large and permanent positive effects for countries that implement such policies, as they increase hours worked, consumption, GDP and produced varieties. Second, as the model supports positive cross-country comovements of GDP and consumption through endogenous tradability and the expansion of the trade sector, unilateral fiscal devaluations are not beggar-thy-neighbor policies. We find *positive spillovers* to other members of the monetary union in terms of economic activity as well as in terms of welfare. Both results stand in contrast with respect to the existing literature and suggest that fiscal devaluation is an efficient and non-aggressive policy option for governments that belong to a monetary union.

Keywords: Fiscal devaluations, endogenous tradability, endogenous varieties, monetary union, taxes.
JEL Class.: E32, E52, F41.

1 Introduction

Fiscal devaluations have recently attracted a lot of attention among policymakers of the Eurozone. The constraint on nominal exchange rates imposed by monetary unification has led to the development of external imbalances within the Eurozone. Arguably,

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the large current account deficits observed in countries like Greece, Spain, Italy or Portugal in the early years of the Eurozone could be explained by a catch-up dynamics and a surge in domestic investment in those countries before 2008. Since the 2008 Great Recession, competitiveness problems have been identified, that prevent the rebalancing of current accounts within the Eurozone. Given the situation and the constraint bearing on monetary policy instruments, fiscal devaluations have appeared as a potential cure. Very recently, Portugal announced that a fiscal devaluation would be implemented. Some countries such as Denmark (in 1987), Germany (in 2007) or France (2012) already proceeded to shifts in the tax burden from labor taxation (payroll taxes or labor income taxes) to consumption taxation (typically VAT). Even though these policy episodes were not extensively studied in the literature, the effects expected from such policies are a reduction in labor costs, production costs and a change in the relative price of tradable goods, leading to a real exchange rate depreciation. This depreciation is in turn expected to improve the trade balance, and to generate a rise in GDP.

The theoretical channels through which fiscal devaluations could affect the economy were recently studied by Farhi, Gopinath and Itskhoki (2013). They show that allocations implied by nominal exchange rate devaluations may be replicated under an extensive set of assumptions regardless of the size of the targeted devaluation, provided governments have access to a sufficiently large number of fiscal instruments. Hence, changes in the tax mix can help governments affect the terms of trade and real exchange rates within a monetary union, inducing positive effects on the trade balance, a reduction in structural current account deficits and a rise in GDP through exports and the rise of hours worked. Relatedly, Langot, Patureau and Sopraseuth (2014) analyze the optimal taxation scheme in an open economy with search labor market frictions. However, most papers focusing on the effects of fiscal devaluations or fiscal policy in open economies disregard the potential permanent effects that fiscal devaluations might have on the patterns of trade, limiting their scope to the effects on trade that go through the real exchange rate and expenditure switching and/or wealth effects (see Bosca, Domenech and Ferri (2012), or Lipinska and von Thadden (2012)). Since Ghironi and Melitz (2005) however, we know that changes in real exchange rates not only induce expenditure-switching effects or wealth effects, but also impact the number of goods traded, altering the overall degree of trade openness in the economy. In addition, open-economy models with endogenous varieties and endogenous tradability most often assume that entry costs and export-market entry costs are paid in units of labor. Hence, any permanent change in the taxation of labor should translate into permanent effects on the number of produced varieties and on the number of exported varieties.

In this paper, we investigate the effects of fiscal devaluations on key macroeconomic aggregates and welfare using an open economy model with endogenous varieties and endogenous tradability. Our two main results are that fiscal devaluations (i) have positive, large and persistent effects for countries implementing them, and (ii) produce positive spillovers within the monetary union on the GDP, consumption and welfare of partners. Both results appear to contradict existing conclusions from the literature. A recent study by the European Commission (2013) uses general equilibrium models to quantify the effects of fiscal devaluations and concludes that fiscal devaluations induce a permanent, though small expansion of employment and GDP, while the trade balance is hardly affected in the long run. We reach different conclusions as the effects of fiscal devaluations are positive, large and permanent. Bosca et al. (2012) develop a general equilibrium model calibrated to Spain and show that a fiscal devaluation may be effective in stimulating output, hours worked and the trade balance, but the magnitude of the effects reported are somehow smaller than in our set-up, even when converted to consider a similar fall in labor income taxation. Finally, Lipinska and von Thadden (2012) find that the effects of fiscal devaluations can be contrasted depending on the structure of international financial markets and depending on the inflation target of the common central bank. In addition, they report permanent but smaller effects from fiscal devaluations, with *negative spillovers* on other members of the monetary union (both in terms of output and welfare), while we find *positive spillovers* from such policy reforms.

The model used in this paper follows Auray, Eyquem and Poutineau (2012). It features an endogenous number of produced varieties and endogenous tradability. It also incorporates pricing to market, sticky prices for both domestic and export goods, and a common central bank that commits to a monetary policy rule that stabilizes aggregate inflation. Precisely because new varieties produced and new exported varieties require the payment of entry costs in units of labor, fiscal devaluations, inducing large and permanent effects on the labor market equilibrium, have strong and permanent effects on the extensive margin of production and on the extensive margin of trade. We model unilateral fiscal devaluations as a large (5 percentage points) increase in the consumption tax rate and a fall in labor income taxation that keeps fiscal revenues raised by the government constant. According to our results, unilateral fiscal devaluations generate large positive effects on hours worked in the country that implements such policies, that boost output both at the intensive and the extensive margin, and allow for an expansion of the trade sector. Unilateral fiscal devaluations also raise both margins of private consumption. Even though the extensive margin of output is dampened for partners, the increase in the size of their export market raises the number of exporters in the country, *i.e.* the extensive margin of trade, with positive effects on output and consumption. Therefore unilateral fiscal devaluations generate positive spillovers for partners. This result is particularly important since unilateral (nominal or fiscal) devaluations are usually considered as *beggar-thy-neighbor* and aggressive policies (see Lipinska and von Thadden (2012) for instance). As a consequence, joint fiscal devaluations yield even larger positive effects, both in terms of output and welfare.

Quantitatively, unilateral fiscal devaluations raise output by 1.88% in the long run, consumption by 1.80%, hours worked by 1.8%, varieties by 1.10% and exported varieties by 0.7%. The implied real depreciation reaches 0.23% in the long run. Figures for joint fiscal devaluations are somehow larger, producing a 2% increase of output in the long run, with no effects on the real exchange rate. Long term effects of unilateral devaluations are negligible for partners. In terms of welfare, for the country that implements the reform, the model predicts that unilateral fiscal devaluations produce welfare gains a bit larger than 1% of steady-state consumption in the long run, and a 0.42% welfare gain on impact. For partners, unilateral fiscal devaluations produce a 0.33% welfare gain on impact but only a small 0.07% welfare gain in the long run. Again, the welfare gains produced by joint fiscal devaluations are magnified with respect to unilateral fiscal devaluations, producing a 0.72% welfare gain in the short run, and a 1.1% welfare gain in the long run.

The paper is organized as follows. Section 2 discusses the key features of the model used to analyze fiscal devaluations. Section 3 investigates qualitatively and quantitatively the effects of a 5 percentage point increase in the consumption tax rate, accompanied by a fall in the labor income tax rate that keeps fiscal revenues constant. The Section considers unilateral and joint fiscal devaluations. Section 3 also quantifies the welfare effects of both policy options over different time horizons. Section 4 concludes.

2 Model highlights

The model is presented in details in Appendix A but some features are useful highlighting before engaging in the analysis of fiscal devaluations.

2.1 The dynamics of varieties

After firms enter in the production sector, a decision that depends on their expected value being above the entry cost, they must decide whether selling in the domestic market or selling both in the domestic and the foreign market. This decision depends on their specific productivity level, which determines their ability to pay the entry cost on export markets. The model therefore provides an endogenous mechanism for both the total number of firms/varieties in the economy, and for the number of exporting firms, which is exactly the extensive margin of trade, due to the fact that each firm produces a single variety. More formally, the number of firms in the domestic economy n_t evolves according to

$$n_t = (1-\delta)(n_{t-1} + n_{e,t-1}) \tag{1}$$

where δ is an exogenous death shock and $n_{e,t}$ is determined by the free-entry condition

$$\widetilde{v}_t = f_e \frac{\varpi_t}{a_t} \tag{2}$$

where $\widetilde{v}_t$ is the average real value of firms, ϖ_t is the real wage and a_t the aggregate productivity of labor. Firms are priced by households as they have access to private equity shares in quantity x_t. Households also have access to an imperfectly integrated bond market as trade in bonds incurs the payment of adjustment costs. Finally, households consume and supply labor and first-order conditions summarize to:

$$\beta \mathsf{E}_t \left[\left(\frac{c_t}{c_{t+1}} \right)^{\gamma} \frac{1+\tau_{ct}}{1+\tau_{ct+1}} \frac{r_t}{(1+\pi_{t+1}) \left(1 + \varphi_b \left(\frac{b_t}{p_t} - \frac{b}{p} \right) \right)} \right] - 1 = 0 \tag{3}$$

$$\widetilde{v}_t - (1-\delta) \beta \mathsf{E}_t \left[\left(\frac{c_t}{c_{t+1}} \right)^{\gamma} \frac{1+\tau_{ct}}{1+\tau_{ct+1}} \left(\widetilde{d}_{t+1} + \widetilde{v}_{t+1} \right) \right] = 0 \tag{4}$$

$$\chi \ell_t^{\psi} c_t^{\gamma} - \frac{1-\tau_{\ell t}}{1+\tau_{ct}} \varpi_t = 0 \tag{5}$$

where c_t is the consumption level, ℓ_t the level of hours worked, τ_{ct} the tax rate on consumption, $\tau_{\ell t}$ the tax rate on labor income, r_t the nominal interest rate, π_t the CPI inflation rate, b_t the amount of risk-free bonds, $\widetilde{d}_t$ the average amount of profits and

ϖ_t is the real wage. The dynamics of varieties is affected by the real interest rate, that directs savings towards the creation of new firms through their average value $\widetilde{v}_t$. In addition, expected dividends raise the current value of firms and trigger new entries. Finally, the dynamics of the real wage shapes the value of the entry cost and therefore plays an important role in the dynamics of new ventures.

