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* Views expressed are those of the authors and do not necessarily reflect official positions of De Nederlandsche Bank.

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Should developed economies manage international capital flows? An empirical and welfare analysis*

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Abstract

At least since the euro area sovereign debt crisis, it is evident that country risk premium shocks have adverse economic effects, not only in emerging economies, but advanced economies as well. Using a Bayesian Panel Vector Autoregression model, we find that increases in the risk premium lower output under monetary union, yet not in countries with flexible exchange rates and independent monetary policies. We study the transmission mechanism in a two-country New Keynesian model and show that capital controls substantially attenuate the effects of risk premium shocks. However, the welfare gain of imposing capital controls hinges on the nature of the shock and the prevailing exchange rate regime.

JEL Classification: F32, F38, F41, F45

Keywords: Bayesian panel VAR, capital controls, exchange rate regime, welfare

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1 Introduction

It has long been acknowledged that open economies are vulnerable to sudden shifts in cross-border capital flows. Historically, periods of sustained capital inflows have been associated with sharp credit expansions, while sudden reversals of such flows have often been the culprit of financial and economic crises (Aliber and Kindleberger, 1978). In fact, empirical evidence suggests that risk premium shocks are important drivers of business cycles fluctuations in emerging market economies (EMEs) (see e.g. Neumeyer and Perri, 2005; Uribe and Yue, 2006; Garcia-Cicco et al., 2010). For instance, Magud et al. (2014) find evidence that EMEs with less flexible exchange rate regimes may benefit most from regulatory policies that reduce banks' incentives to tap external markets and lend or borrow in foreign currency. Exchange rate flexibility may be instrumental in curbing the effects of capital inflows on domestic credit. But are these phenomena, and corresponding policy implications, restricted to EMEs?

Our empirical results suggest differently. A preview of these results in Table 1 shows that, for developed economies, the average historical contribution to output variability of country risk premium shocks (measured by the long-term sovereign bond yield differential vis-à-vis either the US or Germany) is about 9%. While these risk premium shocks may not be the main driver of economic activity, they can hardly be dismissed as negligible. The importance of risk premium shocks in these countries becomes even more palpable when focusing on crisis times. For instance, in Sweden, 69.2% of output variability could be explained by risk premium shocks in July 2002, the epicenter of the 2001-03 recession, while in Portugal this number was a staggering 79.7% during the height of the sovereign debt crisis in April 2013.

Given the significance of risk premium shocks in the developed world, a natural question to ask is how these shocks are transmitted to the real economy. Moreover, does it matter whether countries facing risk premium shocks operate under a floating exchange rate regime with independent monetary policies (such as Sweden) or belong to a monetary union (such as Portugal)? And finally, could capital controls be used to attenuate the (adverse) effects of risk premium shocks? What would be the welfare implications of imposing such controls across different exchange rate regimes and in the presence of different shocks?

In this paper, we attempt to answer these questions. For the first question, we use monthly

Table 1: The importance of risk premium shocks: historical decomposition (1999M1-2016M12)

	Output	**Inflation**	**Interest rate**	**REER**	**Risk premium**
AU	0.049	0.113	0.070	0.052	0.309
JP	0.113	0.143	0.360	0.094	0.597
NZ	0.043	0.120	0.159	0.060	0.338
SW	0.116	0.112	0.157	0.086	0.428
UK	0.122	0.127	0.077	0.089	0.480
Mean	*0.089*	*0.123*	*0.165*	*0.076*	*0.430*
AT	0.051	0.031	0.043	0.042	0.481
BE	0.059	0.033	0.057	0.054	0.489
FI	0.014	0.017	0.016	0.009	0.225
FR	0.039	0.022	0.031	0.030	0.387
IR	0.117	0.055	0.137	0.125	0.661
IT	0.119	0.049	0.104	0.105	0.653
NL	0.019	0.016	0.021	0.016	0.279
PT	0.204	0.097	0.193	0.194	0.780
ES	0.124	0.039	0.110	0.111	0.583
Mean	*0.083*	*0.040*	*0.079*	*0.076*	*0.504*

Note: The table reports the average contribution (over time) of country risk premium shocks in explaining the variability of the endogenous variables in our Bayesian PVAR (see Section 3 for more details). We measure the risk premium as the sovereign spread vis-à-vis either the US (for countries with a floating exchange rate and independent monetary policy, i.e. AU, JP, NZ, SW and UK, upper panel) or Germany (for countries belonging to the euro area, lower panel). Output is proxied by deviations of the Purchasing Managers Index from its HP-trend. 'Inflation' refers to deviations of the Consumer Price Index from its HP-trend, 'Interest rate' to the short-term money market interest rate and 'REER' to deviations of the real effective exchange rate from its trend.

data, covering 1999M1 to 2016M12, and a Bayesian Panel Vector Autoregression (BPVAR) model to estimate the effects of country risk premium shocks on main macroeconomic aggregates. We focus on two groups of developed economies: those with floating exchange rates and independent monetary policies, and those that belong to a monetary union in which monetary autonomy is lost. In estimating the BPVAR model for these two panels, we allow for cross-subsectional heterogeneity, as we do not impose the coefficients to be same, yet rather assume they are drawn from the same posterior distribution. We present a novel empirical result that risk premium shocks are contractionary, *but only under monetary union.* Under floating exchange rates, an increase in the long-term sovereign bond spread does not reduce output. If anything, the median estimates suggest that a higher risk premium *raises* output, although the response is not significant (in Bayesian terms). Although this result is robust to using a range of alternative model specifications, the transmission mechanism is more difficult to infer from the BPVAR model alone. We therefore use a typical two-country New Keynesian model to study in greater detail the effects of risk premium shocks across different exchange rate regimes. We confirm our empirical findings of risk premium shocks being contractionary under monetary union and expansionary under floating exchange rates. Although the real exchange rate depreciates across both regimes following a rise in the risk premium, the response is more pronounced under the floating exchange rate regime which, through the international trade channel, can explain the expansionary effects of the risk premium shock. Indeed, a reduction in the degree of country openness (measured by the import share of consumption) weakens the trade channel and thereby reduces the expansionary effects under the floating regime, while enhancing the contractionary effects under monetary union. To the best of our knowledge, we are the first to tie these theoretical predictions from a baseline DSGE model with empirical results from a BPVAR model on the effects of country risk premium shocks across exchange rate regimes.

We also use the theoretical model to address the second question, i.e. how capital controls affect macroeconomic stability and welfare across exchange rate regimes. We model capital controls as a dynamic and counter-cyclical tax on a country's external debt, as in Schmitt-Grohé and Uribe (2017), among others. Consistent with other key contributions to this literature, such as Bianchi and Mendoza (2010), Bianchi (2011) and Farhi and Werning (2014), we find that such a debt tax substantially attenuates the (adverse) effects of risk premium shocks across both exchange rate regimes. It thereby follows that the welfare gain of imposing the debt tax is positive and increases monotonically with the counter-cyclical bent of the tax (i.e. the tax elasticity with respect to external indebtedness). Under both floating exchange rates and monetary union, the debt tax allows monetary policy to be more accommodative in the face of risk premium shocks such that stabilization is shared between the two policy instruments. Whether or not the welfare gain of imposing a tax on external debt is positive thus depends on the extent to which the tax supports or undermines monetary policy in achieving macroeconomic stability. We make this point clear by investigating the interaction between capital controls and monetary policy when faced with other shocks. When the economy experiences either demand or productivity shocks, the debt tax is welfare enhancing under monetary union, yet welfare *reducing* under a floating exchange rate.

The remainder of this paper is structured as follows. In the following section, we briefly provide an overview of the relevant literature. In Section 3, we perform the empirical analysis and estimate the effects of risk premium shocks across exchange rate regimes. In Section 4, we present the two-country New Keynesian model, while in Section 5 we further investigate the transmission mechanism of risk premium shocks and study the role of capital controls. Finally, Section 6 concludes.

2 Related literature

Our paper relates to a growing literature assessing the role of capital controls and macro-prudential policies to curb violent cross-border capital flows and reduce the severity of financial crises. One important strand of this literature focuses on capital controls and macro-prudential policies to limit over-borrowing arising from a pecuniary externality that works through changes in relative prices that affect the borrowing constraint. For instance, Mendoza (2010), Bianchi and Mendoza (2010) and Bianchi (2011) make the case for macro-prudential regulation geared towards asset price movements that trigger vicious feedback loops, often in the form of a Fisherian debt deflation channel. Bianchi and Mendoza (2010) and Bianchi (2011) show that the pecuniary externality leads to over-borrowing relative to the first best allocation. Bianchi (2011) further shows that state-contingent capital controls can improve welfare by reducing the incentives to borrow. The Bianchi model has, by now, been widely studied: Benigno et al. (2013) add physical capital and an endogenous production sector, thereby creating scope for ex-ante and ex-post policy intervention, while Benigno et al. (2016) add alternative policy instruments to achieve the first best allocation. Finally, Schmitt-Grohé and Uribe (2017) solve the Ramsey problem and show that optimal dynamic capital controls are on average positive, yet *pro-cyclical* (i.e. are loosened during booms and tightened during recessions)–a finding which is at odds with the conventional view. Their argument is that the Ramsey planner delays a tightening of capital controls to ensure the economy enters a recession with sound financial fundamentals.

Another related strand of the literature emphasizes the role of financial frictions, such as domestic and international collateral constraints, that create inefficiencies and, thereby, a potential role for policy intervention (see, for instance, Caballero and Krishnamurthy, 2001, 2004). Relatedly, Schmitt-Grohé and Uribe (2016) argue in favor of prudential and counter-cyclical capital controls to offset inefficiencies arising from fixed exchange rates, free capital mobility and downward nominal wage rigidities. Contrary to these papers, our model does not feature such collateral constraints or pecuniary externalities. Instead, the key frictions in our model are producer price rigidities and an endogenous risk premium that rises with a country's external indebtedness.

The paper most closely related to ours is Farhi and Werning (2012), who also study the macroeconomic stabilization and welfare implications of capital controls in an open economy model, and in the face of different types of shocks. We differ by focusing on two types of exchange rate regimes (floating and monetary union) in the two-country (rather than small open economy) case, and by tying our results to novel empirical evidence on the effects of risk premium shocks.[1]

Lastly, our paper also relates to the vast literature on macro-prudential policies. For instance, Farhi and Werning (2016) show that aggregate demand externalities in the presence of nominal rigidities create an independent rationale for macro-prudential policies even under complete asset markets. Several others focused on macro-prudential policies when financial markets are incomplete and subject to financial frictions. Notably, Mendicino and Punzi (2014) show that optimal monetary policy in a two-country model responds to credit growth. In Medina and Roldós (2018), counter-cyclical capital requirements can, in a small open economy, improve welfare in response to global interest rate shocks, beyond what can be achieved by monetary policy alone. Although we do not consider optimal monetary policy in this paper, we also find that counter-cyclical capital controls can increase welfare as long as they support monetary policy in stabilizing inflation. Finally, Clancy and Merola (2017) show that counter-cyclical minimum capital requirements can attenuate boom-bust cycles in a small open economy that belongs to a monetary union. In their model, counter-cyclical capital requirements, inspired by the Basel-III rules, can promote financial and macroeconomic stability by reducing the pro-cyclicality of the financial system (i.e. the fact that banks impose tighter financial conditions during recessions, which is precisely when the real economy would benefit from more lenient lending policies).

3 The effects of risk premium shocks: empirical evidence

In this section, we estimate the effects of risk premium shocks on main macroeconomic aggregates in a group of advanced economies. We split this group into countries with floating exchange rates and independent monetary policies, and countries belonging to a monetary union, specifically the euro area. A Bayesian Panel Vectorautoregression is used with an hierarchical (or 'exchangeable') prior, which postulates that the parameters of the model for the individual countries within each panel

[1] In a related paper, Farhi and Werning (2014) study the Ramsey problem of optimal capital controls, but only in the face of risk premium shocks.

are similar. The resulting posterior resulting from this prior pools information across countries belonging to the same exchange rate regime, thereby ensuring an efficient use of the data (Jarociński, 2010).[2] Different from standard PVAR models, we therefore allow for cross-subsectional heterogeneity (as in the case of country-by-country regressions). Next, we briefly describe the data and methodology, and then discuss the results of our baseline model.

