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

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December 28, 2023

Abstract

The literature on the effects of country risk premium shocks has mostly focused on emerging market economies. We show empirically that in developed economies, risk premium shocks explain a non-trivial share of aggregate fluctuations and are key drivers of real activity in particular crises. Both our empirical results and results from a two-country New Keynesian model indicate that an increase in the country risk premium leads to a reduction in aggregate output under monetary union, but not so in countries with flexible exchange rates and independent monetary policy. Model simulations suggest that managing international capital flows enhances welfare in countries under monetary union.

JEL Classification: F32, F38, F41, F45

Keywords: country risk premium, capital flow management, Bayesian panel VAR, exchange rate regime, welfare analysis

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*We thank Maurice Bun, James Costain, Peter van Els, Bart Hobijn, Thomas Lubik, Evi Pappa, Christiaan Pattipeilohy, Raf Wouters, Francesco Zanetti and Andrei Zlate for useful comments and suggestions. We are also grateful for comments received from seminar participants at De Nederlandsche Bank and conference participants at the ECB's Workshop on International Financial Flows in 2019, the 2019 Annual Workshop of the ESCB Research Cluster 2 at the Bundesbank and the Dutch Economist Day 2019 at De Nederlandsche Bank. An earlier version of the paper circulated under the name "Country risk premium shocks and capital controls across exchange rate regimes". The views expressed do not necessarily reflect the official position of De Nederlandsche Bank or the Eurosystem.

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1 Introduction

Empirical evidence suggests that swings in international capital flows, captured by changes in country risk premia, are important drivers of business cycle fluctuations in emerging market economies (EMEs).[1] To date, an open question is whether international capital flows are also important for developed economies and, if so, whether developed economies can benefit from managing capital flows.

In this paper, we find that country risk premium shocks also matter for macroeconomic outcomes in developed economies. Inspired by the literature on emerging market economies[2], we start by examining the effects of risk premium shocks in developed economies and the role of the exchange rate regime. By focusing on developed economies, we are better able to isolate the effect of the exchange rate regime, as emerging market countries tend to intervene more often in foreign exchange markets even if they are classified as having a floating exchange rate regime (see e.g. Disyatat and Galati, 2005). Arguably, a country's exchange rate regime plays a crucial role in shaping its ability to react to risk premium shocks, as exemplified by the well-known trilemma of free capital flows, independent monetary policy and fixed exchange rates.

To this end, we estimate a Bayesian Panel Vector Autoregression (BPVAR) model, one for a panel of developed economies with a flexible exchange rate and one for a panel of countries that belong to the European Economic and Monetary Union (EMU). Institutional features other than the exchange rate regime likely vary within each of those two panels, such that risk premium shocks may have different effects on each country within every panel. To allow for this cross-subsectional heterogeneity but pool the information within panels efficiently, our econometric approach assumes that within each of the two panels, the coefficients may differ across countries but are drawn from the same posterior distribution.

We find that risk premium shocks explain a non-trivial share of aggregate fluctuations in developed economies. Importantly, the exchange rate regime matters for the effect of risk premium

[1] For instance, see Neumeyer and Perri (2005); Uribe and Yue (2006); Garcia-Cicco et al. (2010). The mechanisms underlying these results include, among others, the fact that EMEs depend more heavily on foreign currency denominated debt, and are therefore more sensitive to exchange rate fluctuations (Eichengreen and Haussmann, 1999), and the fact that fiscal policy tends to be more pro-cyclical in EMEs, which can amplify the impact of sudden stops (Gavin and Perotti, 1997).

[2] Magud et al. (2014) find 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.

shocks. Under monetary union, an increase in the country risk premium leads to a contraction in domestic real activity as measured by the Purchasing Manager Index. However, under flexible exchange rates, an increase in the risk premium does not reduce output. If anything, the posterior median estimates suggest that a higher risk premium raises output, although the response is not significant.

In a next step, we develop a stylized two-country New Keynesian model and similarly find that an increase in the risk premium causes an output contraction under monetary union, but is expansionary in a regime with flexible exchange rates. We attribute this result to the fact that, in the model, the real exchange depreciates more strongly in response to a risk premium shock in the flexible exchange rate regime than under monetary union, which has a stronger upward effect on net exports and output.

Using the model, we show that a proportional tax on external debt attenuates the effects of risk premium shocks. In monetary union, this type of capital control enhances welfare conditional on a risk premium shock, but also conditional on a demand shock or productivity shock. In a regime with flexible exchange rates, introducing capital controls also improves welfare conditional on a risk premium shock, but by less than under monetary union, and could worsen welfare conditional on demand or productivity shocks. The latter indicates that capital controls are generally complementary to monetary policy under monetary union, yet may undermine monetary policy under a flexible exchange rate regime.