2.2 The dynamics of exported varieties

Among the total number of firms that produce goods during the period (n_t), only a subset of these firms $n_{x,t}$ sells in both domestic and foreign markets. Access to the export market requires the repeated payment of a fixed export cost f_x, paid units of labor, and the payment of an iceberg melting cost $(1+\tau)$, paid in units of consumption goods. Firms access foreign markets only if they generate enough profits to cover these costs, and their ability to make profits depends on a firm-specific productivity draw, that follows a Pareto distribution, as in Ghironi and Melitz (2005). Based on the individual behavior of firms and our assumption of sticky domestic and export prices, we can derive the productivity threshold beyond which firms engage in international trade, denoted $z_{x,t}$

$$z_{x,t} = \mu_{x,t}\left(1+\tau\right)\left(1-\frac{\eta^x}{2}\left(\pi_{x,t}-1\right)^2-\mu_{x,t}^{-1}\right)^{\frac{1}{1-\theta}}\left(\frac{f_x}{c_t^*+ac_{b,t}^*}\right)^{\frac{1}{\theta-1}}\left(\frac{\varpi_t}{q_t a_t}\right)^{\frac{\theta}{\theta-1}} \tag{6}$$

where $\mu_{x,t}$ is the export mark-up, $\pi_{x,t}$ the inflation rate of export goods, c_t^* aggregate consumption in the foreign country and q_t the real exchange rate. The lower $z_{x,t}$ the larger the number of exporting firms. Any macroeconomic mechanism making efficient labor cheaper, firms more competitive (the real exchange rate q_t higher), export mark-ups lower or the export market larger will increase the ability of domestic firms to export. As a consequence the number of exporting firms is decreasing in the threshold

$$n_{x,t} = \left(z_{\min}/z_{x,t}\right)^k n_t \tag{7}$$

where $z_{\min}$ and k are parameters characterizing the distribution of firm-specific productivity levels. The number of exporting firms also feeds back to the total number of varieties as total dividends are

$$\widetilde{d}_t = \widetilde{d}_{d,t} + \frac{n_{x,t}}{n_t}\widetilde{d}_{x,t} \tag{8}$$

A growing export sector, *i.e.* an increase in the share of exporting firms, increases total dividends as dividends of exporting firms are higher than those of non-exporting firms, with a positive effect on the average value of firms and on firms entry.

2.3 Effects on output and prices

The dynamics of GDP is

$$y_t = n_t \widetilde{\rho}_{d,t}^{1-\theta} \left(c_t + ac_{b,t}\right) + q_t n_{x,t} \widetilde{\rho}_{x,t}^{1-\theta} \left(c_t^* + ac_{b,t}^*\right) \tag{9}$$

$$y_t^* = n_t^* \widetilde{\rho}_{d,t}^{*1-\theta} \left(c_t^* + ac_{b,t}^*\right) + q_t^{-1} n_{x,t}^* \widetilde{\rho}_{x,t}^{*1-\theta} \left(c_t + ac_{b,t}\right) \tag{10}$$

It shows that the extensive margin of output and trade affect GDP positively through the composition of output. The impact on prices

$$n_t \widetilde{\rho}_{d,t}^{1-\theta} + n_{x,t}^* \widetilde{\rho}_{x,t}^{*1-\theta} = 1 \tag{11}$$

$$n_t^* \widetilde{\rho}_{d,t}^{*1-\theta} + n_{x,t} \widetilde{\rho}_{x,t}^{1-\theta} = 1 \tag{12}$$

reflects the benefits from a larger number of varieties for consumers. More varieties lower the general price level, and increases the relative prices of varieties ρ. The increase in varieties requires more work to build the firms, pushing wages (corrected by productivity) to rise more than relative prices, bringing mark-ups down. The fall in mark-ups is also consistent with the stronger competition on goods markets implied by entries. In addition, because we assume that production and export prices are sticky, these effects on price may take some time before fully affecting the level of relative prices, magnifying the short-run effects on output.

2.4 Monetary and fiscal policies

As in Farhi et al. (2013), governments have a balanced budget every period and simply rebate the product of distortionary taxes to the households in a lump-sum fashion

$$\tau_{\ell t} \varpi_t \ell_t + \tau_{ct} c_t = tr_t \tag{13}$$

$$\tau_{\ell t}^* \varpi_t^* \ell_t^* + \tau_{ct}^* c_t^* = tr_t^* \tag{14}$$

In particular, we abstract from public spending issues and simply focus on how fiscal devaluations can alter the equilibrium by shifting the distortions from labor income to consumption. Fiscal devaluations consist in replacing a given amount of labor income tax fiscal revenues by an equivalent amount of consumption tax revenues. We consider that governments proceeding to changes in tax rates maintain revenue-neutrality at all times, that is, they keep fiscal revenue constant by adjusting labor income taxes endogenously. Given our monetary union set-up and our assumption of sticky production and export prices, the monetary policy followed by the central bank can affect real interest rates in both countries. We assume that the common central bank controls the nominal interest rate, and commits to the following rule

$$\log (r_t/r) = \rho_r \log (r_{t-1}/r) + (1-\rho_r)\, \phi_\pi \log \pi_t^u \tag{15}$$

where $\pi_t^u = \pi_t^{1/2} \pi_t^{*1/2}$ is the union-wide inflation rate. It therefore serves as an endogenous transmission mechanism in the case of potential asymmetries within the monetary union generated by fiscal devaluations.

3 The effects of fiscal devaluations

3.1 Parameter values

Preferences. The calibration is identical in both countries. The model is quarterly. The discount factor is $\beta = 0.99$. As in Ghironi and Melitz (2005), the risk-aversion parameter is set to $\gamma = 2$. The inverse of the Frisch elasticity is set to $\psi^{-1} = 1$. The steady state value of ℓ is normalized to one and the value of χ is adjusted accordingly.

The production sector. Without loss of generality, we set $f_e = 1$.[1] The quarterly proportion of firms that exit the market each period in the economy is $\delta = 0.025$ (see Bergin and Corsetti (2008)). We follow Ghironi and Melitz (2005) and calibrate the elasticity of substitution between varieties at $\theta = 3.8$. Even though Berman, Martin and Mayer (2011) provide evidence of lower elasticities in France using firm-level data, lower values imply markups that are too high with respect to values found in empirical studies. Incidentally, a value of $\theta = 3.8$ apparently implies very high steady state markups. The question of markups in our model is a little more complex, as noted by Bilbiie, Ghironi and Melitz (2008). In the model, $\frac{\theta}{\theta-1}$ is the markup over marginal costs. Comparing this markup with the markup arising in models without entry and fixed costs, *i.e.* in which the markup over average costs and the markup over marginal costs coincide, might be confusing. In our model, a way to measure the markup over average costs in the steady state is to divide total dividends $\widetilde{d}$ by the aggregate production

[1] Only the ratio between f_e and f_x is relevant in determining the steady state, and f_e can be freely normalized without any consequence on the steady state or on the dynamics.

of the consumption sector y. Our baseline calibration ($\theta = 3.8$) yields a markup on average costs of about 15%, which matches values usually obtained in models without entry.