3.1 Data

We use monthly data for 16 countries in the period covering 1999M1 to 2016M12.[3] Included in our baseline BPVAR model are the composite Purchasing Managers Index (PMI), which we use as a measure for real economic activity, the Consumer Price Index (CPI), the short-term interest rate and the real effective exchange rate (REER). The PMI, CPI and REER series enter the model in deviations from an HP-filtered trend, whereas the short-term interest rate is expressed in levels.[4] More details about the data series, their sources and transformations are given in Appendix A.

To identify risk premium shocks, we also include a measure of the country risk premium. Following Bernoth et al. (2004), Beetsma et al. (2013) and Beirne and Fratzscher (2013), among others, we proxy the country risk premium by the spread between a country's long-term sovereign bond yield and the long-term interest rate of a base country. The choice of the base country may, of course, differ per country. Here, we follow Davis and Zlate (2019) and use either the US or Germany for all the countries. If a country serves as a base country, then it is removed from the corresponding panel (as its risk premium would be zero). Like the short-term interest rate, the country risk premium enters the model in levels. To control for foreign-induced movements in the risk premium, we further include lagged measures of the base country's real economic activity, inflation, the real exchange rate and, if the US is the base country, the short-term interest rate (in line with, e.g. Davis and Zlate, 2019). Finally, we include the VIX volatility index to control for global risk (De Santis, 2012) and the oil price to capture global supply-side shocks, both in deviations from their corresponding HP-filtered trends.

[2] Studies using exchangeable priors include, among others, Zellner and Hong (1989), Canova (2005) and Ciccarelli and Rebucci (2006).

[3] Our data set includes the following countries: Australia, Austria, Belgium, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, New Zealand, Portugal, Spain, Sweden, the United Kingdom and the United States.

[4] In Appendix C, we show that the results are robust to different data treatment, including e.g. first differences, and to using shadow rates from Krippner (2013) instead of short-term money market rates.

Table 2: Exchange rate regime classification

Aggregate class		Reinhart and Rogoff (2011) classification
Fixed	(1)	No separate legal tender
	(2)	Pre announced peg or currency board arrangement
	(3)	Pre announced horizontal band that is narrower than or equal to +/-2%
	(4)	De facto peg
	(5)	Pre announced crawling peg
	(6)	Pre announced crawling band that is narrower than or equal to +/-2%
	(7)	De factor crawling peg
	(8)	De facto crawling band that is narrower than or equal to +/-2%
	(9)	Pre announced crawling band that is wider than or equal to +/-2%
	(10)	De facto crawling band that is narrower than or equal to +/-5%
	(11)	Moving band that is narrower than or equal to +/-2%
	(12)	Managed floating Float
Flexible	(13)	Freely floating
	(14)	Freely falling
	(15)	Dual market in which parallel market data is missing

As mentioned before, we split the countries into two groups. The composition of each of the two panels is based on the *de facto* exchange rate regime classification of Reinhart and Rogoff (2011), extended until 2016M12, given in Table 2. In what follows, we refer to the two panels as *floats* (13-15) and *monetary union* (1-12).

3.2 Methodology

We estimate a *random effects model* for our two panels using Bayesian techniques and an hierarchical prior as developed by Jarociński (2010).[5] Formally, denoting $y_{j,t}$ a vector of endogenous variables and x_t a vector of exogenous controls for country j, we estimate the following model with p lags

$$y_{j,t} = \sum_{i=1}^{p} A_j^i y_{j,t-i} + C_j x_t + D_j y_{b,t-1} + \varepsilon_{j,t}, \qquad \text{with } \varepsilon_{j,t} \sim \mathcal{N}(0, \Sigma_j) \tag{1}$$

and where A_j^i, C_j and D_j are coefficient matrices of conformable size. x_t includes the set of exogenous controls that are the same within panels (the VIX and oil price, the latter in USD), while $y_{b,t-1}$ are the lagged macroeconomic aggregates of the base country. Stacking over T time periods gives $Y_j = X_j B_j + \mathcal{E}_j$, with $X_j = [y_{j,t-1}, \ldots, y_{j,t-p}, x_t, y_{b,t-1}]$ and $B_j = \left[A_j^1, \ldots, A_j^p, C_j, D_j\right]'$

[5]Other studies using an hierarchical prior include Canova (2005) and Ciccarelli and Rebucci (2006). See Appendix B for more details on the Gibbs sampler algorithm used for estimation.

and, finally, vectorizing yields the following expression:

$$y_j = \overline{X}_j \beta_j + \varepsilon_j, \tag{2}$$

with $y_j = \text{vec}(Y_j)$, $\overline{X}_j = (I \otimes X_j)$, $\beta_j = \text{vec}(B_j)$ and $\varepsilon_j = \text{vec}(\mathcal{E}_j)$. The random effects model assumes that, for each country j, β_j can be expressed as $\beta_j = b + b_j$ with $b_j \sim \mathcal{N}(0, \Sigma_b)$ or, similarly, $\beta_j \sim \mathcal{N}(b, \Sigma_b)$.[6] That is, our empirical estimation assumes that the VAR coefficients of each country share a *common* (panel-specific) posterior mean. Intuitively, countries of one group are 'similar' in the underlying economic model and, hence, the posterior distribution pools information across countries ensuring an efficient use of the data.[7] We follow Jarociński (2010) and assume a diffuse prior for b (such that $p(b) \propto 1$) and a prior for Σ_b that replicates the VAR coefficient covariance matrix of the Minnesota prior.[8]

The matrix Y_j consists of our output measure, $\tilde{y}^j$, CPI inflation, $\tilde{\pi}^j$, the short-term interest rate, R^j, the real effective exchange rate, $\tilde{q}^j$, and the country risk premium, ξ^j, in that order:

$$Y_j = [\tilde{y}^j, \tilde{\pi}^j, R^j, \tilde{q}^j, \xi^j]. \tag{3}$$

Tildes refer to the fact that the corresponding variable is expressed in deviation from its trend. We include constants in all equations.

Finally, to identify risk premium shocks, we assume a triangular structure for the structural variance-covariance matrix with the ordering of the variables as described in (3).[9] In other words, we assume that risk premium shocks have no immediate impact (i.e. within the same month) on output, inflation, monetary policy and the real effective exchange rate.

[6]As is usual in the random effects literature, we implicitly assume that the variation in the β's is independent of the variation in the $\bar{X}_j$'s. While this assumption is more stringent than in the usual fixed effects model, our model is also more general as we allow for heterogeneity in the whole parmeter vector and not just the intercept.

[7]According to the Monte Carlo study in Hsiao et al. (1999), classical estimators for heterogeneous panels are much less efficient in small samples and perform worse than a variant of the Bayesian estimator with the exchangeable prior.

[8]Ultimately, $\Sigma_b = (\lambda_1 \otimes I_q)\,\Omega_b$, where q denotes the number of coefficients to be estimated per unit i and Ω_b is a $q \times q$ diagonal covariance matrix governed by the hyper-parameters λ_2, λ_3 and λ_4 (with notation and interpretation as in the Minnesota prior). λ_1, on the other hand, is drawn from an inverse Gamma distribution with scale $v_0/2$ and shape $s_0/2$. We set $\lambda_2 = 1$, $\lambda_3 = 1$, $\lambda_4 = 10$, as suggested by Dieppe et al. (2015), implying a relatively uninformed prior, yet choose a weakly informative prior for λ_1 by setting $s_0 = v_0 = 0.001$, as advocated by Jarociński (2010) and Dieppe et al. (2015).

[9]See Appendix C for results under alternative orderings.

3.3 Results

Figure 1 shows the impulse responses of each panel's mean estimate of the coefficients b to a 100 basis point increase in the risk premium vis-à-vis Germany (panel a) and the US (panel b).[10] In each figure, the first row shows the mean response of the floats, while the second shows the mean response of the monetary union.

The most striking result is that the positive risk premium shock leads to a fall in the PMI, *yet only under monetary union*. For the floats, the PMI does not fall following the shock; if anything, the median estimate points to an *increase* in economic activity, yet the response is not significant (in Bayesian terms). Moreover, when looking at the standard deviation of the risk premium shock, it appears that floats generally face smaller shocks than countries belonging to a monetary union. Specifically, when Germany (the US) is used as the base country, the standard deviation is 12bps (14bps) for floats and 20bps (22bps) for monetary union.

For some variables, the responses are ambiguous as they tend to depend on the base country used to calculate the country risk premium. Because of this, it is difficult to infer, from these results alone, the transmission mechanism that accounts for the differential response of economic activity to the risk premium shock across exchange rate regimes. To shed more light on the transmission, we resort to a standard New Keynesian model in the next section.

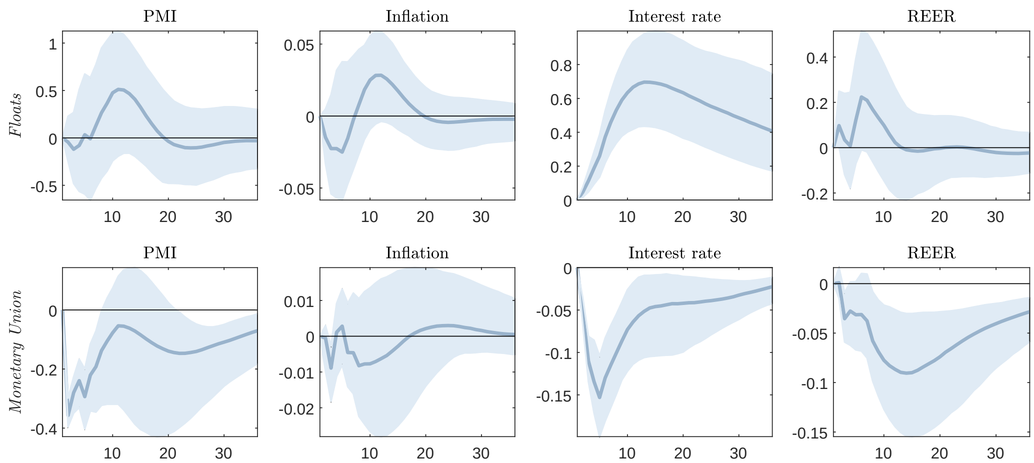
4 A two-country New Keynesian model

To study the effects of country risk premium shocks and dynamic capital controls across exchange rate arrangements, we use a relatively standard New Keynesian model for a two-country economy à-la Benigno (2004). We label the two countries Home (H) and Foreign (F), and denote by $s \in [0, 1]$ the relative size of Home. Consistent with the empirical analysis, we consider two types of exchange rate regimes: (1) a floating exchange rate regime, and (2) a monetary union. The two countries interact on international goods and asset markets. The latter are, however, incomplete and feature financial frictions that affect the effective return on internationally traded bonds. Following Turnovsky (1985), we interpret risk premium shocks as shocks to this financial friction. Capital

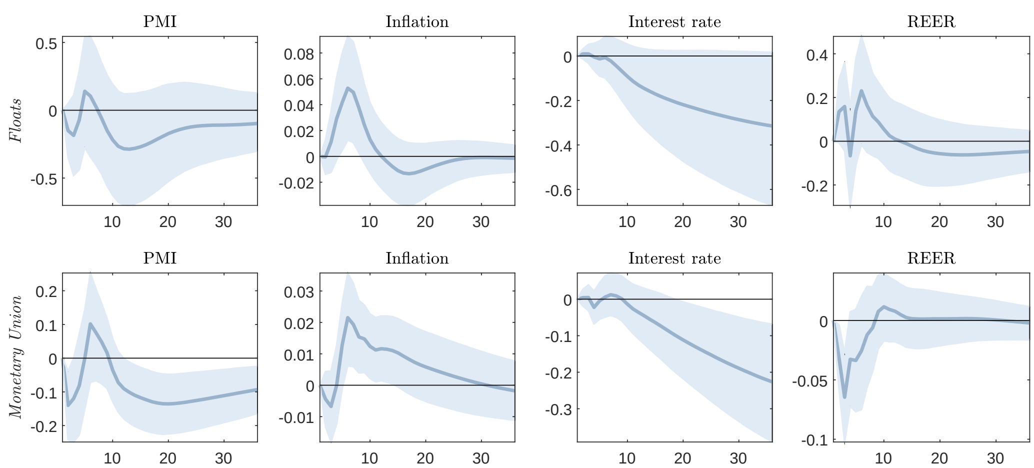
[10] In the Appendix C, we show that the results are robust to several other specifications, including the choice of the base country and data treatment.