In sum, our theoretical findings suggest that developed economies can benefit from managing international capital flows if they belong to a monetary union. In our model, we consider a policy whereby agents internalize the proportional debt tax. In that sense, we focus on a more systematic type of capital flow management than, for example, the ad hoc restrictions on capital outflows that were implemented in Greece and Cyprus at the height of the sovereign debt crisis.

The approach in our empirical section is closest in spirit to that of Uribe and Yue (2006) and Akıncı (2013), who estimate Vector Autoregressions for a panel of developing economies. According to their result, country risk premium shocks are contractionary and explain 12% and 15%, respectively, of business cycle fluctuations in real activity.

Unlike those two studies, we focus on developed economies and examine the role of the exchange rate regime, while also relaxing the assumption that coefficients are the same across countries. Our findings suggest that, unconditionally, risk premium shocks explain a somewhat smaller share of fluctuations in real activity in developed economies. This contribution rose substantially during the sovereign debt crisis, especially in those economies belonging to a monetary union.

The predictions of our model are similar to those of Garcia and González (2013) and Ali and Anwar (2022), who show that in a structural model for a small open economy, risk premium shocks can lead to an expansion in output through a strong depreciation of the real exchange rate.

Our paper also relates to a growing theoretical literature assessing the role of capital controls and other types of macro-prudential policy to curb violent cross-border capital flows and reduce the severity of financial crises. Some of this literature focuses on macro-prudential policy aiming to limit overborrowing (see, among other, Bianchi and Mendoza, 2010; Bianchi, 2011; Schmitt-Grohé and Uribe, 2017). Our paper builds on these contributions by investigating how the effect of capital controls varies across exchange rate regimes.

A working paper by Farhi and Werning (2012) also studies the welfare implications of capital controls for a small open economy that operates under either flexible or fixed exchange rates. Our paper is different in that it studies a two-country model and also by considering the monetary union case. Moreover, we tie our theoretical results to novel empirical evidence on the effects of country risk premium shocks across exchange rate regimes.

Finally, our paper relates to the literature on the role of financial frictions in open economy models[3] and to a broader literature on macro-prudential policy in an open economy.[4] Medina and Roldós (2018), for example, analyze a small open economy model in which, conditional on global interest rate shocks, counter-cyclical bank capital requirements can improve welfare beyond what can be achieved by monetary policy alone. Relatedly, Clancy and Merola (2017) show that counter-cyclical minimum bank capital requirements can attenuate boom-bust cycles in a small open economy that belongs to a monetary union. These results are consistent with our finding that counter-cyclical capital controls that respond to movements in external debt can attenuate the economy's response to a risk premium shock, and thereby improve welfare, as long as they support monetary policy in stabilizing inflation.

[3]For instance, the models of Caballero and Krishnamurthy (2001, 2004) feature domestic and international collateral constraints. Schmitt-Grohé and Uribe (2016) argue for capital controls to offset inefficiencies arising from fixed exchange rates and downward nominal wage rigidity.

[4]See, for instance, Farhi and Werning (2016) and Mendicino and Punzi (2014).

The remainder of this paper is structured as follows. In Section 2, we discuss the empirical analysis and estimate the effects of risk premium shocks across exchange rate regimes. In Section 3, we present the two-country New Keynesian model, while in Section 4 we further investigate the transmission mechanism of risk premium shocks and study the role of capital controls. Finally, Section 5 concludes.

2 The effects of risk premium shocks: empirical evidence

In this section, we estimate the effects of country risk premium shocks on main macroeconomic aggregates for two panels of advanced economies using a Bayesian Panel VAR. The first panel includes countries with floating exchange rates and independent monetary policies, while the second panel includes countries belonging to a monetary union, specifically the euro area. Our hierarchical (or 'exchangeable') prior postulates that model parameters for the individual countries are similar within each panel. Specifically, the resulting posterior pools the information across countries belonging to the same exchange rate regime – thereby ensuring an efficient use of the data (Jarociński, 2010) – but allows coefficients to differ across countries.[5] Different from standard Panel VAR models, we thus allow for cross-subsectional heterogeneity (as in the case of country-by-country regressions). Below, we briefly describe the data and methodology, and then discuss the results of our baseline model.

2.1 Data

We use monthly data for 16 countries in the period covering 1999M1 to 2016M12.[6] Included in our baseline BPVAR model are the composite Purchasing Managers Index (PMI), which we use as a measure for real economic activity[7], 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

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

[6]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.

[7]The PMI is a survey-based measure of economic activity. The composite PMI measure used in our analysis is a GDP-weighted average of the manufacturing and service sectors, which takes into account business output, new orders, employment, costs, selling prices, exports, purchasing activity, supplier performance, backlogs of orders and inventories of both inputs and finished goods.

deviations from an HP-filtered trend, whereas the short-term interest rate is expressed in levels.[8] More details about the data series, their sources and transformations are given in Appendix A.