We make use of this result to calibrate the nominal rigidities parameter η. In a model with Calvo prices, changes in the markup affect the dynamics of inflation with intensity $(1-\eta^c)(1-\beta\eta^c)/\eta^c$ where $1/(1-\eta^c)$ is the average duration of price contracts. With price adjustment costs, the impact is $(\theta-1)/\eta$. The Rotemberg parameter should thus be set to equalize the impact of changes in the markup on inflation dynamics, *i.e.* $\eta = (\theta-1)\eta^c/((1-\eta^c)(1-\beta\eta^c))$. However, due to the discrepancy between the markup over average and marginal costs implied by our model, we choose to adjust the value of θ used to calibrate η, so as to obtain a consistent value of the parameter governing nominal rigidities, *i.e.* $\eta = \left(\theta^{no-entry}-1\right)\eta^c/((1-\eta^c)(1-\beta\eta^c))$, where $\theta^{no-entry}$ is the value of the elasticity among varieties usually calibrated in models without entry. Based on empirical evidence about EMU countries (see Benigno and Lopez-Salido (2006)), we assume that retailers change prices every 4 quarters on average ($1/(1-\eta^c) = 4$ implying $\eta^c = 0.75$), which given that $\theta^{no-entry} = 7.5$ and $\beta = 0.99$, implies $\eta = \eta^x = \eta^d = 76$.

The trade sector. Following Berman et al. (2011), we adjust the fixed export cost so that the share of exporting firms is exactly $\varphi = 20\%$, in accordance with the observed proportion in France. We do not dispose of clear-cut empirical evidence about trade costs and productivity distributions in Europe. In particular, based on various measures of the freeness of trade, empirical studies show that trade costs may vary largely across countries and sectors (see Chen and Novy (2011) for an illustration). Based on US data, Ghironi and Melitz (2005), choose $\tau = 0.3$. Corsetti, Martin and Pesenti (2008) allow trade costs to vary from 0.2 to 0.75. Berman et al. (2011) set $\tau = 0.2$, which is lower than the value of Ghironi and Melitz (2005). Identically, for the parameter k, which governs the distribution of firms' productivity, Ghironi and Melitz (2005) set $k = 3.4$ while Berman et al. (2011) choose much lower values ($k = 1.5$ in their benchmark calibration).[2] Due to the lack of converging values for Europe, we choose to set $k = 3.4$ and $\tau = 0.3$ resulting in a degree of trade openness in the steady state $n_x\widetilde{\rho}_x^{1-\theta} = 0.26$, close to the observed degree of intra-zone trade openness in the EMU, which is around 30% (see European Commission, 2006). Our calibration implies that

[2] Notice however that they are not tied by the requirement that k should be higher than $(\theta-1)$ due to the presence of distribution costs in their model.

exporters are 60.54% more productive than non-exporters, and domestic prices are 23.49% higher than export prices.

Tax rates and monetary policy. We set tax rates in the steady state to $\tau_{ct} = 0.15$ and $\tau_{\ell t} = 0.30$, as in Lipinska and von Thadden (2012). The Taylor rule parameters are set to $\rho_r = 0.7$ and $\phi_\pi = 1.5$.

3.2 Unilateral and joint fiscal devaluations

We start our analysis with the effects of a permanent unilateral 5 percentage point increase in VAT together with a reduction in labor income tax that keeps the budget balanced at all times under different assumptions of the model. First, we consider our baseline model. Second, we contrast the effects of this policy change with a constant extensive margin of production (*i.e.* a constant number of varieties) keeping an endogenous extensive margin of trade. This is achieved by substituting an additional equation $n_t = n$ to the free entry condition. Third, we consider another interesting case by assuming constant production and trade extensive margins together, which amounts to add a constant export threshold to the previous model, *i.e.* $z_{x,t} = z_x$ and $n_t = n$. In all cases, the model is solved using a non-linear Newton-type algorithm. The effects of unilateral fiscal devaluations are reported in Figures 1, 2 and 3 below.
The effects of fiscal devaluations can be traced considering that they basically consist in a fall in the labor wedge. The latter is defined as

$$lw_t = 1 - \frac{(1-\tau_{\ell t})}{(1+\tau_{ct})} = \frac{\tau_{ct} + \tau_{\ell t}}{1+\tau_{ct}} \tag{16}$$

and captures the overall effect of distortions induced by taxation in the economy. Let ν be the size of the fiscal devaluation, the rise in the consumption tax is, $\Delta\tau_{ct} = \nu\frac{gdp}{c}$. Our assumption of revenue-neutrality implies that

$$c_t \Delta\tau_{ct} + \tau_{ct}\Delta c_t + \varpi_t \ell_t \Delta\tau_{\ell t} + \tau_{\ell t}\Delta\left(\varpi_t \ell_t\right) = 0 \tag{17}$$

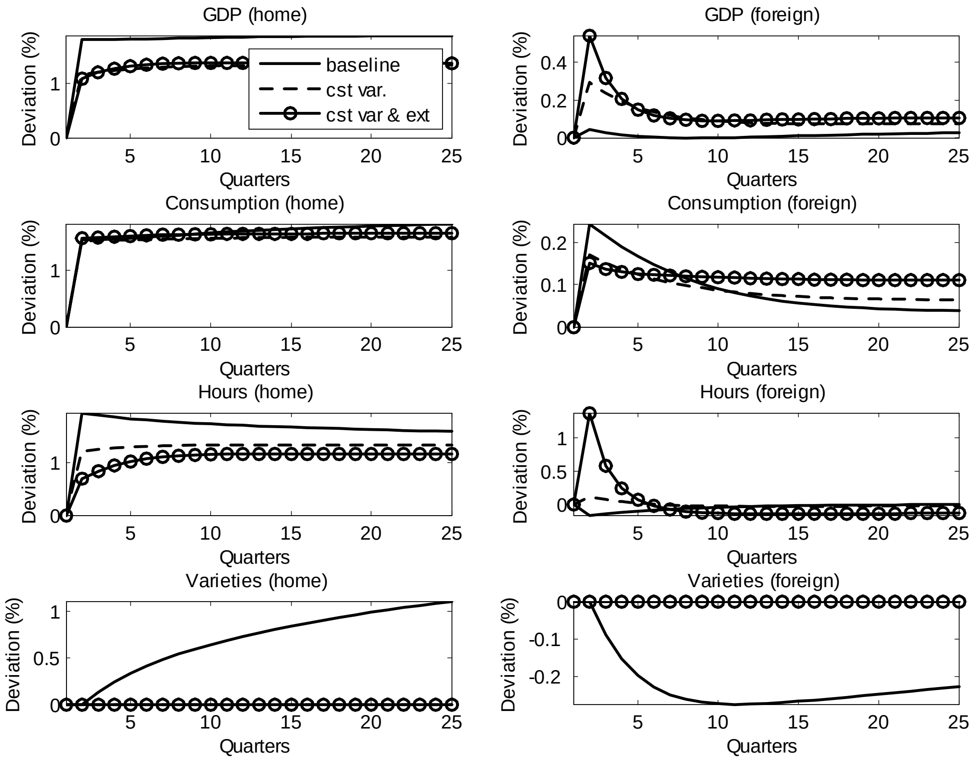
which, neglecting the immediate impact on endogenous variables ($\Delta c_t = \Delta\left(\varpi_t \ell_t\right) = 0$) and using steady-state values gives

$$\Delta\tau_\ell = -\frac{c}{\varpi\ell}\Delta\tau_c \tag{18}$$

The impact variation of the labor wedge is thus

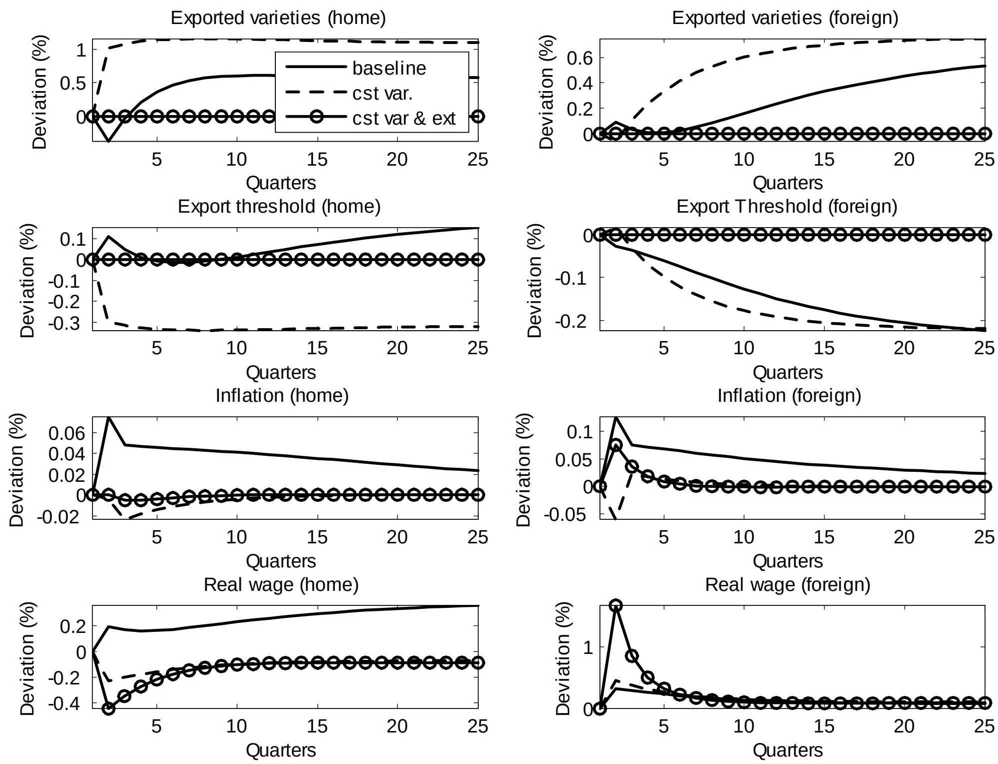
$$\Delta lw = \nu\frac{gdp}{c}\frac{(1-\tau_\ell)\,\varpi\ell - gdp\,(1+\tau_c)}{(1+\tau_c)^2\,\varpi\ell} < 0 \tag{19}$$

Figure 1: The effects of a domestic unilateral fiscal devaluation under alternative model specification 1. τ_{ct} is increase to transfer 5 pct pts of fiscal revenue from labor income to consumption.