Figure 1: Impulse responses to a positive risk premium shock

a Base country = Germany



b Base country = US



Note: The figures show the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis either Germany (top panel) or the US (lower panel). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. The shaded area reflects the 5%-95% credibility intervals.

controls are modeled as a counter-cyclical tax on external debt, as in Costinot et al. (2014), Davis and Presno (2017) and Schmitt-Grohé and Uribe (2017), among others. In this section, we briefly outline the main building blocks of the model.

4.1 Households

Each country $j = \{H, F\}$ is populated by an infinitely-lived, forward-looking representative household. In each period t, the household decides on how much to consume, c_t^j, how many hours to work, n_t^j, and how many one-period nominal domestic bonds, B_t^j, and internationally traded bonds (denominated in Foreign currency), D_t, to hold. Domestic bonds earn a gross nominal return R_t^j, set by the (supra)national central bank, while the return on (or carrying cost of) internationally traded bonds is given by $R_{d,t}$. We interpret Home as the debtor country that borrows from Foreign investors, such that $D_t > 0$ represents a surplus (deficit) on the capital account of Home (Foreign). Households supply labor to domestic firms, which they own, against the nominal wage rate W_t^j. Firm profits, $\mathcal{P}_t^j$, are distributed to the households as lump-sum dividends.

The period budget constraint facing Home households is given by

$$P_t^H c_t^H + B_t^H + e_t^{-1} (1 + \tau_{t-1}) R_{d,t-1} D_{t-1} = W_t^H n_t^H + R_{t-1}^H B_{t-1}^H + e_t^{-1} D_t + \mathcal{P}_t^H + P_t^H \mathcal{T}_t, \tag{4}$$

where P_t^j denotes the consumer price index of country j, and e_t the nominal exchange rate, defined as the Foreign currency price of one unit of Home currency. Foreign households face a similar such budget constraint. The interest rate on external debt is determined by the risk-free Foreign interest rate, R_t^F, and a country-specific risk premium, ξ_t:

$$R_{d,t} = R_t^F + \xi_t. \tag{5}$$

The risk premium is an increasing function of the degree of Home's external indebtedness:

$$\xi_t = \chi e_t^{-1} \frac{D_t}{P_t^H y_t^H} + z_{\xi,t} - 1, \tag{6}$$

where $\chi \geq 0$ denotes the risk premium elasticity, y_t^H aggregate Home output, and $z_{\xi,t}$ a risk premium shock that evolves according to a stationary AR(1) process. The risk premium can be interpreted as the additionally required return, over and above the risk-free interest rate, that compensates Foreign investors for bearing elevated (credit) risks associated with higher levels of external debt. Innovations to the risk premium, $z_{\xi,t}$, can be thought of as sudden changes in investor sentiment or risk aversion that drive surges in cross-border capital flows.[11]

The variable τ_t that appears in the budget constraint of the household is a dynamic tax on external debt, which is proportional to the external debt position of Home:

$$\tau_t = \psi e_t^{-1} \frac{D_t}{P_t^H y_t^H}. \tag{7}$$

An increase in external indebtedness is met by a rise in τ_t, the counter-cyclical bent of which is determined by the tax elasticity $\psi \geq 0$. The tax is thus meant to discourage an all too large buildup of external debt and thereby prevent financial imbalances from becoming unsustainable. Conversely, shocks that trigger sharp capital outflows from Home to Foreign result in a decline in τ_t that support the demand for external debt. The proceeds of the debt tax, i.e. $\mathcal{T}_t = \tau_{t-1} e_t^{-1} R_{d,t-1} D_{t-1}$, are rebated to Home households in a lump-sum manner. Our objective is to examine the macroeconomic and welfare implications of imposing this debt tax, both when Home operates under flexible exchange rates (and autonomous monetary policy) and under monetary union.

Subject to (4) and an appropriate transversality condition, households maximize expected lifetime utility, given by

$$E_t \sum_{k=0}^{\infty} \beta^k z_{D,t+k}^j \left(\log c_{t+k}^j - \frac{\left(n_{t+k}^j\right)^{1+\varphi}}{1+\varphi} \right), \tag{8}$$

where E_t denotes the rational expectations operator, $z_{D,t}^j$ a demand shock, $\beta \in (0,1)$ the discount factor, and $\varphi > 0$ the inverse Frisch elasticity of labor supply. The first-order conditions common across countries are given by

$$\left(n_t^j\right)^{\varphi} = \frac{w_t^j}{c_t^j}, \tag{9}$$

$$1 = \beta E_t \left[\frac{z_{D,t+1}^j}{z_{D,t}^j} \frac{c_t^j}{c_{t+1}^j} \frac{R_t^j}{\pi_{t+1}^j} \right], \tag{10}$$

[11] Others interpret risk premium shocks as departures from the uncovered interest rate parity condition (Kollmann, 2002) or as financial transaction costs (Benigno, 2009).

where $w_t^j \equiv W_t^j / P_t^j$ is the real wage rate and $\pi_t^j \equiv P_t^j / P_{t-1}^j$ CPI inflation.

Home's decision to borrow abroad is governed by the following Euler equation:

$$1 = \beta E_t \left[\frac{q_t}{q_{t+1}} \frac{z_{D,t+1}^H}{z_{D,t}^H} \frac{c_t^H}{c_{t+1}^H} (1+\tau_t) \frac{R_{d,t}}{\pi_{t+1}^F} \right], \tag{11}$$

where the real exchange rate, q_t, is defined as the relative CPI:

$$q_t \equiv \frac{e_t P_t^H}{P_t^F}. \tag{12}$$

By combining the two Euler equations for the domestic and internationally traded bonds, we obtain a utility-based uncovered interest rate parity (UIP) condition:

$$R_t^H = q_t (1+\tau_t) R_{d,t} \frac{E_t \left[z_{D,t+1}^H \left(c_{t+1}^H \right)^{-1} \left(\pi_{t+1}^F \right)^{-1} q_{t+1}^{-1} \right]}{E_t \left[z_{D,t+1}^H \left(c_{t+1}^H \right)^{-1} \left(\pi_{t+1}^H \right)^{-1} \right]}. \tag{13}$$

4.2 Monetary and fiscal policy policy

Naturally, monetary policy is designed differently across the two exchange rate regimes we consider. However, in each regime, we can describe monetary policy by an interest rate rule that relates the nominal risk-free interest rate to deviations of inflation from the central bank's inflation aim. Under a floating exchange rate regime, the following interest rate rule governs the behavior of each national central bank:[12]

$$\frac{R_t^j}{R^j} = \left(\frac{\pi_t^j}{\pi^j} \right)^{\phi_\pi}, \tag{14}$$

with $\phi_\pi > 1$ and where variables without a t subscript represent steady-state values. When the two countries form a monetary union, a supranational central bank sets the union-wide interest rate $R_t^{MU} \left(= R_t^H = R_t^F \right)$ to stabilize union-wide inflation:

$$\frac{R_t^{MU}}{R^{MU}} = \left[\left(\frac{\pi_t^H}{\pi^H} \right)^s \left(\frac{\pi_t^F}{\pi^F} \right)^{1-s} \right]^{\phi_\pi}. \tag{15}$$

In each country, there is a fiscal authority that issues bonds, B_t^j, which are held only by domestic

[12] Adding an interest rate smoothing or output gap term in the interest rate rule does not affect our main results.

citizens, and levies lump-sum taxes, $\tau_{l,t}^j$, to finance its consumption expenditures, g_t^j, and to service outstanding debt. The fiscal authority's budget constraint is given by

$$B_t^j + P_t^j \tau_{l,t}^j = R_{t-1}^j B_{t-1}^j + P_{j,t} g_t^j. \tag{16}$$

For simplicity, we set $g_t^j = g^j$ for all t. Lump-sum taxes, on the other hand, are set to stabilize public debt:

$$\tau_{l,t}^j - \tau_l^j = \phi_b \left(b_{t-1}^j - b^j \right), \tag{17}$$

with $\phi_b > 1/\beta - 1$.

4.3 Consumption, production and price setting

Total household consumption, c_t^j, consist of expenditures on domestically produced goods, $c_{j,t}^j$, and imported goods, $c_{i,t}^j$, for $i, j = \{H, F\}$ and $i \neq j$:

$$c_t^j = \left[\left(1 - \overline{\alpha}^j\right)^{\frac{1}{\eta}} \left(c_{j,t}^j\right)^{\frac{\eta-1}{\eta}} + \left(\overline{\alpha}^j\right)^{\frac{1}{\eta}} \left(c_{i,t}^j\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}},$$

where $\overline{\alpha}^H \equiv (1-s)\,\alpha$ and $\overline{\alpha}^F \equiv s\alpha$, with $\alpha \in [0,1]$ denoting the degree of country openness, and where $\eta > 1$ measures the trade elasticity. Assuming the Law of One Price holds and using standard CES aggregators for $c_{j,t}^j$ and $c_{i,t}^j$ (detailed in Appendix D), the following market clearing conditions can be derived:

$$y_t^j = \left(\gamma_t^j\right)^{-\eta} \left[\left(1 - \overline{\alpha}^j\right) c_t^j + \Omega_{j,t} c_t^i \right] + g_t^j, \tag{18}$$

where $\gamma_{j,t} \equiv P_{j,t}/P_t^j$, $\Omega_{H,t} \equiv (1-s)\,\alpha q_t^{-\eta}$ and $\Omega_{F,t} \equiv s\alpha q_t^{\eta}$. Note that we assume full home bias in government consumption.

Each differentiated intermediate Home (Foreign) good, $y_t^j(\iota)$, is produced by a monopolistic Home (Foreign) firm, indexed by $h \in [0, s)$ ($f = [s, 1]$), using the following Cobb-Douglas production function:

$$y_t^j(\iota) = z_{A,t}^j n_t^j(\iota), \tag{19}$$

where $\iota = h$ ($\iota = f$) if $j = H$ ($j = F$), and where $z_{A,t}^j$ is an aggregate productivity shock. $n_t^j(\iota)$

is the firm-specific demand for labor whose demand schedule is derived from a cost-minimization problem where the firm takes wages as given:

$$mc_t^j = \frac{1}{\gamma_t^j}\frac{w_t^j}{z_{A,t}^j}. \tag{20}$$

Firms set prices at a mark-up over marginal costs, yet are subject to a price-setting friction à-la Calvo (1983). Firms that are unable to reset their price in a given period set their current price to lagged aggregate inflation. The optimal reset price, $\overline{P}_{j,t}$, is symmetric across firms belonging to country j and is derived by maximizing firm profits subject to (18) and (19):

$$\overline{P}_{j,t} = \frac{\epsilon}{\epsilon-1}\frac{E_t\sum_{k=0}^{\infty}\theta^k \mathcal{Q}_{t,t+k}^j P_{j,t+k}^{1+\epsilon} mc_{t+k}^j y_{t+k}^j}{E_t\sum_{k=0}^{\infty}\theta^k \mathcal{Q}_{t,t+k}^j P_{j,t+k}^{\epsilon} y_{t+k}^j}, \tag{21}$$

with $\epsilon > 1$ the elasticity of substitution between intermediate goods, $\theta \in (0,1)$ the constant probability of non-price adjustment in a given period and $\mathcal{Q}_{t,t+k}^j$ the stochastic discount factor of households living in country j.

4.4 Steady state and calibration

To solve the model, we either take a first- or second-order approximation around the model's non-stochastic steady state, depending on whether we analyze impulse response functions or welfare. With regards the steady state, we assume prices are fully flexible ($\theta \to 0$) and Home has a zero net external debt position ($D = 0$). Although our focus is on the effects of risk premium shocks and the role of the dynamic debt tax, we also consider the results under demand and productivity shocks to show that the introduction of the debt tax may not always be complementary to monetary policy. These shocks evolve according to stationary AR(1) processes:

$$\ln z_{\xi,t} = \rho_\xi \ln z_{\xi,t-1} + \varepsilon_{\xi,t}, \tag{22}$$

$$\ln z_{D,t}^j = \rho_D \ln z_{D,t-1}^j + \varepsilon_{D,t}^j, \tag{23}$$

$$\ln z_{A,t}^j = \rho_A \ln z_{A,t-1}^j + \varepsilon_{A,t}^j, \tag{24}$$

with $\{\rho_\xi, \rho_D, \rho_A\} \in [0,1]$, $\varepsilon_{\xi,t} \sim \mathcal{N}\left(0, \sigma_\xi^2\right)$, $\varepsilon_{D,t}^j \sim \mathcal{N}\left(0, \sigma_D^2\right)$ and $\varepsilon_{A,t}^j \sim \mathcal{N}\left(0, \sigma_A^2\right)$.