Following Bernoth et al. (2004), Uribe and Yue (2006), 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. As the base country may differ across countries, 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, it is removed from the corresponding panel (as its risk premium would be zero). Like the short-term interest rate, the long-term rate spread 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 PMI, 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 following De Santis (2012) and the oil price to capture global supply-side shocks, both in deviations from their corresponding HP-filtered trends.

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 1. In what follows, we refer to the two panels as *monetary union* (for regimes 1-12) and *floats* (for regimes 13-15).

2.2 Methodology

We estimate a *random effects model* for our two panels using Bayesian techniques and an hierarchical prior as developed by Jarociński (2010).[9] 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:

$$y_{j,t} = \sum_{i=1}^{p} A_j^i y_{j,t-i} + C_j x_t + D_j y_{b,t-1} + \varepsilon_{j,t}, \tag{1}$$

with $\varepsilon_{j,t} \sim \mathcal{N}(0, \Sigma_j)$ 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,

[8] In Appendix D, we show that the results are robust to different model specifications, using Industrial Production as an alternative measure for economic activity, and to using shadow rates from Krippner (2013) instead of short-term money market rates.

[9] See Appendix B for more details on the Gibbs sampler algorithm used for estimation.

Table 1: Exchange rate regime classification

Aggregate class		Reinhart and Rogoff (2011) classification
Monetary union	(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
Floats	(13)	Freely floating
	(14)	Freely falling
	(15)	Dual market in which parallel market data is missing

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 $B_j = \left[A_j^1, \ldots, A_j^p, C_j, D_j\right]'$ 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, $\beta_j \sim \mathcal{N}\,(b, \Sigma_b)$.[10] 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.[11] 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.[12] Based on the marginal data density, we use $p = 6$ lags.

[10] 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.

[11] 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.

[12] Ultimately, $\Sigma_b = (\lambda_1 \otimes I_q)\,\Omega_b$, where q denotes the number of coefficients to be estimated per country j 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

Table 2: The importance of risk premium shocks for economic activity

	Floats						*Monetary Union*									
	AU	**JP**	**NZ**	**SW**	**UK**	*Mean*	**AT**	**BE**	**FI**	**FR**	**IR**	**IT**	**NL**	**PT**	**ES**	*Mean*
Mean	0.05	0.11	0.04	0.12	0.12	0.09	0.05	0.06	0.01	0.04	0.12	0.12	0.02	0.2	0.12	0.08
Top 90%	0.3	0.52	0.14	0.33	0.33	0.32	0.09	0.06	0.03	0.07	0.2	0.30	0.12	0.29	0.28	0.16

Note: The table reports the average and top 90th percentile contribution (over time) of country risk premium shocks in explaining the variability of the endogenous variables in our Bayesian PVAR. 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, left panel) or Germany (for countries belonging to the euro area, right panel).

The matrix Y_j consists of our output measure PMI, $\tilde{y}^j$, 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) in line with Uribe and Yue (2006).[13] Our risk premium shocks thus reflect the variation in long term rate spreads that are not explained by the uncovered interest rate parity condition. Therefore, the Cholesky order is such that we allow country risk premia to react contemporaneously to all other variables in the VAR, whereas we assume that the other variables do not respond to risk premium shocks within the month.

2.3 Results

Historically, country risk premium shocks have – on average – contributed about 9% to output variability (as measured by the PMI) in developed countries as illustrated in Table 2, a figure that lies somewhat below those estimated for EMEs (see e.g. Uribe and Yue, 2006). While risk premium shocks may not be the main driver of economic activity, they can hardly be dismissed as

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).

[13] See Appendix D for results under alternative orderings.

negligible. The 90th percentile of the contribution of risk premium shocks to output variability is 16% on average for countries belonging to a monetary union using the German interest rate as the benchmark with notable differences across countries. That is to say, in one tenth of all months, risk premium shocks contributed more than 16% to output fluctuations. For floats with the US as benchmark, the respective number is even 32%.

In order to gauge the effects of risk premium shocks, Figure 1 shows the impulse responses of each panel's posterior median estimate of the mean model, i.e. the model for coefficients b, to a 100 basis point increase in the risk premium vis-à-vis Germany (panel a) and the US (panel b).[14] In each figure, the first row shows the mean response of the floats, while the second shows the mean response of the monetary union.

Focusing on the results with the German benchmark, 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).