The latter is always negative given our tax substitution experiment since $gdp \geq \varpi \ell$ always. The fall in the labor wedge induces an increase in labor supply in the domestic economy as well as an increase in consumption, leading GDP to rise. The larger the increase in hours, the larger the increase in GDP for two reasons: more hours increase the intensive margin of production but also allow for more firm creations, because the latter are built with labor units. These firm creations are made possible because both domestic and export profits rise in the domestic economy, as shown by the response of the total number of varieties and the response of exported varieties, that both rise. The effect on the extensive margin of output (varieties) is very persistent and takes some time to fully impact the economy. In addition, real wages go up since the rise in the demand for goods and in profits is large enough to push supply and the creation of new firms to a level where labor demand actually rises more than supply. This rise in real wages turns into a moderate inflation in the domestic economy, that forces the central bank of the monetary union to increase the nominal rate. It also supports the

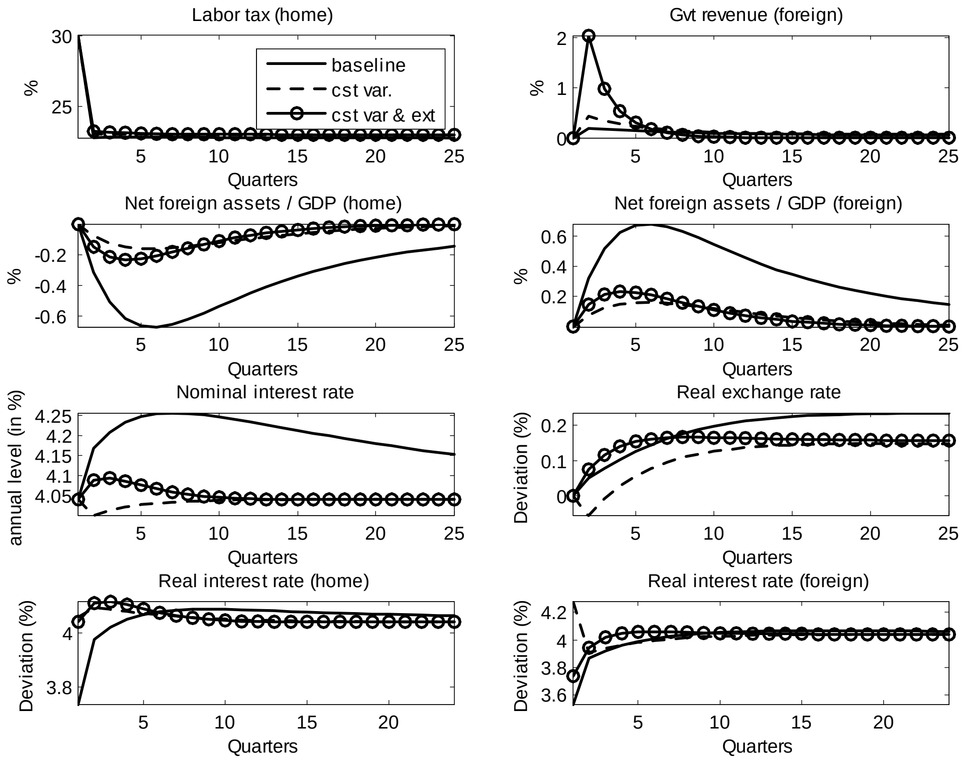
Figure 2: The effects of a domestic unilateral fiscal devaluation under alternative model specification 2. τ_{ct} is increase to transfer 5 pct pts of fiscal revenue from labor income to consumption.



rise in consumption since the joint rise of hours worked and wages produces a large increase in labor income.

The transmission to the foreign economy goes through several channels. The first one is trade. Because the size of the domestic market increases, the export threshold falls and the export sector grows in the foreign economy, which favors a moderate increase in foreign GDP. The second channel lies in the rise of the real exchange rate, capturing the fall in the relative price of domestic goods with respect to foreign goods. It favors an increase in foreign consumption, but a fall in the total number of varieties produced in the foreign country. The rise in foreign consumption is further reinforced by the monetary policy response induced by the shock, as the foreign real interest rate falls, lowering the intertemporal price of consumption. Overall, the effects of a fiscal devaluation are positive on all key variables of the domestic economy (GDP, consumption, investment in the creation of plants, hours). The spillovers to foreign

Figure 3: The effects of a domestic unilateral fiscal devaluation under alternative model specification 3. τ_{ct} is increase to transfer 5 pct pts of fiscal revenue from labor income to consumption.



variables are also clearly positive on all macroeconomic variables. Growth in the size of the trade sector and consumption are large enough to overturn the negative effects on the extensive margin of output.

Considering cases with constant varieties and constant export shares also sheds light on the specific impact of our specific assumptions, *i.e.* endogenous tradability and endogenous varieties. In particular, introducing endogenous varieties magnifies the positive effects of fiscal devaluations in the domestic economy but also significantly lowers positive spillovers from the fiscal devaluation to the foreign economy. As the responses under alternative assumptions make clear, the model with endogenous varieties features an increase in total varieties in the domestic economy and a reduction in total varieties in the foreign economy, that drive the dynamics of output in both countries. The no-arbitrage condition on assets requires that the real interest rate falls in the foreign country, boosting consumption and therefore limiting the fall in output. Hence, even with an endogenous number of varieties, the model predicts a positive spillover to the foreign economy after a fiscal devaluation in the domestic economy. Because the number of varieties rises in the domestic economy, hours worked rise more than under constant varieties, while consumption is broadly unaffected. In the foreign economy, the fall in produced varieties requires less labor to build plants, resulting in a moderate fall in hours, while consumption is driven by the fall in the real interest rate. Hence, in terms of welfare, we expect unilateral fiscal devaluations to have positive effects in both economies. However, given that movements are permanent in the domestic economy and almost completely temporary in the foreign economy, the effects unilateral fiscal devaluations on partners are expected to be positive but vanishing, while the effects in the economy implementing the reform should be positive and permanent.

We now characterize allocations when fiscal devaluations are conducted symmetrically in the monetary union. We report the very same cases, *i.e.* the baseline model, the model with constant varieties and the model with constant varieties and extensive margin of trade, in Table 1 and focus on steady-state effects. We also provide the steady-state effects of unilateral fiscal devaluations to provide a comparison.

Table 1: Percentage change in steady-state after fiscal devaluations.

	Baseline			Constant varieties			Cst. prod. and exp. varieties		
	Unilateral FD		Joint FD	Unilateral FD		Joint FD	Unilateral FD		Joint FD
	Home	Foreign	–	Home	Foreign	–	Home	Foreign	–
gdp	1.8823	0.0271	1.9559	1.3293	0.0755	1.4218	1.3648	0.1054	1.4790
c	1.8077	0.0379	1.9242	1.5805	0.0638	1.6642	1.6409	0.1100	1.7615
ℓ	1.5843	−0.0025	1.5251	1.3303	−0.0239	1.3214	1.1562	−0.1324	1.0278
n	1.1060	−0.2257	1.1796	–	–	–	–	–	–
n_x	0.5747	0.5332	1.2948	1.0968	0.7487	1.8779	–	–	–
z_x	0.1551	−0.2226	−0.0335	−0.3203	−0.2192	−0.5457	–	–	–
π	0.0234	0.0237	0.0231	0.0000	−0.0001	−0.0000	0.0000	−0.0001	−0.0000
ϖ	0.3581	0.0733	0.4777	−0.0723	0.1038	0.0311	−0.0871	0.0874	−0.0000
τ_ℓ	−24.0155	–	−24.147	−23.3285	–	−23.463	−23.2300	–	−23.2889
r	0.0277		0.0271	−0.0000		−0.0000	−0.0000		−0.0000
q	0.2338		–	0.1474		–	0.1560		–

In the case of joint fiscal devaluations, key variables exhibit an adjustment pattern that is qualitatively very close to the pattern observed in a country implementing a unilateral fiscal devaluation. A joint fiscal devaluation boosts hours worked, firm creations, GDP and consumption symmetrically for both countries. The mechanisms at work are similar to those described for unilateral fiscal devaluations. The export threshold falls, inducing more firms to participate in the export market, raising the size of the tradable sector. Because unilateral fiscal devaluations feature positive spillovers to the other members of the monetary union, a joint fiscal devaluation produces larger effects from a quantitative perspective than unilateral fiscal devaluations, as countries benefit from direct positive effects induced by their own fiscal devaluation, and from the indirect benefits from the fiscal devaluation of partners.