Table 3: Benchmark calibration

Parameter	Description	Value
χ	Risk premium elasticity	0.001
ψ	Debt tax elasticity	$[0, 0.1]$
φ	Inverse Frisch elasticity	3
β	Discount factor	0.99
ϵ	Elasticity of substitution between intermediate goods	11
θ	Probability of non-price adjustment	0.75
η	Trade elasticity	2
s	Relative size of Home	0.5
α	Import share of consumption	0.4
ϕ_b	Fiscal response to debt	0.03
g/y	Steady state government consumption to output ratio	0.2
ρ_ξ, ρ_D, ρ_A, ρ_g	Auto-correlation coefficients	0.9
ϕ_π	Monetary policy response to inflation	1.5

We calibrate the model parameters based on a quarterly frequency for t. The baseline calibration, shown in Table 3, is based on commonly used values in the macroeconomics literature. The impulse responses from the Bayesian PVAR help us evaluate whether the model, although highly stylized, can generate dynamics which are empirically plausible. Nevertheless, we do discuss to which parameters our results are most sensitive. The elasticity of the debt tax with respect to external indebtedness, ψ, is varied throughout the analysis between 0 and 0.1.

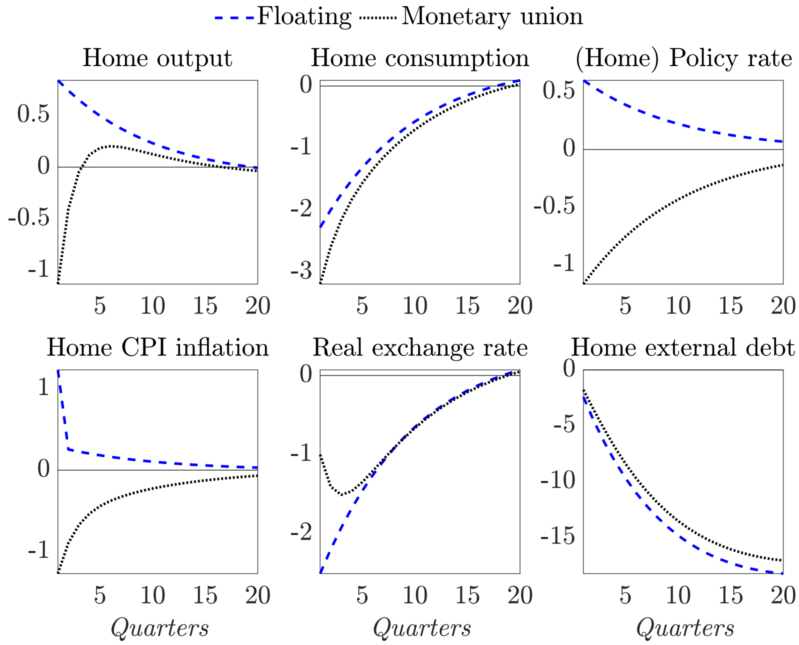
5 Risk premium shocks and capital controls

5.1 The effects of a risk premium shock

Before examining the role of the dynamic capital control tax introduced in the previous section, we first discuss the effects of a country risk premium shock across exchange rate regimes in the absence of the debt tax (i.e. for $\psi = 0$).

Figure 2 shows the impulse responses under our baseline calibration of selected Home variables to a temporary positive risk premium shock, both under floating exchange rates (blue dashed lines) and monetary union (black dotted lines). The shock leads to an increase in the effective interest rate on external debt for Home households. Consequently, households wish to borrow less, which is reflected in a marked decline in consumption and a reduction in the external debt position (i.e. D_t falls). The positive real interest rate differential induces a depreciation of the real exchange rate

Figure 2: Impulse responses to a risk premium shock



Note: Responses are in percent deviations from steady state.

by the UIP condition. These responses to the risk premium shock of consumption, cross-border capital flows and the real exchange rate are similar across exchange rate regimes. Monetary policy, however, responds differently across regimes.

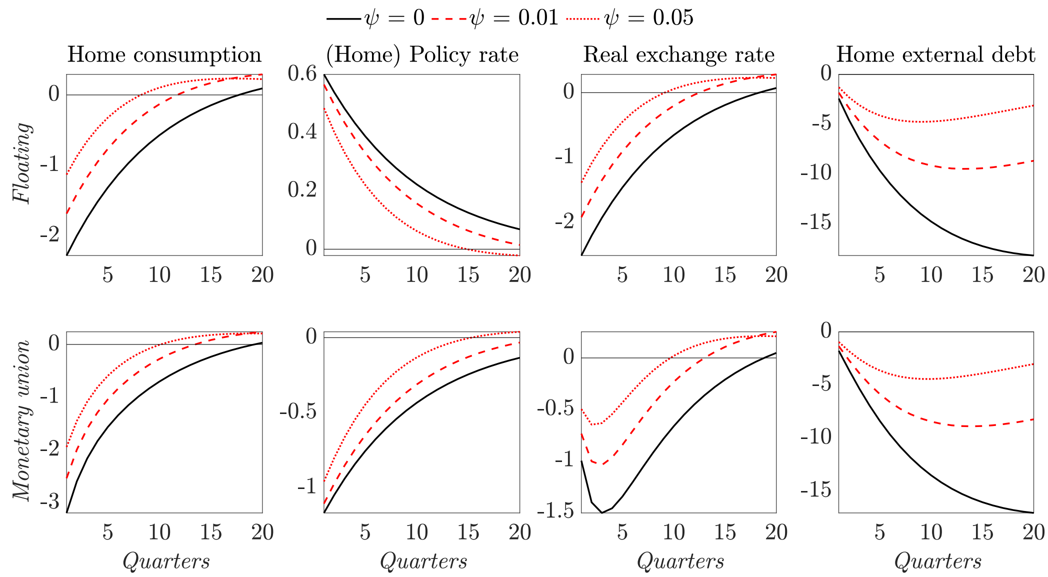
Under a regime of floating exchange rates, and given our benchmark calibration, the central bank in Home raises the policy interest rate. It does so because the depreciation of the exchange rate puts upward pressure on CPI inflation, due to inflated import prices and an increase in exports that supports output growth. In fact, the response of output is actually positive, a finding which may seem surprising yet which does not necessarily disagrees with our own empirical results. Also, Krugman (2014) shows that sudden losses of confidence that trigger large capital outflows can be expansionary, provided countries operate under floating exchange rates and can borrow in their own currency. Hence, despite the steep decline in Home consumption, the overall response of inflation to the risk premium shock is positive, which prompts the central bank to tighten monetary conditions through an increase in the interest rate. The higher interest rate discourages consumption, over and above the effects of the higher risk premium. The more open is the economy to international trade, i.e. the larger is α, the stronger is the effect of the real exchange rate on inflation and so the more contractionary is the monetary policy response. Conversely, if the economy is more closed, inflation is less sensitive to exchange rate fluctuations, which allows monetary policy to take a less restrictive stance following the risk premium shock. In fact, when α is close to zero, such that the economy is effectively closed, monetary policy is able to fully offset the risk premium shock and stabilize consumption, output and inflation, by keeping the interest rate constant. In general, however, the monetary policy response to a risk premium shock under a float fails to stabilize the economy as the central bank raises the interest rate to counter the inflationary effects of the real exchange rate depreciation, thereby enhancing the adverse effects of the risk premium shock on consumption.

Under monetary union, in which the supranational central bank targets union-wide inflation, the interest rate is lowered in response to the risk premium shock. However, because the central bank weighs its interest rate decision by the relative size of the Home country, i.e. by s, the monetary policy accommodation is less than what it would have been if Home was a more closed economy. Also, because the nominal exchange rate is fixed, the real exchange rate depreciates by less on impact than under flexible exchange rates, thereby limiting any expansionary impact that may arise from higher exports. Consequently, the output response to the risk premium shock is negative. Would s have been closer to 1, such that Home were to make up a relatively large share of the monetary union and thus carried a larger weight in the central bank's reaction function, we would have observed a much stronger monetary expansion following the risk premium shock and, consequently, a less steep decline in consumption and output.

The results shown in Figure 2 are broadly in line with our empirical estimates of the effects of sovereign bond spreads in countries with floating exchange rates and countries that belong to the euro area. These estimates confirm that the effects of risk premium shocks are contractionary in a currency union, and significantly so, while domestic production in floating regimes is much less vulnerable to such shocks. However, the sharp real exchange rate depreciation under a float as predicted by the theoretical model is not supported by the empirical evidence, which instead suggests a negligible response of the real exchange rate. The responses of the euro area panel are, in that regard, much more in line with our theoretical predictions.

In sum, the impulse response functions suggest that risk premium shocks discourage private consumption as they raise the cost of external borrowing. The corresponding outflow of capital results in a real exchange rate depreciation which, in itself, is inflationary. The monetary policy

Figure 3: Impulse responses to a risk premium shock under a debt tax



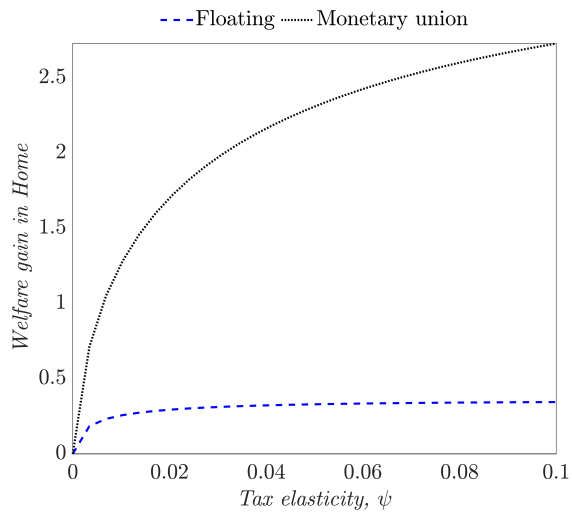
Note: Responses are in percent deviations from steady state.

response to the risk premium shock is either too restrictive or not sufficiently accommodative to stabilize consumption: under a float, the central bank raises the interest rate to offset the inflationary effects of the real exchange rate; under monetary union, monetary policy is accommodative, yet insufficiently so due to the common central bank's focus on union-wide, rather than regional, economic conditions. In both cases, therefore, there may be scope for capital controls to support monetary policy in stabilizing economic conditions when faced with country-specific risk premium shocks.

5.2 The effects of a dynamic tax on external debt

We now investigate the effects of a risk premium shock when the tax elasticity is positive, i.e. $\psi > 0$. Figure 3 again shows the responses of Home variables to a positive risk premium shock, yet now under different calibrations of the debt tax elasticity. The figure shows that imposing a tax on external debt mutes the impulse responses under both exchange rate regimes. Because of its counter-cyclical design, the tax falls and turns into a subsidy the moment the economy is hit by the risk premium shock and capital starts flowing out. The stronger the counter-cyclical bent of the tax, i.e. the higher is ψ, the more responsive the tax is to a given risk premium shock. The (negative) tax thereby attenuates the adverse effects of a higher risk premium on consumption and

Figure 4: Welfare gain of tax on external debt, conditional on risk premium shocks



Note: Welfare units are measured in consumption perpetuities (i.e. the perpetual increase in consumption as a percentage of steady-state consumption). Welfare gain derived by comparing welfare outcomes against a baseline scenario in which $\psi = 0$.

the willingness to borrow abroad.

Furthermore, the fall in the tax generates downward pressure on the real exchange rate, causing the response of the real exchange rate to also be more attenuated. Technically, this result arises from the UIP condition, which is repeated here for convenience:

$$R_t^H = q_t \left(1 + \tau_t\right) R_{d,t} \frac{E_t \left[z_{D,t+1}^H \left(c_{t+1}^H\right)^{-1} \left(\pi_{t+1}^F\right)^{-1} q_{t+1}^{-1} \right]}{E_t \left[z_{D,t+1}^H \left(c_{t+1}^H\right)^{-1} \left(\pi_{t+1}^H\right)^{-1} \right]}.$$

For a given monetary policy stance, a reduction in τ_t forces q_t to rise in order to satisfy the UIP condition which therefore reduces the overall inflationary effect of the real exchange rate. Under a floating exchange rate regime, this allows for a less contractionary monetary policy response needed to curtail inflation back towards the inflation target. Under monetary union, the required accommodation of monetary policy is reduced as the negative tax on external debt substantially diminishes the fall in consumption by limiting the rise in the *effective* interest rate on external debt. Hence, across the two regimes, the debt tax supports the central bank in stabilizing macroeconomic conditions when faced with a risk premium shock. These results, at least those under the floating exchange rate regime, are in line with earlier findings of Farhi and Werning (2014).