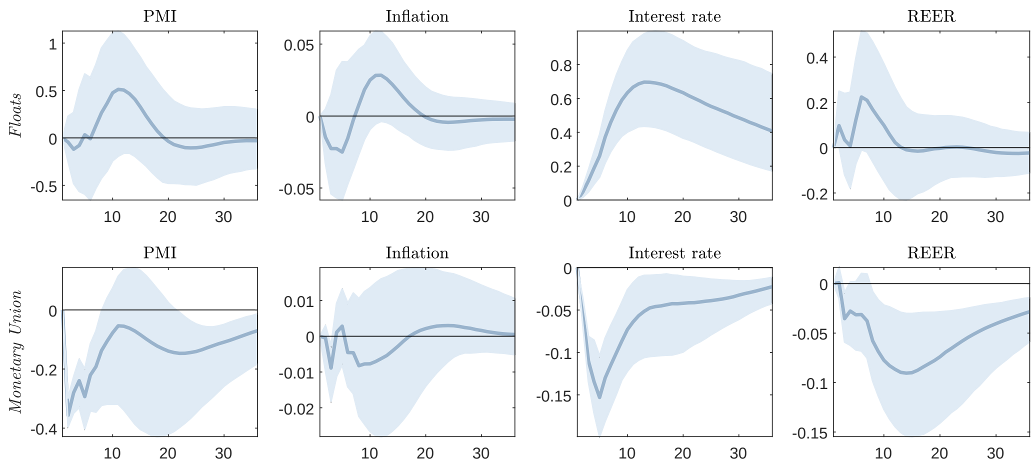
The difference between the PMI responses is less pronounced when we use the United States as the base country. This likely relates to a difference in the degree to which the two measures for the spread capture country-specific variation in risk premia for euro area economies. To the extent that euro area-wide shocks affect the interest rates of individual euro area countries in similar ways, these would have little effect on the spread of individual member states' interest rates with respect to the German rate. Therefore, the spread with the German benchmark is plausibly a cleaner measure of country-specific variation in interest rates within the euro area.

In our model, we show that in monetary union, the effect of country-specific risk premium shocks on output is amplified because the nominal intra-union exchange rate does not adjust. For shocks that are common to all countries of a monetary union, the nominal exchange rate of the common currency with respect to the rest of the world should adjust, much like it would in countries with a floating exchange rate, such that being in a monetary union could not explain differences in output responses conditional on common shocks.

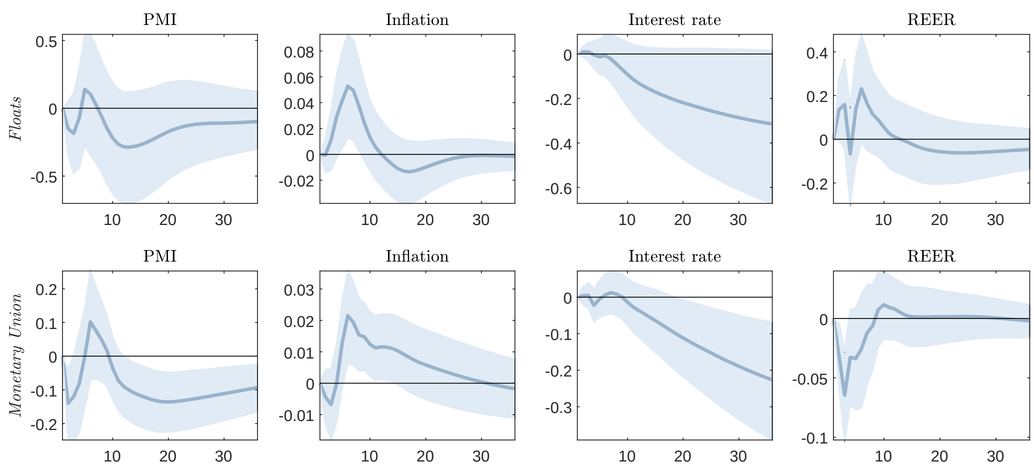
[14]Even though there are notable differences across countries in the extent to which risk premium shocks matter across countries as shown in the historical decomposition in Table 2, the responses to a risk premium shock of the same size are qualitatively and quantitatively similar across panels as shown in Appendix C. Moreover, in Appendix D, 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.

Therefore, if the spread with the German rate is indeed a cleaner measure of country-specific risk premium shocks, it is the better measure for testing the implication of our model that such shocks are contractionary in a monetary union. We also report results with the US benchmark because this is standard for countries outside the euro area.

Most of the other responses to a positive risk premium shock with the German benchmark are consistent with the implications of our theoretical model. In monetary union, the model implies that the real exchange rate depreciates, inflation and output decline, and the central bank responds by cutting the policy rate.[15] This is consistent with the empirical responses, with the nuance that the empirical decline in inflation is insignificant.