3.3 Welfare

In terms of welfare, we compute the Hicksian consumption equivalent $\mathcal{W}$ that keeps domestic and foreign households indifferent between staying at the initial steady state and experiencing the fiscal devaluation. Welfare effects are reported in Table 2 below.

Table 2: Welfare effects of fiscal devaluations (5 pct pt transfer of fiscal revenue from labor income to consumption), expressed in % of consumption

	Baseline			Constant varieties			Cst. prod. and exp. varieties		
	Unilateral FD		Joint FD	Unilateral FD		Joint FD	Unilateral FD		Joint FD
Horizon	Home	Foreign	–	Home	Foreign	–	Home	Foreign	–
1	0.4187	0.3391	0.7203	0.8102	0.1043	0.9313	1.1670	−0.6266	1.1701
4	0.4991	0.2249	0.7211	0.7837	0.1165	0.9129	1.0082	0.0871	1.1701
8	0.6240	0.1325	0.7621	0.7905	0.1052	0.9086	0.9666	0.1857	1.1701
32	0.9474	0.0398	1.0086	0.8191	0.0758	0.9051	0.9784	0.1845	1.1635
∞	1.0655	0.0712	1.1455	0.8191	0.0758	0.8971	0.9784	0.1845	1.1667

Table 2 shows that unilateral fiscal devaluations always bring substantial welfare gains to the country that implements the fiscal reform. Gains range from 0.4% to 1.16% of steady-state consumption depending on model assumptions and time horizon considered. Those gains are either stable or increasing over the time horizon, especially when the baseline model is considered. This time lag mainly comes from the very slow increase in produced varieties, that in turn affect other variables persistently. In addition, in the very short run, in all cases but the constant extensive margin of production and trade, there are positive spillovers from fiscal devaluations to monetary union partners. With constant varieties, the size of welfare gains for partners is around 0.10% of steady-state consumption and remain stable over time. With endogenous produced varieties, short-run gains are larger, around 0.30% and slowly fall to 0.07% over the long run. To conclude, unilateral fiscal devaluations generate sustained welfare gains for countries implementing the reform. They produce positive welfare spillovers to other monetary union members. Joint fiscal devaluations generate even larger welfare gains for all monetary union members, as they combine direct benefits and positive spillovers from partners.

3.4 Sensitivity analysis

The above analysis shows that the adjustment patterns of consumption, hours and exported varieties all crucially matter for the effects of fiscal devaluations. We now investigate the sensitivity of our results to changes in key parameter values. We consider higher risk aversion ($\gamma = 5$), lower labor supply elasticity ($\psi = 5$), and lower exchange rate pass-through, proxied by stickier export prices ($\eta_x = 537$, corresponding to a 0.9 Calvo parameter). Table 3 reports changes in steady-state allocations and welfare effects under these alternative calibrations.

Table 3: Percentage change in steady-state after fiscal devaluations and welfare – Sensitivity analysis.

	$\gamma = 5$			$\psi = 5$			$\eta_x = 537$		
	Unilateral FD		Joint FD	Unilateral FD		Joint FD	Unilateral FD		Joint FD
	Home	For.	–	Home	For.	–	Home	For.	–
gdp	0.7593	0.0023	0.7619	0.6737	0.0099	0.7153	1.8740	−0.0041	1.9236
c	0.7322	0.0080	0.7512	0.6524	0.0223	0.7094	1.8193	0.0364	1.9168
ℓ	0.6404	−0.0106	0.5942	0.5841	−0.0023	0.5777	1.5855	0.0022	1.5477
n	0.4445	−0.0905	0.4612	0.3410	−0.0896	0.3624	1.0206	−0.3482	0.9707
n_x	0.2384	0.2147	0.5094	0.2023	0.1704	0.4419	0.5313	0.2911	1.0549
z_x	0.0604	−0.0896	−0.0141	0.0407	−0.0764	−0.0233	0.1429	−0.1879	−0.0245
π	0.0092	0.0091	0.0087	0.0161	0.0165	0.0212	0.0198	0.0198	0.0236
ϖ	0.1429	0.0296	0.1867	0.1175	0.0330	0.1688	0.3738	0.0750	0.4804
τ_ℓ	−22.3369	–	−22.3494	−22.2142	–	−22.2916	−24.0367	–	−24.1609
r	0.0107		0.0102	0.0183		0.0238	0.0226		0.0267
q	0.0963		–	0.0817		–	0.2596		–
$\mathcal{W}$									
1	0.7944	0.4057	1.1747	0.2016	0.1195	0.3121	0.4533	0.3787	0.7959
4	0.9427	0.2882	1.2116	0.2022	0.0843	0.2883	0.5388	0.2712	0.7917
8	1.1098	0.1733	1.2875	0.2337	0.0574	0.2875	0.6607	0.1657	0.8282
32	1.5479	0.0484	1.6049	0.3352	0.0199	0.3607	0.9551	0.0255	0.9951
∞	1.6855	0.0811	1.7682	0.4083	0.0277	0.4375	1.0655	0.0712	1.1367

The results of our sensitivity analysis show that larger risk-aversion and a lower labor supply elasticity both reduce the reaction of key variables to a fiscal devaluation. Risk-aversion magnifies the wealth effect on labor supply after a fall in the labor wedge, reducing the response of labor supply, and hence, of produced and exported varieties. In addition, consumption smoothing is stronger, restraining the adjustment of consumption adjustments, with negative effects on the aggregate demand for domestic and imported goods, and therefore on GDP. A lower Frisch elasticity on labor supply has similar implications for the adjustment pattern of key variables. In terms of welfare however, both assumptions have different implications. A larger risk-aversion parameter produces larger welfare gains from the fiscal devaluation while a lower Frisch elasticity on labor supply produces lower welfare gains. Both parameters shape the weights attached to the path of consumption and hours in the welfare function. As both variables increase permanently after a fiscal devaluation, a larger relative weight placed on consumption (through a higher risk-aversion parameter) will produce larger welfare gains (even for attenuated reactions of key variables) while a larger relative weight placed on hours worked (through a lower Frisch elasticity on labor supply) will lower the welfare gains.

Finally, a lower exchange rate pass-through, proxied by stickier export prices significantly increase the positive effects of fiscal devaluations on key variables (GDP, produced and exported varieties, consumption and hours worked) with little effects on the size of welfare gains, as both consumption and hours worked increase in similar proportions.

Noticeably, none of the parameterizations considered in Table 3 overturns the qualitative pattern uncovered in the previous section, according to which unilateral fiscal devaluations produce positive effects both on domestic and foreign key macroeconomic aggregates, and welfare gains for all monetary union members. Similarly, the conclusion that joint fiscal devaluations produce larger effects than unilateral fiscal devaluations through positive cross-country spillovers is qualitatively robust.

4 Conclusion

This paper is, to our knowledge, the first attempt to quantify the effect of fiscal devaluations in a monetary union characterized by both endogenous entry and tradability. Countries that decide to follow these types of policies unilaterally experience positive outcome and these policies are not beggar-thy-neighbor policies. The potential welfare gains are massive. Our results contrast with the existing literature as they show that fiscal devaluation is an efficient and non-aggressive policy option for governments that belong to a monetary union. Taking into account the effects of fiscal devaluations on produced and exported varieties therefore proves to be essential in the quantification of the welfare effects of such policies.

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Appendix

A Model

A.1 Households

In each country the number of households with infinite life is normalized to unity. In the home country the representative household maximizes a welfare index:[3]

$$\Omega_t = \mathsf{E}_t \left[\sum_{s=t}^{\infty} \beta^{s-t} \left(\frac{c_s^{1-\gamma}}{1-\gamma} - \chi \frac{\ell_s^{1+\psi}}{1+\psi} \right) \right] \tag{A.1}$$

subject to the budget constraint:

$$b_t + p_t \left(\widetilde{v}_t \left(n_t + n_{e,t} \right) x_t + \left(1 + \tau_{ct} \right) c_t + ac_{b,t} \right) = r_{t-1} b_{t-1} + p_t \left(\widetilde{d}_t + \widetilde{v}_t \right) n_t x_{t-1} + \left(1 - \tau_{\ell t} \right) w_t \ell_t + tr_t \tag{A.2}$$

and to the appropriate transversality conditions.