Compared to a baseline scenario in which the tax is absent, it therefore follows that imposing a counter-cyclical tax on external debt, conditional on the economy facing only risk premium shocks, is welfare enhancing in both exchange rate regimes, as is shown in Figure 4. In order to generate this figure, we took a second-order linear approximation of the model and simulated the model using alternative calibrations of the tax elasticity. We then compared the welfare outcome in each iteration against the welfare obtained under the baseline scenario. As a proxy for welfare, we used the utility function of the Home household:

$$\mathcal{W}_t^H = z_{D,t}^H \left(\log c_t^H - \frac{\left(n_t^H\right)^{1+\varphi}}{1+\varphi} \right) + \beta E_t \mathcal{W}_{t+1}^H.$$

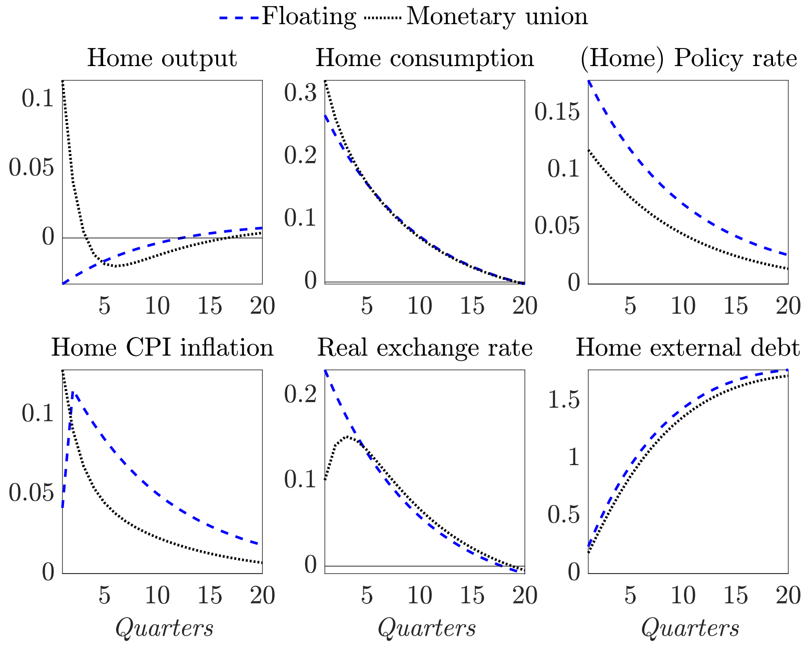
Figure 4 shows that the magnitude of the welfare gain differs across regimes and turns out to be greater under monetary union (black dotted line) than under a regime of floating exchange rates (blue dashed line). This reflects the trade-offs faced by monetary policy in the face of risk premium shocks, which in turn depends on different characteristics of the economy. For instance, if the economy would be very closed to international trade, the inflationary effects of the real exchange rate are reduced. A central bank operating under a floating exchange rate regime would then be free to stabilize economic conditions when faced with risk premium shocks. In fact, the welfare gain from introducing a tax on external debt becomes virtually zero under a float when α is set close to zero (see Farhi and Werning, 2014, for a similar result). Under monetary union, the welfare benefits of the debt tax diminishes as the Home country makes up a larger share of the monetary union. As $s \to 1$, and Home behaves more like a closed economy, the welfare benefits of the tax vanish.

5.3 A dynamic tax on external debt in the face of other shocks

Although imposing a tax on external debt proves welfare enhancing when the Home economy only faces risk premium shocks, the welfare implications may be different when faced with other shocks. The welfare gain may even be negative if the debt tax does not support, but instead undermines, monetary policy.

Consider, for example, the responses to a temporary positive demand shock in Home, shown in

Figure 5: Impulse responses to a demand shock



Note: Responses are in percent deviations from steady state.

Figure 5. This shock leads to an increase in Home consumption, financed by a buildup of external debt, which leads to an increase in inflation and, consequently, an appreciation of the real exchange rate. These responses are similar across exchange rate regimes. Output, however, rises on impact under a float, yet falls under monetary union due to the reduction in exports that suffer from the real exchange rate appreciation (the more sticky are prices, the less exchange rate changes feed into producer prices and so the more greater is the scope for output to respond positively under monetary union). Monetary policy tightens in both regimes, yet in varying degrees: under a float, the tightening is strongest, as the central bank aims to counteract the rise in inflation; under monetary union, the central bank also raises the interest rate to curtail inflation, yet the monetary contraction is less than what it would have been if Home was a closed economy because the central bank targets union-wide, rather than regional, inflation.

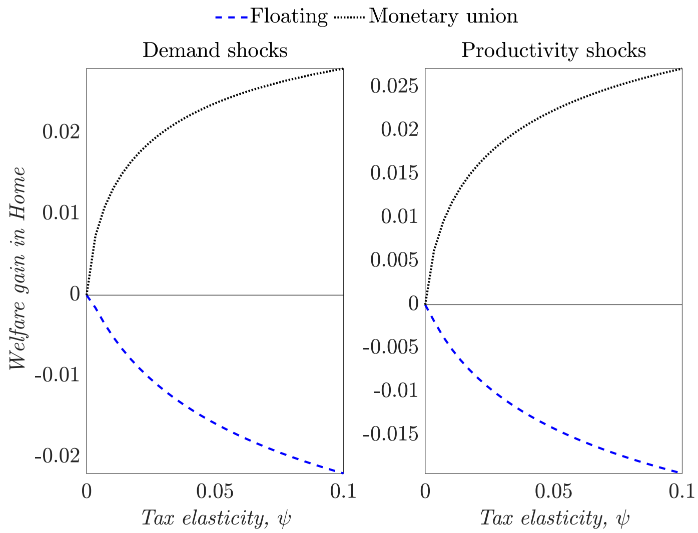
Introducing a dynamic tax on external debt when facing demand shocks is welfare enhancing under monetary union, yet *reduces* welfare under flexible exchange rates given our benchmark calibration (see Figure 6, left panel). In contrast to the case in which the economy is hit by a risk premium shock, a demand shock leads to a rise in the level of external debt which results in a tightening of the dynamic debt tax. The higher tax puts downward pressure on the exchange rate, which in turn raises inflation. Under a float, the tax thereby goes against the grains of monetary policy: by depreciating the exchange rate, and thereby aggravating the inflation response, the higher debt tax makes it more difficult for the central bank to stabilize inflation, and monetary policy is required to be more restrictive than it would have been in the absence of the tax. This is why, in the face of demand shocks, the tax is welfare reducing under a float compared to the baseline case without the tax.

Under a peg, instead, the real exchange rate depreciation triggered by the tax prompts the central bank to raise the interest rate by more than it would have in the absence of the shock, which helps offset the initial rise in inflation caused by the demand shock. Recall that, in the absence of the tax, the monetary tightening in response to the demand shock is weak in order to prevent the exchange rate from appreciating further. Such a weak monetary response, however, aggravates the inflation and output response to the demand shock. Imposing a tax, therefore, is welfare enhancing under a peg as it 'corrects' the monetary policy stance in a way that promotes inflation stability.

Under monetary union, the rise in the debt tax prompts the central bank to raise the interest rate by more than it would have in the absence of the shock, which helps offset the initial rise in inflation caused by the demand shock. If we were to assume that Home carried a larger weight in the common central bank's interest rate rule, and/or the supranational central bank adopted a more aggressive monetary policy (i.e. by assuming a higher value for ϕ_π), the monetary contraction becomes more 'appropriate' and, consequently, the welfare benefits of the tax are lower.

Now assume the Home economy faces only productivity shocks. A positive productivity shock raises Home output, which in turn induces households to raise consumption, see Figure 7. Meanwhile, as marginal costs fall, monopolistically competitive firms lower their prices causing inflation to fall as well, which leads to a real exchange rate depreciation. These responses are similar across exchange rate regimes, yet again the monetary policy response differs in terms of magnitude: under a float, the interest rate is reduced the most to ward-off deflation; under monetary union, the supranational central bank also battles deflation by lowering the interest rate, yet does so by less than it would have if Home were a closed economy. The response of the external debt position is ambiguous and depends on the structural parameters of the model. Under our baseline calibration, we find that external debt falls which reflects a negative output response in Foreign that

Figure 6: Welfare gain of tax on external debt,
conditional on demand and productivity shocks



Note: Welfare units are measured in consumption perpetuities. Welfare gain derived by comparing welfare outcomes against a baseline scenario in which $\psi = 0$.

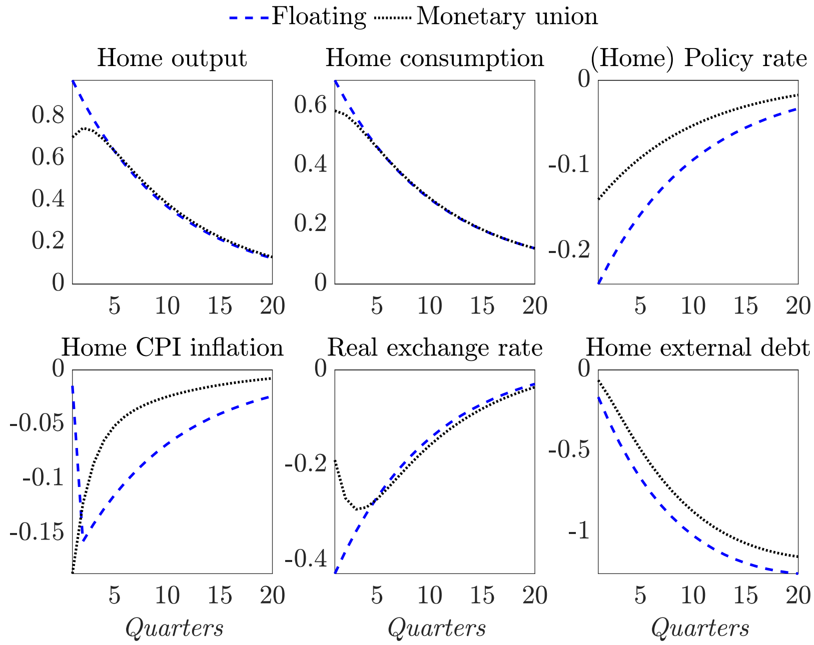
makes Home households want to lend to Foreign households. Nevertheless, we shall also discuss the implications of the debt tax if, instead, we would have observed a rise in the external debt position.

The welfare implications of the dynamic tax on external debt when facing productivity shocks that generate capital *outflows* are the same as those when facing only demand shocks: a more counter-cyclical tax on external debt enhances welfare under monetary union, yet reduces welfare under a float (see Figure 6, right panel).

With capital flowing out, the debt tax falls, i.e. turns into a subsidy, and, by the UIP condition, thereby puts upward pressure on the real exchange rate. The real exchange rate appreciation works to further lower inflation. Under monetary union, the downward pressure on inflation induces a more expansionary monetary policy stance, which partly overcomes the lack of monetary accommodation that would otherwise befall in the absence of the tax. Under a float, on the other hand, the tax produces welfare losses as it makes it more difficult for monetary policy to contain inflation.

If the productivity shock would have led to an *inflow* of capital, then the welfare implications of the external debt tax are reversed, with positive welfare gains under a floating exchange rate regime, and welfare losses under monetary union. With a rise in the external debt position of Home, the tax rises. This now puts downward pressure on the exchange rate, which thereby helps stabilize inflation. Under monetary union and in the absence of the tax, the central bank lowers

Figure 7: Impulse responses to a productivity shock



Note: Responses are in percent deviations from steady state.

the interest rate in response to the productivity shock in order to counter the fall in inflation. As mentioned earlier, this monetary policy response is less than what it would have been if Home were to make up the whole monetary union. In the presence of the tax, and the associated downward pressure on the exchange rate and inflation, the monetary expansion is even less, which is why the tax is welfare reducing. If, on the other hand, Home would behave more like a closed economy, then the negative welfare effects of the tax vanish. Under a float, the tax on external debt is supportive of monetary policy in stabilizing inflation by manipulating the dynamics of the real exchange rate, which is why imposing such a tax is welfare enhancing.