Furthermore, the model implies that under a floating exchange rate regime, an increase in the risk premium is associated with a real exchange rate depreciation that is sufficiently large in magnitude for it to imply an increase in inflation as well as in aggregate output.[16] In response, the central bank raises the policy rate. This is consistent with the positive empirical responses of PMI and interest rates for floats, although the PMI response is insignificant. For inflation, the sign of the empirical response is ambiguous.

Unlike in theory, in the data there is no real exchange rate depreciation for floats conditional on an increase in the risk premium. Limited availability of the trade balance of international capital flows at monthly frequency across our panel of 16 countries restricts us in further examining this result. One possible reason could be that, unlike in the model, the empirical evidence in support of the uncovered interest rate parity is limited owing to the fact that real exchange rate adjustments tend to be more gradual.

We now turn to a standard New Keynesian model to shed more light on the way risk premium shocks transmit to real activity.

[15] Note that the real exchange in the structural model reflects the real exchange rate of the countries within the monetary union and not with respect to the most important trading partners as in our empirical exercise. This difference may explain the stronger depreciation in the data, as REER adjustments within a monetary union tend to be more sluggish. As most trade in the euro area, however, occurs within the currency area, the trade-weighted real effective exchange rates used in the empirical exercise are broadly comparable to the theoretical counterparts.

[16] Similarly, the small open economy models of Garcia and González (2013) and Ali and Anwar (2022) imply that risk premium shocks can lead to an expansion in output through a strong depreciation of the real exchange rate.

3 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 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.

3.1 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, which are not traded internationally, earn a gross nominal return R_t^j, set by the (supra)national central bank, and are in zero-net supply, i.e. $\int_0^s B_t^H(h)\, dh = 0$ and $\int_s^1 B_t^F(f)\, df = 0$, with h and f the index for Home and Foreign households. These domestic bonds allow households to smooth consumption over the business cycle. The return on (or carrying cost of) internationally traded bonds is given by $R_{d,t}$. Having access to internationally traded bonds allows the household to insure (albeit incompletely) against country-specific aggregate shocks. Moreover, allowing for the possibility of agents to engage in international lending and borrowing is consistent with the observation that many (developing and advanced) economies run (sometimes large and persistent) external debt positions and current account imbalances. In what follows, 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

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

where P_t^j denotes the consumer price index of country j, e_t the nominal exchange rate, defined as the Foreign currency price of one unit of Home currency, and $\tau_{l,t}^H$ lump-sum taxes paid to the home government. 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:

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

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

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

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.[17]

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:

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

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,

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

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 country-specific 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

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

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

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:

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

3.2 Monetary and fiscal 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:[18]

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

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

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

3.3 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 E), the following goods market clearing condition 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 (country-specific) 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, subject to (18) and (19), the discounted sum of current and future expected firm profits, and is given by:

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

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 $\mathcal{Q}^j_{t,t+k}$ the stochastic discount factor of households living in country j.

Finally, the Home balance of payments conditions, which pins down the dynamics of internationally traded bonds, is derived by consolidating the budget constraints of the household and government, and using the profit condition of the firm, i.e. $\mathcal{P}^H_t = P_{H,t} y^H_t - W^H_t n^H_t$:

$$q_t^{-1} d_t = q_t^{-1} \left(1 + \tau_{t-1}\right) \frac{R_{d,t-1}}{\pi^F_t} d_{t-1} - \left(\gamma_{H,t} y^H_t - \gamma_{H,t} g^H_t - c^H_t + \mathcal{T}_t\right). \tag{22}$$

3.4 Steady state and calibration

To solve the model, we use perturbation methods, taking either 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 in logs:

$$\ln z_{\xi,t} = \rho_\xi \ln z_{\xi,t-1} + \varepsilon_{\xi,t}, \tag{23}$$

$$\ln z^j_{D,t} = \rho_D \ln z^j_{D,t-1} + \varepsilon^j_{D,t}, \tag{24}$$

$$\ln z^j_{A,t} = \rho_A \ln z^j_{A,t-1} + \varepsilon^j_{A,t}, \tag{25}$$

with $\{\rho_\xi, \rho_D, \rho_A\} \in [0,1)$, $\varepsilon_{\xi,t} \sim \mathcal{N}\left(0, \sigma^2_\xi\right)$, $\varepsilon^j_{D,t} \sim \mathcal{N}\left(0, \sigma^2_D\right)$ and $\varepsilon^j_{A,t} \sim \mathcal{N}\left(0, \sigma^2_A\right)$. Note that changes in $z_{\xi,t}$, $z^j_{D,t}$ and $z^j_{A,t}$ are immediately observed by all agents once they occur, yet future realizations of $\varepsilon_{\xi,t}$, $\varepsilon^j_{D,t}$ and $\varepsilon^j_{A,t}$ are random and cannot be predicted.