In the above expressions, β is the subjective discount factor, c_t is the aggregate consumption bundle, ℓ_t is the quantity of labor supplied. The degree of risk-aversion is γ and the elasticity of labor supply with respect to the real wage is ψ^{-1}. Variable p_t denotes the CPI in the domestic country in period t, and w_t the nominal wage. τ_{ct} and $\tau_{\ell t}$ denote the tax rates on consumption and labor income, respectively. Domestic households have access to a couple of different assets: a mutual fund shares of domestic firms (x_t) and a nominal bond issued in the monetary union in quantity b_t, that pays a risk-free nominal interest rate r_{t-1} between periods $t-1$ and t. Trading bonds requires the payment of adjustment costs

$$ac_{b,t} = \frac{\varphi_b}{2} \left(\frac{b_t}{p_t} - \frac{b}{p} \right)^2 \tag{A.3}$$

In period t, the household determines the optimal fraction x_t of the national fund to be held, given the average value of national firms in period t, $\widetilde{v}_t$, and the average total real amount of dividends $\widetilde{d}_t$. Similar relations do hold for the representative foreign household, where foreign variables are denoted with a $*$. First order conditions of the

[3] We do not describe in details relations characterizing the foreign economy. However, similar conditions hold.

domestic household j with respect to c_t, ℓ_t and b_t imply:

$$\beta \mathsf{E}_t \left[\left(\frac{c_t}{c_{t+1}} \right)^\gamma \frac{1+\tau_{ct}}{1+\tau_{ct+1}} \frac{r_t}{(1+\pi_{t+1}) \left(1+\varphi_b \left(\frac{b_t}{p_t} - \frac{b}{p} \right) \right)} \right] - 1 = 0 \tag{A.4}$$

$$\widetilde{v}_t - (1-\delta) \beta \mathsf{E}_t \left[\left(\frac{c_t}{c_{t+1}} \right)^\gamma \frac{1+\tau_{ct}}{1+\tau_{ct+1}} \left(\widetilde{d}_{t+1} + \widetilde{v}_{t+1} \right) \right] = 0 \tag{A.5}$$

$$\chi \ell_t^\psi c_t^\gamma - \frac{1-\tau_{\ell t}}{1+\tau_{ct}} \varpi_t = 0 \tag{A.6}$$

where $\pi_t = \frac{p_t}{p_{t-1}}$ is the CPI inflation rate, and $\varpi_t = \frac{w_t}{p_t}$ is the CPI-based real wage.

The aggregate consumption of the representative domestic household at time t is defined over a continuum of domestic goods Ω and a continuum of foreign goods Ω^*:

$$c_t = \left(\int_{\omega \in \Omega} c_{d,t} (\omega)^{\frac{\theta-1}{\theta}} d\omega + \int_{\omega \in \Omega^*} c^*_{x,t} (\omega)^{\frac{\theta-1}{\theta}} d\omega \right)^{\frac{\theta}{\theta-1}} \tag{A.7}$$

where $\theta > 1$ is the elasticity of substitution between different varieties. Price aggregates are defined over subsets of domestic goods Ω_t with (time-varying) mass n_t, corresponding to the number of domestic firms and over a subset of foreign exported goods $\Omega^*_{x,t}$ with (time-varying) mass $n^*_{x,t}$, corresponding to the number of foreign exporting firms

$$p_t = \left(\int_0^{n_t} p_{d,t} (\omega)^{1-\theta} d\omega + \int_0^{n^*_{x,t}} p^*_{x,t} (\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}} \tag{A.8}$$

Optimal variety demands are thus:[4]

$$c_{d,t} (\omega) = \rho_{d,t} (\omega)^{-\theta} c_t \tag{A.9}$$

$$c^*_{x,t} (\omega) = \rho^*_{x,t} (\omega)^{-\theta} c_t \tag{A.10}$$

where $\rho_{d,t} (\omega) = \frac{p_{d,t}(\omega)}{p_t}$ and $\rho^*_{x,t} (\omega) = \frac{p^*_{x,t}(\omega)}{p_t}$ are the real prices of domestic and imported varieties.

A.2 Firms

The production sector follows Ghironi and Melitz (2005), allows for endogenous entry and endogenous tradability, and incorporates sticky prices. After firms enter in the production sector, they must decide whether selling in the domestic market or selling both in the domestic and the foreign market, depending on their specific productivity level, which determines their ability to pay the entry cost on export markets.

[4] Adjustment costs are paid in terms of consumption goods and so give rise to demand functions that have the exact same form as demands for consumption goods.

The model therefore provides an endogenous mechanism for both the total number of firms/varieties in the economy, and for the number of exporting firms, which is exactly the extensive margin of trade, due to the fact that each firm produces a single variety.

Total number of varieties. We describe the endogenous determination of the total number of firms in the economy. At each period t, there are two types of firms in the domestic economy: n_t firms that are already on the market at the beginning of the period and $n_{e,t}$ firms that are newly created during this period.[5] At the end of the period a fraction $\delta \in [0, 1]$ of all existing firms is exogenously affected by an exit shock. We assume that the entry occurs one period ahead of production. The total number of varieties in the domestic economy thus evolves according to:

$$n_t = (1 - \delta)(n_{t-1} + n_{e,t-1}) \tag{A.11}$$

In period t, $n_{e,t}$ new firms enter the market. They start producing in $t + 1$, as period t is devoted to build the plant. As in Ghironi and Melitz (2005), each entrepreneur uses a sunk and fixed amount f_e of labor units to build the firm. Entry in the market occurs as long as the expected (average) profit is greater than the entry cost, *i.e.* until:

$$\widetilde{v}_t = f_e \frac{\varpi_t}{a_t} \tag{A.12}$$

Each of the n_t firms is specialized in the production of a differentiated variety. In period t, the production function of the representative domestic firm specialized in variety ω is:

$$y_t(\omega) = z(\omega)\, a_t \ell_t^d(\omega) \tag{A.13}$$

where a_t is the aggregate labor productivity common to all domestic firms, $z(\omega)$ is the firm-specific labor productivity drawing in a Pareto distribution, and $\ell_t^d(\omega)$ is the quantity of labor.

Exporters and non-exporters. Given the total number of firms that produce goods during the period n_t, the subset of these firms selling in both domestic and foreign markets, denoted $n_{x,t}$, is determined. While all firms supply the domestic market, the ability of firms to access foreign markets depends on their individual productivity. Access to the export market indeed requires the repeated payment of a fixed export cost f_x, expressed in units of labor, and the payment of an iceberg melting cost $(1 + \tau)$.[6] The condition to access foreign markets is to generate enough profits to cover these costs, and depends on firm-specific productivity. Let $p_{d,t}(\omega)$ denote the nominal price of a domestic variety sold in the domestic market, and $p_{x,t}(\omega)$ the nominal price of a domestic variety sold in the foreign market.[7] Prices are chosen subject adjustment

[5] Similar conditions hold in the foreign economy.

[6] Out of a quantity $y_t(\omega)$ produced, only $y_t^d(\omega) = \frac{y_t(\omega)}{1+\tau}$ is actually sold, so producing for the foreign markets increases the production cost proportionally by a factor $1 + \tau$.

[7] Symmetrically, $p_{d,t}^*(\omega)$ is the nominal price of a foreign variety sold in the foreign market, and $p_{x,t}^*(\omega)$ is the nominal price of a foreign variety ω sold in the domestic market.

costs $\varrho_t^d(\omega)$ and $\varrho_t^x(\omega)$, as in Rotemberg (1982):

$$\varrho_t^d(\omega) = \frac{\eta^d}{2}\left(\frac{p_{d,t}(\omega)}{p_{d,t-1}(\omega)} - 1\right)^2 \rho_{d,t}(\omega)\, y_t^d(\omega), \quad \eta^d \geq 0 \tag{A.14}$$

$$\varrho_t^x(\omega) = \frac{\eta^x}{2}\left(\frac{p_{x,t}(\omega)}{p_{x,t-1}(\omega)} - 1\right)^2 q_t\rho_{x,t}(\omega)\, y_t^{*d}(\omega), \quad \eta^x \geq 0 \tag{A.15}$$

where $y_t^d(\omega)$ (resp. $y_t^{*d}(\omega)$) is the demand faced by the firm on the domestic (resp. foreign) market. Total real profits (dividends) are thus made of profits on the domestic goods market and profits on foreign markets of a domestic plant ω are:[8]

$$d_t(\omega) = d_{d,t}(\omega) + d_{x,t}(\omega) \tag{A.16}$$

where

$$d_{d,t}(\omega) = \left(\rho_{d,t}(\omega) - \frac{\varpi_t}{z(\omega)\, a_t}\right) y_t^d(\omega) - \varrho_t^d(\omega) \tag{A.17}$$

$$d_{x,t}(\omega) = \left(q_t\rho_{x,t}(\omega) - \frac{(1+\tau)\,\varpi_t}{z(\omega)\, a_t}\right) y_t^{*d}(\omega) - \varrho_t^x(\omega) - f_x\frac{\varpi_t}{a_t} \tag{A.18}$$