5.4 Summary

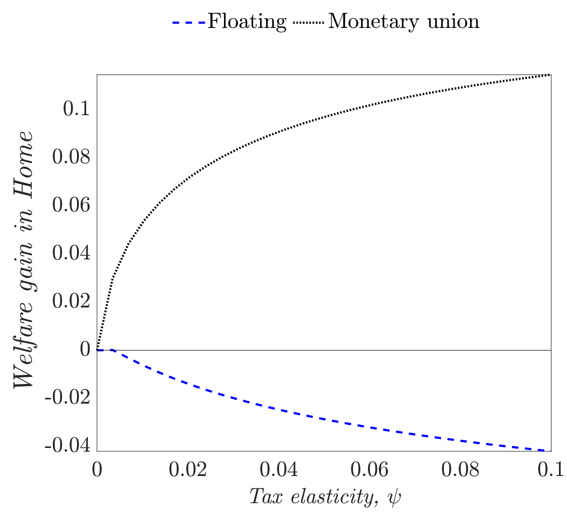
In sum: the welfare implications of imposing a tax on external debt depend on whether that tax supports or undermines monetary policy in stabilizing inflation. The latter, in turn, depends on (1) the exchange rate regime and (2) the nature of the shock. Table 4 summarizes these results.

Risk premium shocks that lead to an outflow of capital result in a fall in the tax on external debt. By the UIP condition, the lower tax leads to an appreciation of the real exchange rate, which in turn lowers inflation. The real exchange rate response induces monetary policy to lower the

Table 4: Summary of the welfare implications of a dynamic tax on external debt

	Risk premium shocks	**Demand shocks**	**Productivity shocks**
Float	Supports MP	Undermines MP	Undermines MP
MU	Supports MP	Supports MP	Supports MP

Figure 8: Welfare gain of tax on external debt, conditional on all three shocks



Note: Welfare units are measured in consumption perpetuities. Welfare gain derived by comparing welfare outcomes against a baseline scenario in which $\psi = 0$. The variance of the shocks are based on the results from the BPVAR model described in Section 3.

interest rate by more than it would have in the absence of the tax, thus displaying more effort to stabilize inflation. Although this result holds under both a flexible exchange rate and under monetary union, the welfare gain of the tax is largest under the latter.

Demand shocks that generate higher inflation and capital inflows prompt an increase in the tax on external debt and thereby a depreciation of the real exchange rate. This depreciation, in turn, leads to even higher inflation. Under a float, the tax on external debt therefore weakens the ability of monetary policy to stabilize inflation and is welfare reducing compared to the baseline scenario without the tax. Under monetary union, the rise in the tax induces a stronger contractionary response of monetary policy that would otherwise have been lacking in the absence of the tax because of the central bank's focus on union-wide, rather than regional, inflation dynamics.

Productivity shocks that lower inflation and household indebtedness reduce the tax on external debt. The resulting exchange rate appreciation lowers inflation by more. Under a float, the tax therefore undermines monetary policy in stabilizing inflation and reduces welfare compared to the baseline. Under monetary union, the downward pressure on inflation induces monetary policy to lower the interest rate by more than it would have in the absence of the tax, which again helps better stabilize inflation in Home.

In order to gauge the unconditional welfare implications of the capital control tax, we calculate the welfare gain as a function of ψ while considering all three shocks simultaneously, rather than separately as we have done before. To ensure empirically plausible shock sizes, we calibrate the variances of the shocks using the empirical estimates from the BPVAR model in Section 3. The results, shown in Figure 8, show that the capital control tax remains welfare enhancing under monetary union. This is not surprising, as we observed earlier that the tax has positive welfare effects under all shocks, except under productivity shocks if the shock is associated with an inflow of capital. The potentially negative welfare effects under productivity shocks, however, are dominated by the positive effects under risk premium and demand shocks. Under a floating exchange rate, we find that the unconditional welfare effects are negative for all the values we consider for ψ. This follows from the tax being welfare reducing under demand and productivity shocks that may dominate the positive welfare effects that arise under risk premium shocks.

6 Conclusion

The sovereign debt crisis in Europe is just one example that, like emerging market economies, also advanced economies are not impervious to sudden reversals in cross-border capital flows and associated surges in country risk premia. In this paper, we provide empirical evidence on the adverse effects of risk premium shocks for a panel of euro area countries using a monthly Bayesian Panel Vectorautoregression model and an hierarchical prior that allows for cross-subsectional heterogeneity. We also apply the model to a panel of countries that operate under flexible exchange rates and independent monetary policies, and show that these are much less vulnerable to risk premium shocks, and may even experience an increase in economic activity following such shocks. These results are strongly robust to a range of alternative model specifications and assumptions.

To better understand the propagation mechanism of risk premium shocks across exchange rate regimes, we employ a standard two-country New Keynesian model with incomplete asset markets. The model predictions confirm our empirical results and show that risk premium shocks are contractionary under monetary union, yet expansionary under flexible exchange rates. The latter result arises from a corresponding depreciation of the real exchange rate that supports output growth through the international trade channel. This, in turn, renders the risk premium shock inflationary, thus forcing the central bank to tighten monetary conditions despite the contraction in household consumption following the rise in the risk premium. It thereby follows that there may be scope for capital controls to support monetary policy in stabilizing macro-economic conditions.

We show that whether the welfare gain of imposing a counter-cyclical tax on external debt is positive or negative depends on the type of exchange rate regime and the nature of the shock hitting the economy. For monetary unions, the tax is generally welfare improving. In fact, using the results from the BPVAR model to calibrate the variances of the shocks shows that the unconditional welfare gain is monotonically increasing in the counter-cyclical bent of the tax. For flexible exchange rate regimes, however, the unconditional welfare gain is negative. This is because, when facing either demand or productivity shocks, the tax undermines monetary policy in stabilizing inflation.

Our results provide a rationale for imposing capital controls in countries that belong to a monetary union. A counter-cyclical tax on external debt is found to make up for the loss in monetary autonomy and to have an unconditional enhancing effect on welfare. Whether this holds for other types of capital controls as well is a question we leave for future research.

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Table 5: Descriptive statistics

Floats	US as benchmark Mean	Std	Min	Max	GER as benchmark Mean	Std	Min	Max
$\tilde{y}_t$	0.002	2.592	-16.637	10.208	0.004	2.460	-16.637	10.208
$\tilde{\pi}_t$	-0.001	0.103	-0.336	0.480	-0.001	0.109	-0.336	0.610
R_t	2.815	2.348	-0.632	8.330	2.663	2.334	-0.632	8.330
$\tilde{q}_t$	0.002	0.862	-3.910	2.652	0.001	0.821	-3.910	2.652
ξ_t	0.026	1.610	-4.969	2.850	0.599	1.490	-3.849	3.310
	US as benchmark				GER as benchmark			
Monetary union	**Mean**	**Std**	**Min**	**Max**	**Mean**	**Std**	**Min**	**Max**
$\tilde{y}_t$	0.024	1.440	-7.376	3.817	0.025	1.437	-7.376	3.817
$\tilde{\pi}_t$	-0.001	0.126	-0.543	0.810	-0.001	0.130	-0.543	0.810
R_t	1.872	1.633	-0.373	5.113	1.876	1.634	-0.373	5.113
$\tilde{q}_t$	-0.012	0.318	-1.332	1.178	-0.012	0.313	-1.332	1.178
ξ_t	0.121	1.501	-2.240	11.879	0.776	1.408	-1.800	12.029

A Data sources and treatment

We use PMI data from the Directorate General for Economic and Financial Affairs (DG-Ecfin) from the European Commission for the European countries and Markit otherwise.[13] To ensure comparability of these indexes, we re-scale them to have the same balance. The data for the overnight money market rates, consumer price index and the real effective exchange rate (based on CPI) are taken from the IMF's IFS database, while long-term interest rates (# LTINT) are taken from the OECD's Economic Outlook database.[14] The VIX (# VXOCLS) and the oil price (#DCOILBRENTEU) are taken from the FRED database. Finally, data for the VSTOXX index (the European equivalent of the VIX) was taken from Bloomberg (BBG000V9J5H5). If the data was not already seasonally adjusted, we used the multiplicative X-13 procedure for seasonal adjustment. Descriptive statistics are summarized in Table 5.

[13] Exemptions are Australia, Japan, New Zealand and the United States, where we use data from the Australian Industry group, Tankan, the Australian and New Zealand Banking Group Limited (ANZ) and the Institute for Supply Management, respectively.

[14] For Austria, Belgium, France, Germany, Italy and Portugal, we used the EONIA rates from the ECB's Statistical Data Warehouse as a measure for the short-term interest rate. Inflation data for Australia and New Zealand were taken from their respective central banks and interpolated using cubic splines.

B The Gibbs sampler algorithm for the hierarchical prior

The algorithm is based in Jarociński (2010) and Dieppe et al. (2015), and briefly outlined here for completeness. For more details, we refer the reader to Dieppe et al. (2015). The algorithm can be described as follows:

1. Define initial values for β, b, Σ_b and Σ. For β, use OLS estimates $\beta^{(0)} = \left\{\hat{\beta}_1, \hat{\beta}_1, \ldots, \hat{\beta}_N\right\}$, where $\hat{\beta}_j$ denotes the OLS estimate for β_j. For b, set $b^{(0)} = N^{-1}\sum_{j=1}^{N}\hat{\beta}_j$. For Σ_b, set $\lambda_1^0 = 0.01$, which implies $\sqrt{\lambda_1^0} = 0.1$, such that $\Sigma_b^{(0)}$ corresponds to the Ω_0 matrix from the Minnesota prior. Finally, for Σ, also use the OLS values $\Sigma^{(0)} = \left\{\hat{\Sigma}_1, \hat{\Sigma}_2, \ldots, \hat{\Sigma}_N\right\}$, with $\hat{\Sigma}_j$ defined as $\hat{\Sigma}_j = (T-k-1)^{-1}(\hat{\mathcal{E}}^j)'\hat{\mathcal{E}}^j$, where $\hat{\mathcal{E}}^j$ are the OLS residuals from country j.

2. At iteration n, draw $b^{(n)}$ from a multivariate normal distribution:

$$b^{(n)} \sim \mathcal{N}\left(\beta_m^{(n-1)}, \frac{1}{N}\Sigma_b^{(n-1)}\right),$$

   with

$$\beta_m^{n-1} = \frac{1}{N}\sum_{j=1}^{N}\beta_j^{(n-1)}.$$

3. At iteration n, draw $\Sigma_b^{(n)}$. To do so, draw $\lambda_1^{(n)}$ from an inverse Gamma distribution:

$$\lambda_1^{(n)} \sim \mathcal{IG}\left(\frac{\tilde{s}}{2}, \frac{\tilde{v}}{2}\right),$$

   with $\tilde{s} = h + s_0$ and

$$\tilde{v} = v_0 + \sum_{j=1}^{N}\left[\left(\beta_j^{(n-1)} - b^{(n)}\right)'\left(\Omega_b^{-1}\right)\left(\beta_j^{(n-1)} - b^{(n)}\right)\right].$$

   Then, obtain Σ_b^n from $\Sigma_b^n = (\lambda_1^n \otimes I_q)\,\Omega_b$.

4. At iteration n, draw $\beta^{(n)} = \left\{\beta_1^{(n)}, \beta_2^{(n)} \ldots, \beta_N^{(n)}\right\}$ from a multivariate normal distribution

$$\beta_j^{(n)} \sim \mathcal{N}\left(\overline{\beta}_j, \overline{\Omega}_j\right),$$

with

$$\overline{\Omega}_j = \left[\left(\Sigma_j^{(n-1)} \right)^{-1} \otimes X_j' X_j + \left(\Sigma_b^{(n)} \right)^{-1} \right],$$

and

$$\overline{\beta}_j = \Omega_j \left[\left(\left(\Sigma_j^{n-1} \right)^{-1} \otimes X_j' \right) y_j + \left(\Sigma_b^{(n)} \right)^{-1} b^{(n)} \right].$$

5. At iteration n, draw $\Sigma^{(n)} = \left\{ \Sigma_1^{(n)}, \Sigma_2^{(n)}, \ldots, \Sigma_N^{(n)} \right\}$ from an inverse Wishart distribution:

$$\Sigma_j^{(n)} \sim \mathcal{IW} \left(\tilde{S}_j, T \right),$$

with

$$\tilde{S}_j = \left(Y_j - X_j B_j^{(n)} \right)' \left(Y_j - X_j B_j^{(n)} \right).$$

This concludes the algorithm.