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 (see e.g. Galí and Monacelli, 2005). For our purposes, key parameters are the risk premium elasticity, χ, and the elasticity of the debt tax with respect to external indebtedness, ψ. We set the risk premium elasticity to 0.001, which is comparable to the figure used by Schmitt-Grohé and Uribe (2003). We consider a range of values for ψ, between 0 and 0.1, to evaluate the macroeconomic and welfare implications of implementing the debt tax. 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.

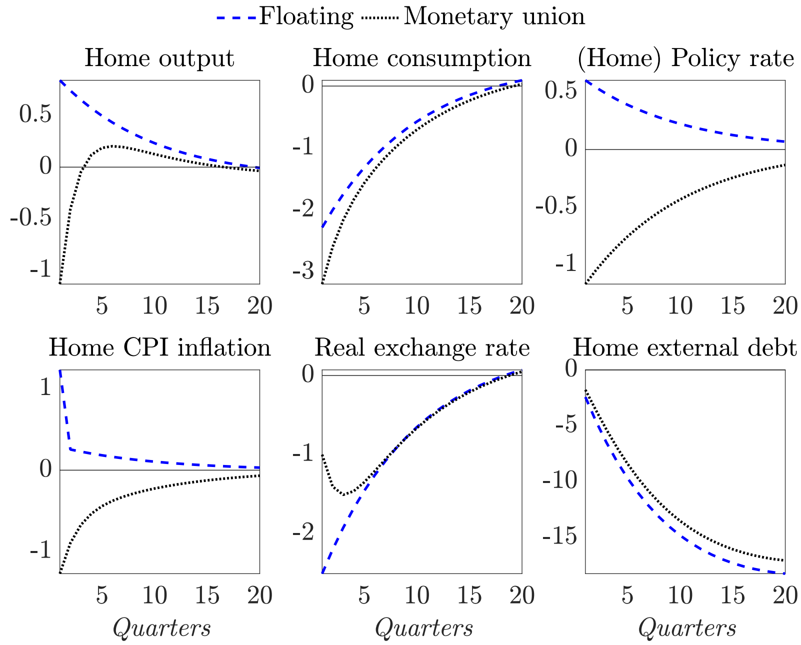
4 Risk premium shocks and capital controls

4.1 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)

Figure 2: Impulse responses to a risk premium shock



Note: Responses are in percent deviations from steady state.

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 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 disagree 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.[19] 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

[19] As discussed by Farhi and Werning (2014*b*), among others, allowing for cross-border labor mobility may partially mitigate the negative macroeconomic effects of the risk premium shock, as migration out of a depressed country increases domestic employment, income and consumption. However, cross-border labor mobility has historically been relatively small in the euro area as compared to e.g. the US (Bonin et al., 2008), suggesting that this adjustment mechanism is less relevant in the euro area.

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 shows 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. One reason might be that, while our theoretical model assumes that the exchange rate regime is the only dimension in which countries differ from one another, in the data, cross-country differences other than the exchange rate regime might also contribute to the differences in the responses to risk premium shocks between the set of countries with flexible exchange rates and that of EMU members.

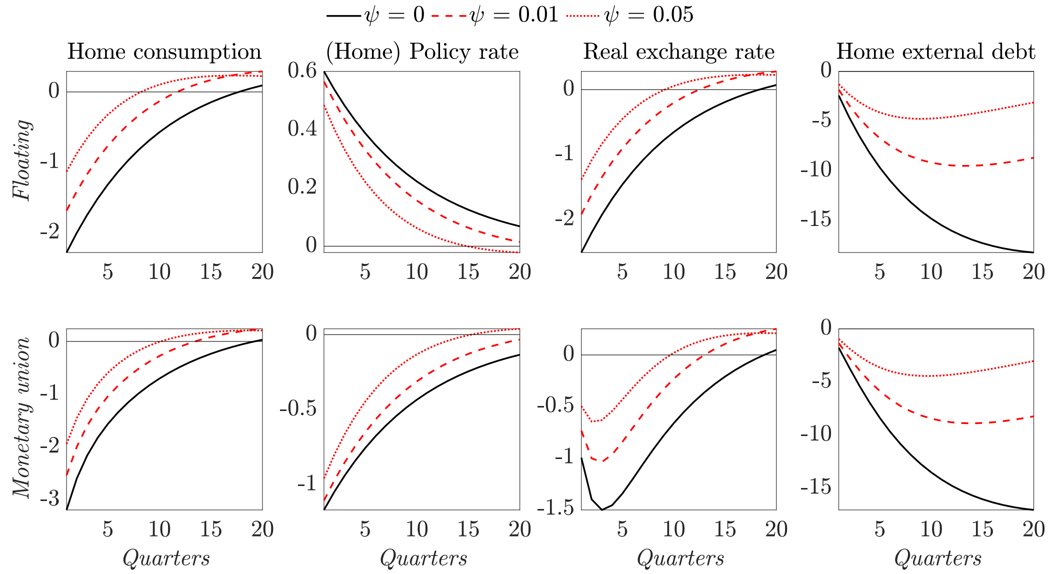
In sum, the impulse response functions suggest that risk premium shocks discourage private consumption as they raise the cost of external borrowing. The corresponding outflow of capital results in a real exchange rate depreciation which, in itself, is inflationary. The monetary policy response to the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