In period t, the representative firm ω chooses $p_{d,t}(\omega)$ and $p_{x,t}(\omega)$ to maximize the sum of the current dividends and the value of the firm, which is the expected present discounted value of future dividends. Optimal pricing conditions are:

$$\rho_{d,t}(\omega) = \mu_{d,t}\frac{\varpi_t}{z(\omega)\, a_t} \tag{A.19}$$

$$\rho_{x,t}(\omega) = \mu_{x,t}\frac{(1+\tau)\,\varpi_t}{q_t z(\omega)\, a_t} \tag{A.20}$$

where, after defining $\pi_{d,t} = \frac{p_{d,t}(\omega)}{p_{d,t-1}(\omega)}$ and $\pi_{x,t} = \frac{p_{x,t}(\omega)}{p_{x,t-1}(\omega)}$, markups write:

$$\mu_{d,t} = \frac{\theta}{(\theta-1)\left(1-\frac{\eta^d}{2}(\pi_{d,t}-1)^2\right) + \eta^d\left((\pi_{d,t}-1)\,\pi_{d,t} - \beta(1-\delta)\,\mathsf{E}_t\left[\frac{(\pi_{d,t+1}-1)\pi_{d,t+1}^2 y_{t+1}c_t^\gamma}{\pi_{t+1}y_t c_{t+1}^\gamma}\right]\right)} \tag{A.21}$$

$$\mu_{x,t} = \frac{\theta}{(\theta-1)\left(1-\frac{\eta^x}{2}(\pi_{x,t}-1)^2\right) + \eta^x\left((\pi_{x,t}-1)\,\pi_{x,t} - \beta(1-\delta)\,\mathsf{E}_t\left[\frac{q_{t+1}(\pi_{x,t+1}-1)\pi_{x,t+1}^2 y_{t+1}c_t^\gamma}{q_t\pi_{t+1}y_t c_{t+1}^\gamma}\right]\right)} \tag{A.22}$$

Importantly, firms entering the market price exactly like firms already on the market and behave as the (constant number of) price setters in Rotemberg (1982). Pricing conditions are the same for entrants as for firms operating on the market during period $t-1$. This is consistent with the time-to-build structure of entries: new firms start

[8] The entry cost is paid once, when the plant is created, and does not enter the expression of profits, as opposed to the cost of exporting, that is paid each period. If the latter is not paid, the firm stops exporting.

producing after one period, have time to learn the pricing decisions made by 'old' firms in period t and imitate them in period $t+1$.[9] Substituting the production cost using the pricing equations and using the demand functions, dividends are:

$$d_{d,t}(\omega) = \left(1 - \frac{\eta^d}{2}(\pi_{d,t}-1)^2 - \mu_{d,t}^{-1}\right)\rho_t(\omega)^{1-\theta}\, y_t^d \tag{A.23}$$

$$d_{x,t}(\omega) = \max\left(\left(1 - \frac{\eta^x}{2}(\pi_{x,t}-1)^2 - \mu_{x,t}^{-1}\right) q_t \rho_{x,t}(\omega)^{1-\theta}\, y_t^{d*} - f_x \frac{\varpi_t}{a_t}, 0\right) \tag{A.24}$$

where $y_t^d = c_t + ac_{b,t}$ and $y_t^{d*} = c_t^* + ac_{b,t}^*$.

Firm-specific productivity draws and cut-off exporting firm. The determination of the number of exporting firms depends on the (time-varying) individual productivity $z_{x,t}$ of the cut-off exporting firm, *i.e.* the last firm productive enough to pay exports costs. The latter is determined by a zero-export-profit condition $d_{x,t}(\omega) = 0$, which, using the expression above and the pricing equation, yields:

$$z_{x,t} = \mu_{x,t}(1+\tau)\left(1 - \frac{\eta^x}{2}(\pi_{x,t}-1)^2 - \mu_{x,t}^{-1}\right)^{\frac{1}{1-\theta}} \left(\frac{f_x}{y_t^{d*}}\right)^{\frac{1}{\theta-1}} \left(\frac{\varpi_t}{q_t a_t}\right)^{\frac{\theta}{\theta-1}} \tag{A.25}$$

Firm-specific productivity $z(\omega)$ has a Pareto distribution with lower bound $z_{\min}$ and shape parameter $k > \theta - 1$. The probability density function of z is $g(z) = k z_{\min}^k / z^{k+1}$ and the cumulative density function is $G(z) = 1 - (z_{\min}/z)^k$. The relative weight of exporting firms is thus determined by:

$$n_{x,t} = (1 - G(z_{x,t}))\, n_t = (z_{\min}/z_{x,t})^k\, n_t \tag{A.26}$$

The number of exporting firms is thus a decreasing function of the productivity threshold. In addition, equation (A.26) sheds light on the determinants of the number of exporting firms in the model, $n_{x,t}$: the level of the marginal production cost affects $n_{x,t}$ negatively, as well as the fixed export cost; the size of the foreign market affects $n_{x,t}$ positively, just as the real exchange rate (a real depreciation, *i.e.* an increase in q_t affects $n_{x,t}$ positively). Finally, trade costs increase the export threshold, *i.e.* larger trade costs lower the number of exporters.

A.3 Governments

As in Farhi et al. (2013), governments have a balanced budget every period and simply rebate the product of distortionary taxes to the households in a lump-sum fashion

$$\tau_{\ell t}\varpi_t \ell_t + \tau_{ct} c_t = tr_t \tag{A.27}$$

$$\tau_{\ell t}^*\varpi_t^* \ell_t^* + \tau_{ct}^* c_t^* = tr_t^* \tag{A.28}$$

[9] See Bilbiie et al. (2008) for more discussion.

A.4 Aggregation and equilibrium

Average values. The model is solved by averaging the productivity of domestic suppliers and the productivity of firms addressing both markets.[10] The average productivity of each type of firm is:

$$\widetilde{z}_{d,t} = \bigtriangledown z_{\min},\ \widetilde{z}_{x,t} = \bigtriangledown z_{x,t}, \tag{A.29}$$

where $\bigtriangledown = \left(\frac{k}{k-(\theta-1)}\right)^{\frac{1}{\theta-1}}$, which gives the average pricing conditions:

$$\widetilde{\rho}_{d,t} = \rho_{d,t}\left(\widetilde{z}_{d,t}\right) = \mu_{d,t}\frac{\varpi_t}{\bigtriangledown z_{\min} a_t} \tag{A.30}$$

$$\widetilde{\rho}_{x,t} = \rho_{x,t}\left(\widetilde{z}_{x,t}\right) = \left(1+\tau\right)\mu_{x,t}\frac{\varpi_t}{\bigtriangledown \widetilde{z}_{x,t} q_t a_t} \tag{A.31}$$

and the average domestic and export dividends:

$$\widetilde{d}_{d,t} = \widetilde{d}_{d,t}\left(\widetilde{z}_{d,t}\right) = \left(1 - \frac{\eta^d}{2}\left(\pi_{d,t}-1\right)^2 - \frac{1}{\mu_{d,t}}\right)\widetilde{\rho}_{d,t}^{1-\theta} y_t^d \tag{A.32}$$

$$\widetilde{d}_{x,t} = \widetilde{d}_{x,t}\left(\widetilde{z}_{x,t}\right) = \frac{\theta-1}{k-(\theta-1)} f_x \tag{A.33}$$

The total average dividend thus writes:

$$n_t \widetilde{d}_t = n_t \widetilde{d}_{d,t} + n_{x,t}\widetilde{d}_{x,t} \tag{A.34}$$

and the total average value of firms, $\widetilde{v}_t$, is defined similarly. Symmetric relations characterize the foreign economy.

Equilibrium. Assuming symmetry in asset holdings (so that, $x_t = x_{t-1} = x_t^* = x_{t-1}^* = 1$) in each economy, and defining the aggregate (domestic) output of the consumption sector as $y_t = \int_0^{n_t} \rho_{d,t}\left(\omega\right) y_t\left(\omega\right) d\omega$, a competitive equilibrium is defined as a sequence of quantities:

$$\left\{\mathcal{Q}_t\right\}_{t=0}^{\infty} = \left\{y_t, y_t^*, c_t, c_t^*, \ell_t, \ell_t^*, n_t, n_t^*, n_{e,t}, n_{e,t}^*, n_{x,t}, n_{x,t}^*, \widetilde{z}_{x,t}, \widetilde{z}_{x,t}^*, \widetilde{d}_t, \widetilde{d}_t^*, b_t, b_t^*\right\}_{t=0}^{\infty},$$

and a sequence of real prices:

$$\left\{\mathcal{P}_t\right\}_{t=0}^{\infty} = \left\{\widetilde{\rho}_{d,t}, \widetilde{\rho}_{d,t}^*, \widetilde{\rho}_{x,t}, \widetilde{\rho}_{x,t}^*, \varpi_t, \varpi_t^*, \mu_{d,t}, \mu_{d,t}^*, \mu_{x,t}, \mu_{x,t}^*, \pi_{d,t}, \pi_{d,t}^*, \pi_{x,t}, \pi_{x,t}^*, q_t\right\}_{t=0}^{\infty},$$

such that, for a given sequence of shocks $\left\{\mathcal{S}_t\right\}_{t=0}^{\infty} = \left\{a_t, a_t^*\right\}_{t=0}^{\infty}$, and conditional on a certain monetary and fiscal policy:

(*i*) For a given sequence of prices $\left\{\mathcal{P}_t\right\}_{t=0}^{\infty}$, the sequence $\left\{\mathcal{Q}_t\right\}_{t=0}^{\infty}$ satisfies first-order conditions of domestic and foreign households and maximizes domestic and foreign firms' dividends.