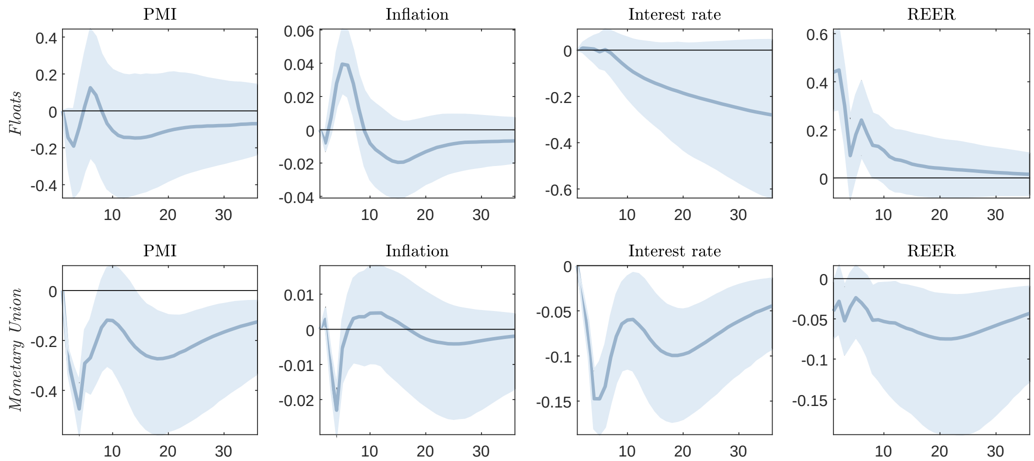
C Robustness of the empirical results

In the main text, we presented evidence suggesting that risk premium shocks are more contractionary for member countries of a monetary union than for countries with a floating exchange rate and independent monetary policy. This section verifies that this conclusion remains intact, even if we (i) change the ordering of the endogenous variables, (ii) include the first three principal components for each panel as additional controls, (iii) use alternative data transformations (i.e. entering some variables in growth rates or log levels), or (iv) choose a smaller time period that excludes the Great Recession and the sovereign debt crisis in the euro area. We also (v) discuss the effects of our main hyper-parameters, $s_0/2$ and $v_0/2$, that govern the shape of the inverse Gamma distribution from which λ_1 is drawn, and therefore govern the degree of shrinkage. Finally, (vi) to show that our results are not biased by the effective lower bound (ELB) on nominal interest rates, we use shadow rate estimates from Krippner (2013) for the Euro area, Japan, the UK and the US instead of the respective market short-term rates.

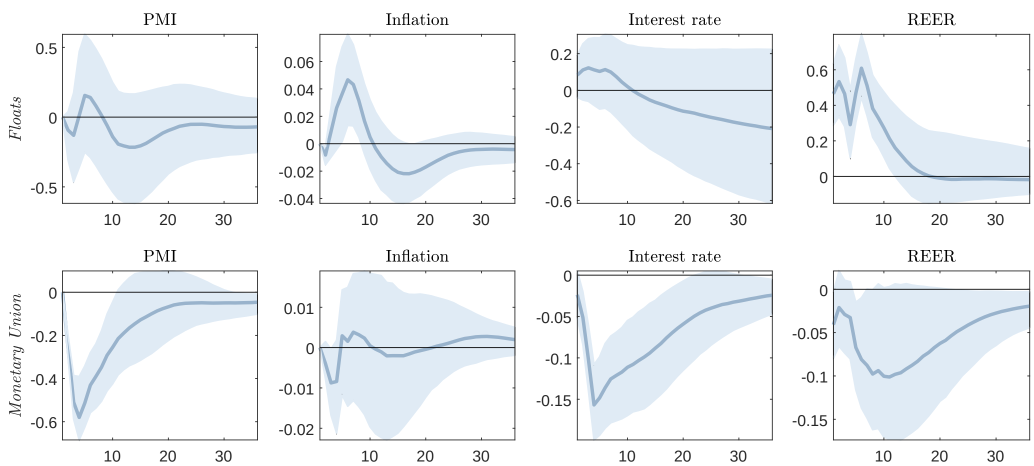
First, we *change the order of the variables* in the model. In Figure 9, panel a, we place the risk premium *fourth*, rather than last as in the baseline, and the REER last, while we keep the−arguably less controversial−order for output, inflation and the short-term interest rate unaltered. For the floats, we use the US as a base country to calculate the risk premium, whereas for monetary union we use Germany as a base country. The impulse responses for the floats are shown in the top row, and those for monetary union are shown in the bottom row. For floats, the only notable difference is that now the REER appreciation is significant, whereas for the monetary union panel, the REER appreciation is not significant on impact any longer, but only in the long run, despite the fact that inflation falls significantly in response to the risk premium shock. These conclusions are only strengthened if we order the spread *third*, allowing both the short-term interest rate and the REER respond immediately to a risk premium shock. In that case, the short-term interest rate increases under floats (although insignificantly), but falls under monetary union (see panel *b*), which is consistent with our theoretical predictions.

Figure 9: Impulse responses to a risk premium shock: different ordering of variables

a Ordering: $\tilde{y}_t$, $\tilde{\pi}_t$, R_t, ξ_t and $\tilde{q}_t$



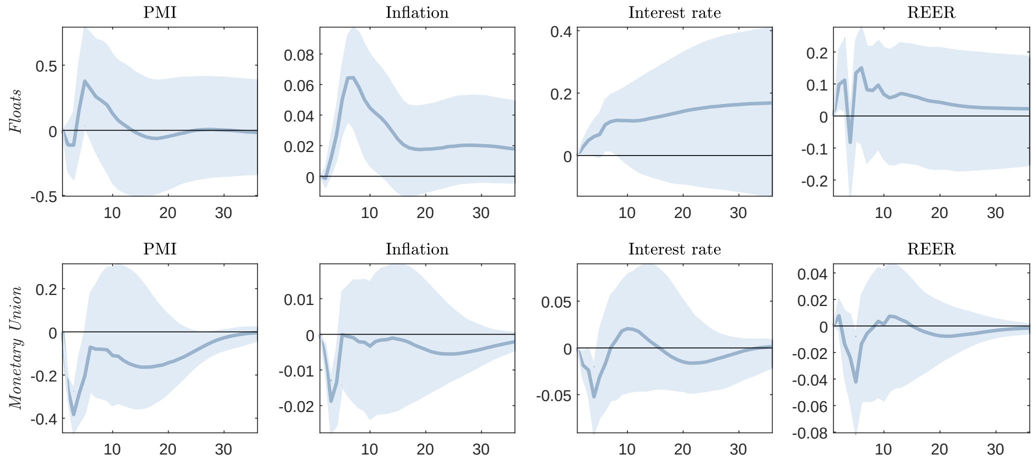
b Ordering: $\tilde{y}_t$, $\tilde{\pi}_t$, ξ_t, R_t and $\tilde{q}_t$



Note: The figures show posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. The shaded area reflects the 5%-95% credibility intervals.

To ensure we are really identifying a country's idiosyncratic movements in the risk premium, we now *include the first three lagged principal components* of all countries' endogenous variables to capture the global economic cycle, as inspired by Amendola et al. (2019). The results in Figure 10 suggest that controlling for the base country's macroeconomic aggregates, as well as the VIX and oil prices, is sufficient to extract country-specific shocks to the risk premium. Moreover, we now find that the expansionary effect of the risk premium shock under floats is significant.

Figure 10: Impulse responses to a risk premium shock: including additional controls

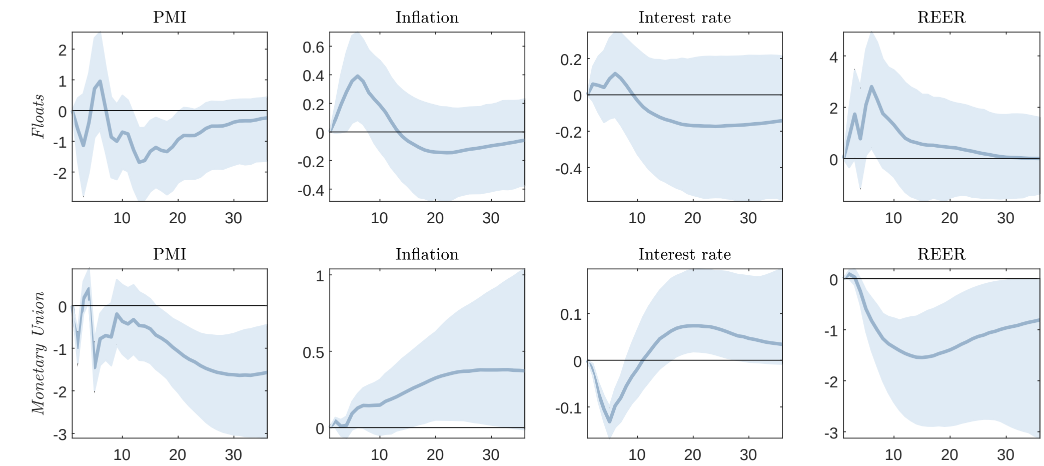


Note: The figure shows the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. The first three principle components of all endogenous variables in the panel are added as additional controls. The shaded area reflects the 5%-95% credibility intervals.

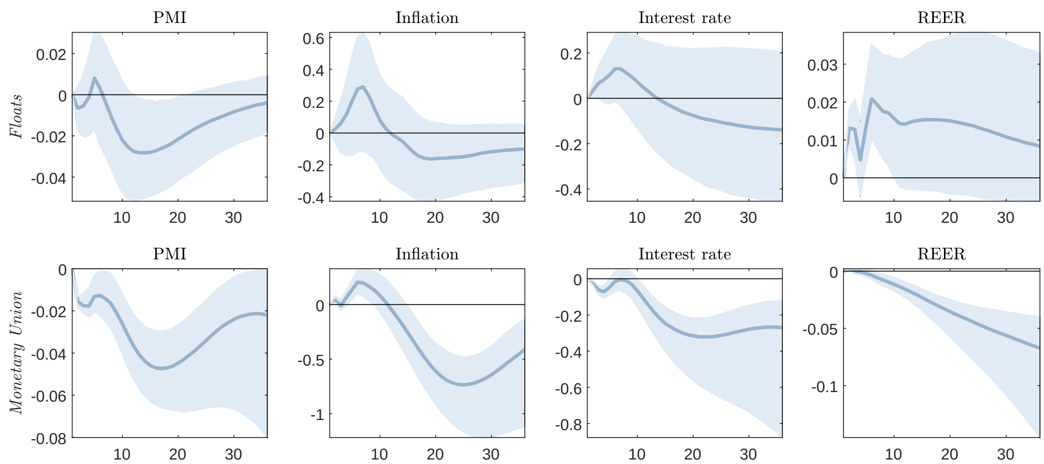
Next, in Figure 11, we show that the results are robust to *alternative data transformations*, in particular using either (annual) growth rates (panel *a*) or log levels for output, inflation and the REER (panel *b*).