4.2 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 the willingness to borrow abroad.

Furthermore, the fall in the tax generates downward pressure on the real exchange rate, causing

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



Note: Responses are in percent deviations from steady state.

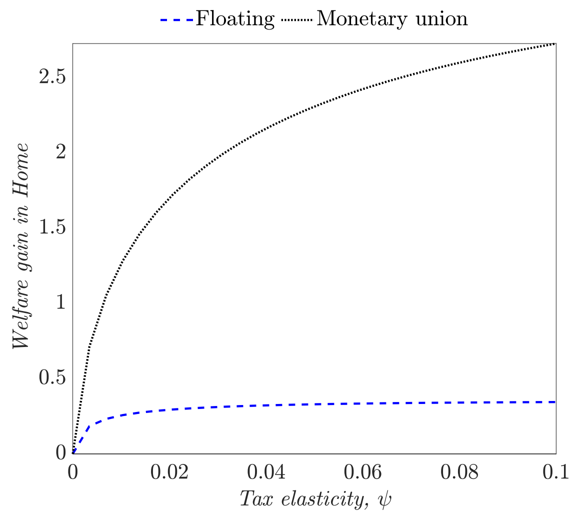
the response of the real exchange rate to also be more attenuated. Technically, this result arises from the UIP condition, which is repeated here for convenience:

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

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*a*).

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

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



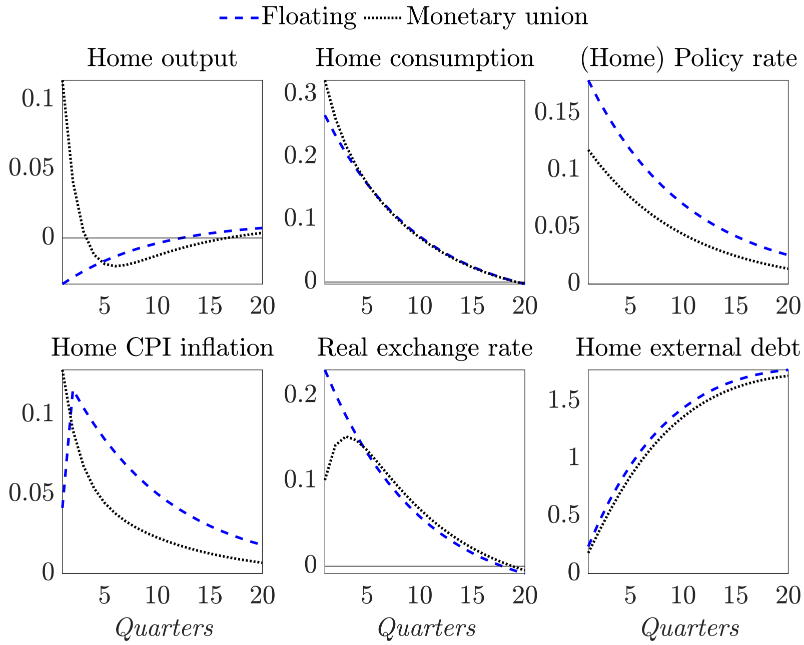
Note: Welfare units are measured in consumption perpetuities (i.e. the perpetual increase in consumption as a percentage of steady-state consumption). Welfare gain derived by comparing welfare outcomes against a baseline scenario in which $\psi = 0$.

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 depend 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*a*, 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

Figure 5: Impulse responses to a demand shock



Note: Responses are in percent deviations from steady state.

union. As $s \to 1$, and Home behaves more like a closed economy, the welfare benefits of the tax vanish.

4.3 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. 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 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.