[10] An extensive discussion of the calculations can be found in Ghironi and Melitz (2005).

(ii) For a given sequence of quantities $\{\mathcal{Q}_t\}_{t=0}^{\infty}$, the sequence $\{\mathcal{P}_t\}_{t=0}^{\infty}$ guarantees the equilibrium of labor markets:

$$\ell_t = \frac{1}{\varpi_t}\left(n_t \frac{\widetilde{d}_{d,t}}{\sigma_{d,t}} + n_{x,t}\frac{\widetilde{d}_{x,t}}{\sigma_{x,t}}\right) + \frac{1}{a_t}\left(n_{x,t} f_x\left(1+\sigma_{x,t}^{-1}\right) + n_{e,t} f_e\right) \tag{A.35}$$

$$\ell_t = \frac{1}{\varpi_t^*}\left(n_t^* \frac{\widetilde{d}_{d,t}^*}{\sigma_{d,t}^*} + n_{x,t}^*\frac{\widetilde{d}_{x,t}^*}{\sigma_{x,t}^*}\right) + \frac{1}{a_t^*}\left(n_{x,t}^* f_x^*\left(1+\sigma_{x,t}^{*-1}\right) + n_{e,t}^* f_e^*\right) \tag{A.36}$$

where $\sigma_{d,t} = \mu_{d,t} - \frac{\eta^d}{2}\left(\pi_{d,t}-1\right)^2 \mu_{d,t} - 1$ and $\sigma_{x,t} = \mu_{x,t} - \frac{\eta^x}{2}\left(\pi_{x,t}-1\right)^2 \mu_{x,t} - 1$, the equilibrium of consumption goods markets:

$$y_t = n_t \widetilde{\rho}_{d,t}^{1-\theta}\left(c_t + ac_{b,t}\right) + q_t n_{x,t}\widetilde{\rho}_{x,t}^{1-\theta}\left(c_t^* + ac_{b,t}^*\right) \tag{A.37}$$

$$y_t^* = n_t^* \widetilde{\rho}_{d,t}^{*1-\theta}\left(c_t^* + ac_{b,t}^*\right) + q_t^{-1} n_{x,t}^*\widetilde{\rho}_{x,t}^{*1-\theta}\left(c_t + ac_{b,t}\right) \tag{A.38}$$

and the equilibrium of financial markets:

$$b_t + b_t^* = 0 \tag{A.39}$$

Variety effect. The structure of price indexes implies the following variety effect:

$$n_t \widetilde{\rho}_{d,t}^{1-\theta} + n_{x,t}^* \widetilde{\rho}_{x,t}^{*1-\theta} = 1 \tag{A.40}$$

$$n_t^* \widetilde{\rho}_{d,t}^{*1-\theta} + n_{x,t} \widetilde{\rho}_{x,t}^{1-\theta} = 1 \tag{A.41}$$

Net foreign assets. Net foreign asset dynamics is obtained simplifying the budget constraint of domestic households and combining with market clearing conditions:

$$b_t^r = r_{t-1}\frac{b_{t-1}^r}{\pi_t} + y_t - c_t - ac_{b,t} \tag{A.42}$$

B Steady state

We define the symmetric steady state as a situation without inflation where all variables are constant and where $c = c^* => q = 1$. We assume $a = z_{\min} = 1$. In what follows, we denote $\mu = \frac{\theta}{\theta-1}$. Some immediate relations yield:

$$r = \beta^{-1},\ n_e = \frac{\delta}{1-\delta} n \tag{B.1}$$

and

$$\widetilde{d} = f_e \frac{\left(1-\left(1-\delta\right)\beta\right)}{\left(1-\delta\right)\beta}\varpi \tag{B.2}$$

First, we use the expression of export profits:

$$\widetilde{d}_x = \frac{\theta-1}{k-\left(\theta-1\right)} f_x \varpi \tag{B.3}$$

Export dividends $\widetilde{d}_x$ are initially defined as:

$$\widetilde{d}_x = \left(\frac{1}{\theta}\right)\left((1+\tau)\,\mu\frac{\varpi}{\nabla z_x}\right)^{1-\theta} y - f_x\varpi \tag{B.4}$$

Using $\widetilde{\rho}_x = (1+\tau)\,\mu\frac{\varpi}{\nabla z_x}$ and $\widetilde{\rho}_d = \mu\frac{\varpi}{\nabla}$, we express domestic dividends $\widetilde{d}_d$ as a function of $\widetilde{d}_x$:

$$\widetilde{d}_d = \left(\frac{1}{\theta}\right)\left(\mu\frac{\varpi}{\nabla}\right)^{1-\theta} y = \left(\frac{1+\tau}{z_x}\right)^{\theta-1}\left(\widetilde{d}_x + f_x\varpi\right) \tag{B.5}$$

Using $\widetilde{d}_x = \frac{\theta-1}{k-(\theta-1)} f_x\varpi$, we plug (B.3) and (B.5) into the equation of total dividends to get:

$$\widetilde{d} = \widetilde{d}_d + \frac{n_x}{n}\widetilde{d}_x = \left(\left(\frac{1+\tau}{z_x}\right)^{\theta-1}\frac{k}{k-(\theta-1)} + \frac{n_x}{n}\frac{\theta-1}{k-(\theta-1)}\right) f_x\varpi \tag{B.6}$$

Using equation (B.2) we get:

$$\frac{f_e}{f_x}\frac{(1-(1-\delta)\,\beta)}{(1-\delta)\,\beta} = \left(\frac{1+\tau}{z_x}\right)^{\theta-1}\frac{k}{k-(\theta-1)} + \frac{n_x}{n}\frac{\theta-1}{k-(\theta-1)} \tag{B.7}$$

We choose to fix the share of exporting firms $\varphi = n_x/n$ and assume $f_e = 1$ without loss of generality, as only the ratio of f_e/f_x matters. Equation (B.7) gives the corresponding value of f_x:

$$f_x = \frac{1-(1-\delta)\,\beta}{(1-\delta)\,\beta\kappa_2} \tag{B.8}$$

where

$$\kappa_1 = \frac{k}{k-(\theta-1)} \tag{B.9}$$

$$\kappa_2 = (1+\tau)^{\theta-1}\varphi^{\frac{\theta-1}{k}}\kappa_1 + \varphi\,(\kappa_1 - 1) \tag{B.10}$$

In addition, because $\varphi = z_x^{-k}$, the value of the export threshold z_x is known.

The labor market clearing condition, using $n\widetilde{d}_d + n_x\widetilde{d}_x = n\widetilde{d}$, equation (B.2), and the expression of n_x:

$$\frac{\ell}{n} = (\theta-1)\,\frac{(1-(1-\delta)\,\beta)}{(1-\delta)\,\beta} + \frac{\delta}{1-\delta} + \theta\varphi f_x \tag{B.11}$$

The following remaining relations (the labor supply equation, the export cut-off and the variety effect):

$$\chi\ell^{\psi}c^{\gamma} = \frac{(1-\tau_\ell)}{(1+\tau_c)}\varpi \tag{B.12}$$

$$z_x = \mu\,(1+\tau)\left(\frac{\theta f_x}{y}\right)^{\frac{1}{\theta-1}}\varpi^{\frac{\theta}{\theta-1}} \tag{B.13}$$

$$1 = \left(\mu\frac{\varpi}{\nabla}\right)^{1-\theta} n + \varphi n\left((1+\tau)\,\mu\frac{\varpi}{\nabla z_x}\right)^{1-\theta} \tag{B.14}$$

together with equations (B.7)-(B.11) close the steady state. Further, we impose $\ell = 1$ in the baseline steady state, adjusting the value of χ. We thus get

$$\begin{aligned} n &= 1/\kappa_3 && \text{(B.15)} \\ \varpi &= (n\kappa_5)^{\frac{1}{\theta-1}} && \text{(B.16)} \\ y &= \kappa_4 \varpi^{\theta} && \text{(B.17)} \end{aligned}$$

where

$$\begin{aligned} \kappa_3 &= (\theta - 1) \frac{(1 - (1-\delta)\beta)}{(1-\delta)\beta} + \frac{\delta}{1-\delta} + \theta\varphi f_x && \text{(B.18)} \\ \kappa_4 &= \left(\mu \frac{1+\tau}{z_x}\right)^{\theta-1} \theta f_x && \text{(B.19)} \\ \kappa_5 &= \kappa_1 \mu^{1-\theta} \left(1 + \varphi \left(\frac{1+\tau}{z_x}\right)^{1-\theta}\right) && \text{(B.20)} \end{aligned}$$

Using the labor supply condition gives the compatible value of χ.