Figure 11: Impulse responses to a risk premium shock: alternative data transformations

a Variables in growth rates



b Variables in log levels

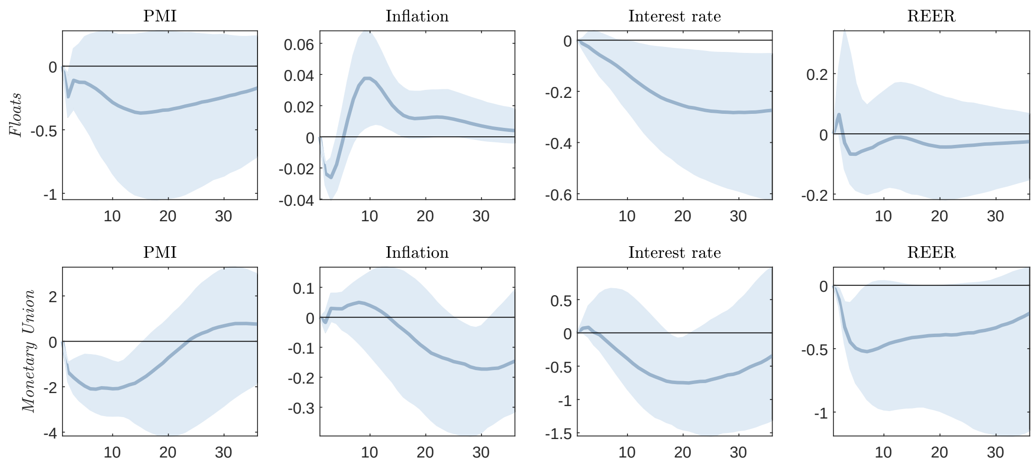


Note: The figures show the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. In panel *a*, the results are obtained using the PMI and REER in (annual) growth rates, interest rates in levels and inflation calculated as the annual change in the CPI. In panel *b*, all variables in log levels, except interest rate and spread. The shaded area reflects the 5%-95% credibility intervals.

One may wonder whether our results are solely driven by the recent crisis episodes during which risk premia were above average. Figure 12, therefore, shows the impulse responses when the model is estimated using data excluding the Great Recession and the subsequent sovereign debt crisis. We chose October 2008 as a cutoff date, as it symbolizes the beginning of the Great Recession.[15]

[15] Due to the smaller sample size, we reduced the lag length from 6 to 3, thereby reducing the number of coefficients to estimate *per* country by 75.

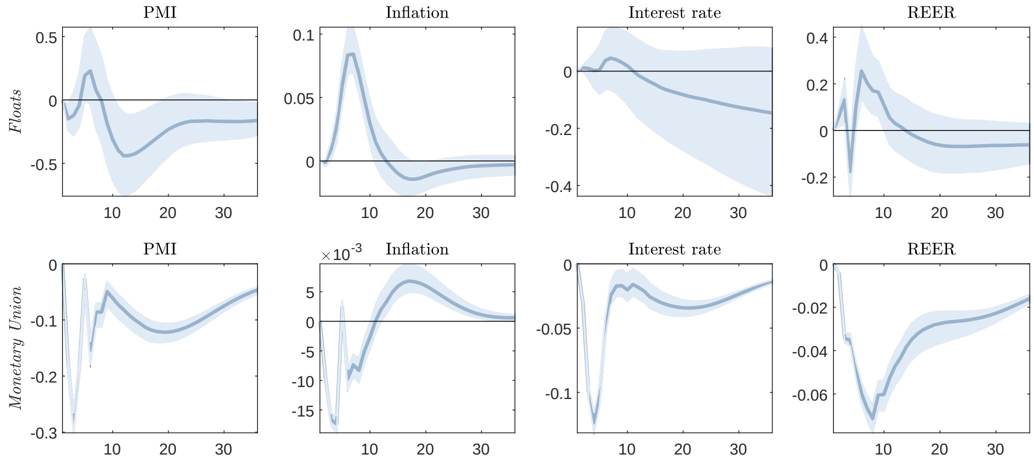
Figure 12: Impulse responses to a risk premium shock: shorter sample, excluding the Great Recession and sovereign debt crisis



Note: The figure shows the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. Estimation sample is 1999M1-2008M10 and lag length is 3. The shaded area reflects the 5%-95% credibility intervals.

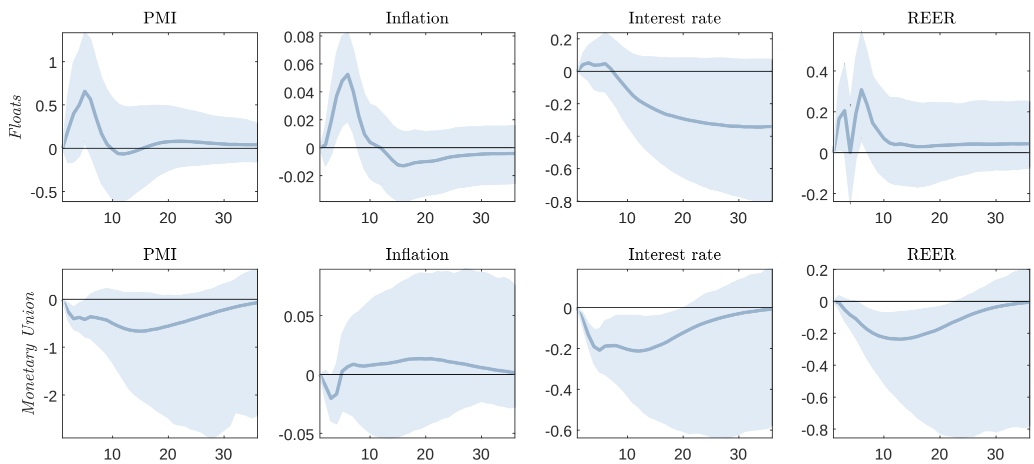
The impulse responses of the two extreme cases of our model are shown in Figures 13 and 14. In particular, Figure 13 plots the responses of a *homogeneous panel*, i.e. $\lambda_1 = 0$, while Figure 14 plots the mean responses of *country-by-country regressions*. Comparing both figures illustrates the power of the hierarchical prior: while the credibility bands are very dispersed for the country-by-country regressions, fully pooling the data yields much sharper results. The latter, however, comes at the cost of loosing the cross-subsectional heterogeneity. Also, note the differences in size of the credibility bands across panels in Figure 13, which are arguably driven by the fact that coefficients (and hence dynamics) across euro area countries are more similar than those in our float countries.

Figure 13: IRFs to a risk premium shock: Fully pooled model (homogeneous panel)



Note: The figure shows the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. For estimation, we set $s_0/2 = v_0/2 = 0.000001$, implying $\lambda_1 \to 0$ and hence resulting in a full pooling of the panel. The shaded area reflects the 5%-95% credibility intervals.

Figure 14: IRFs to a risk premium shock: Mean response of country-by-country regressions



Note: The figure shows the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In each figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. For estimation, we set $s_0/2 = v_0/2 = 1$, implying $\lambda_1 \to 1$ and hence resulting in country-by-country regressions. The shaded area reflects the 5%-95% credibility intervals.

Finally,

Figure 15: IRFs to a risk premium shock: Using shadow rates with US as benchmark country

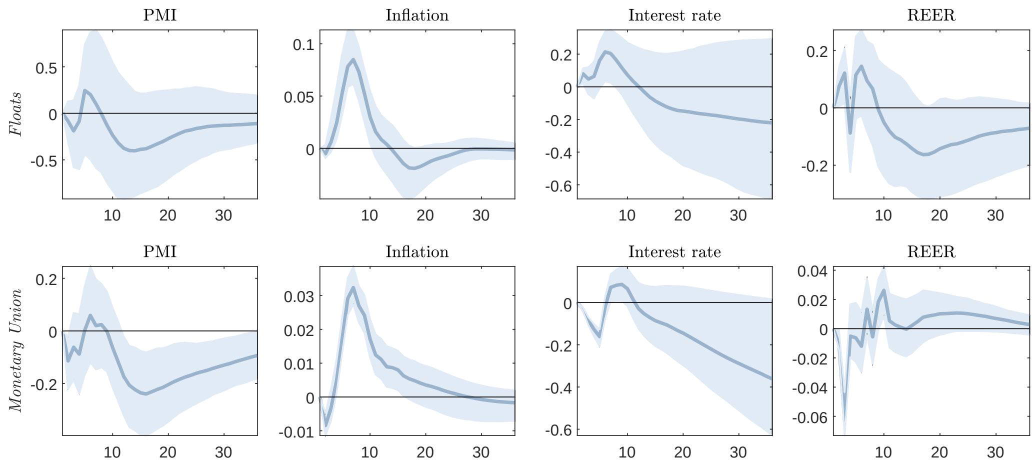
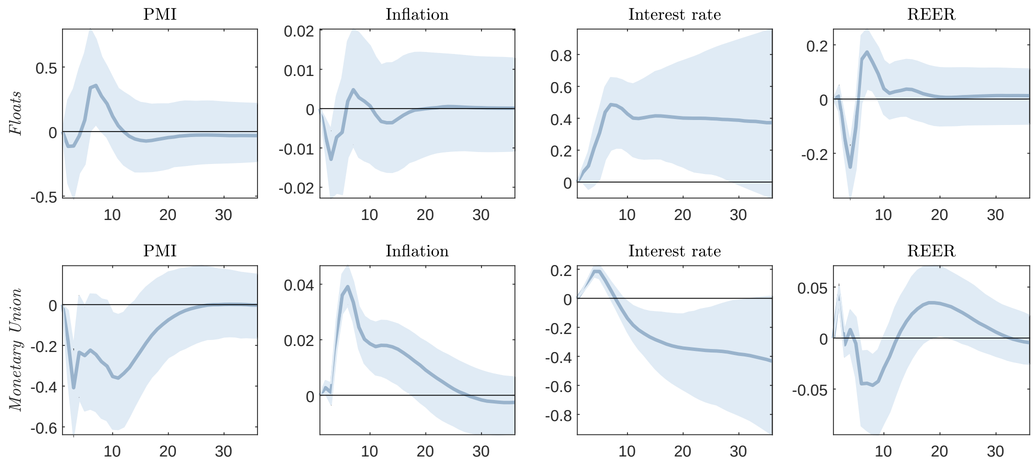


Figure 16: IRFs to a risk premium shock: Using shadow rates with Germany as benchmark country



D Demand schedules and price indices

In this section, we present the conditions that pin down optimal household demand for Home and Foreign goods, and the consumer and producer price indices.

As described in the main text, total household expenditure on consumption, c_t^j, consists of domestically produced goods, $c_{j,t}^j$, and imported goods, $c_{i,t}^j$:

$$c_t^j = \left[\left(1 - \overline{\alpha}^j\right)^{\frac{1}{\eta}} \left(c_{j,t}^j\right)^{\frac{\eta-1}{\eta}} + \left(\overline{\alpha}^j\right)^{\frac{1}{\eta}} \left(c_{i,t}^j\right)^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}},$$

where $c_{j,t}^j$ and $c_{i,t}^j$ are aggregated according to the following functions:

$$c_{H,t}^j = \left[\left(\frac{1}{s}\right)^{\frac{1}{\epsilon}} \int_0^s c_{H,t}^j(h)^{\frac{\epsilon-1}{\epsilon}} dh \right]^{\frac{\epsilon}{\epsilon-1}}, \qquad c_{F,t}^j = \left[\left(\frac{1}{1-s}\right)^{\frac{1}{\epsilon}} \int_s^1 c_{F,t}^j(f)^{\frac{\epsilon-1}{\epsilon}} df \right]^{\frac{\epsilon}{\epsilon-1}}.$$

Assuming households face standard expenditure constraints and take prices as given, we can derive the following demand schedules:

$$c_{j,t}^j = \left(1 - \overline{\alpha}^j\right) \left(\frac{P_{j,t}}{P_t^j}\right)^{-\eta} c_t^j, \qquad c_{i,t}^j = \overline{\alpha}^j \left(\frac{P_{i,t}^j}{P_t^j}\right)^{-\eta} c_t^j.$$

Furthermore, optimal demand schedules for intermediate goods are given by

$$c_{H,t}^j(h) = \frac{1}{s} \left(\frac{P_{H,t}^j(h)}{P_{H,t}^j}\right)^{-\epsilon} c_{H,t}^j, \qquad c_{F,t}^j(f) = \frac{1}{1-s} \left(\frac{P_{F,t}^j(f)}{P_{F,t}^j}\right)^{-\epsilon} c_{F,t}^j.$$

Finally, the consumer price index is given by

$$P_t^j = \left[\left(1 - \overline{\alpha}^j\right) P_{j,t}^{1-\eta} + \overline{\alpha}^j P_{i,t}^{1-\eta} \right]^{\frac{1}{1-\eta}},$$

while the producer price indices are given by

$$P_{H,t} = \left(\frac{1}{s} \int_0^s P_{H,t}(h)^{1-\epsilon} dh \right)^{\frac{1}{1-\epsilon}}, \qquad P_{F,t} = \left(\frac{1}{1-s} \int_s^1 P_{F,t}(f)^{1-\epsilon} df \right)^{\frac{1}{1-\epsilon}}.$$

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