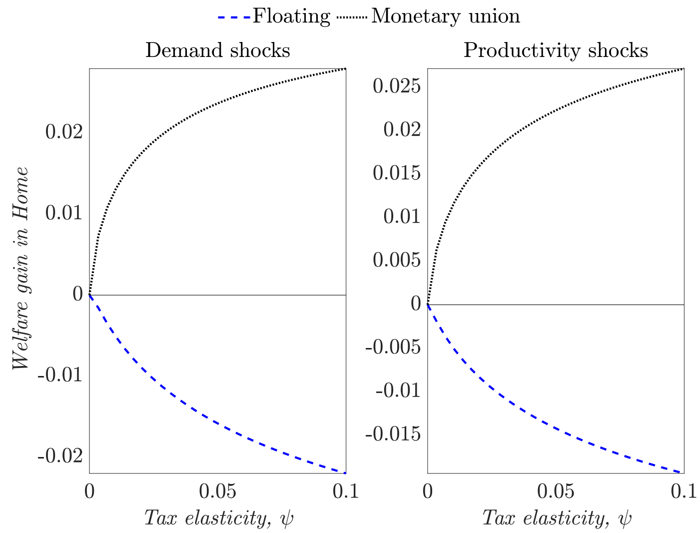
Introducing a dynamic tax on external debt when facing demand shocks is welfare enhancing under monetary union, yet *reduces* welfare under flexible exchange rates given our benchmark calibration (see Figure 6, left panel). In contrast to the case in which the economy is hit by a risk premium shock, 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

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



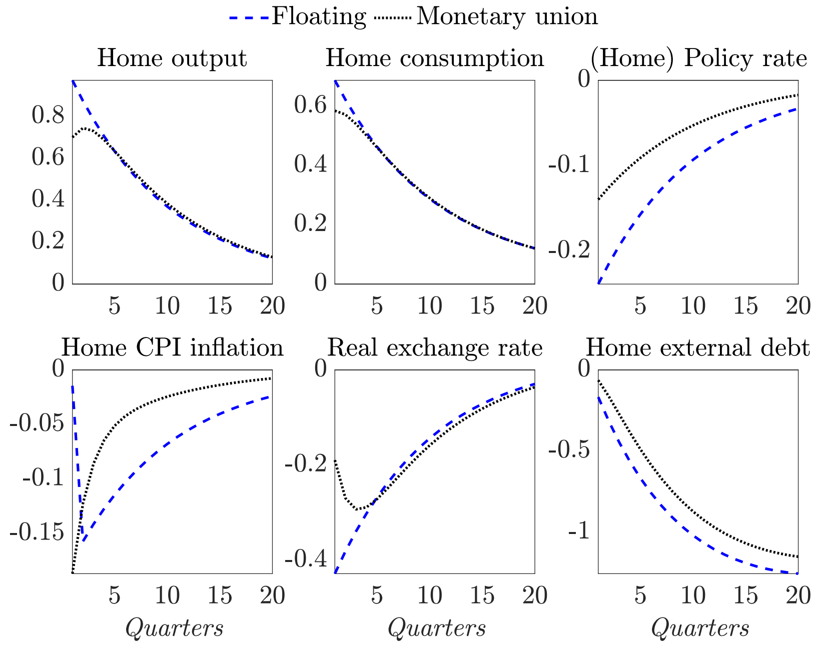
Note: Welfare units are measured in consumption perpetuities. Welfare gain derived by comparing welfare outcomes against a baseline scenario in which $\psi = 0$.

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 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

Figure 7: Impulse responses to a productivity shock



Note: Responses are in percent deviations from steady state.

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 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 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,

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

which is why imposing such a tax is welfare enhancing.

4.4 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.

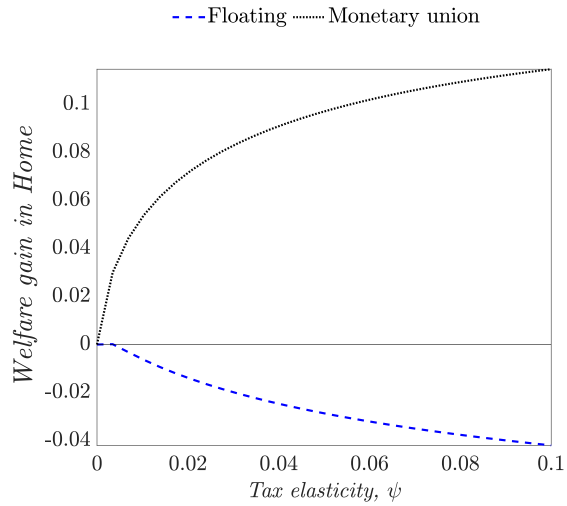
Risk premium shocks that lead to an outflow of capital result in a fall in the tax on external debt. By the UIP condition, the lower tax leads to an appreciation of the real exchange rate, which in turn lowers inflation. The real exchange rate response induces monetary policy to lower the interest rate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

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 2.

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 2. 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.

5 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 Vectoraautoregression 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

	US as benchmark				GER as benchmark			
Floats	**Mean**	**Std**	**Min**	**Max**	**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.[20] 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.[21] 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.

[20] 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.

[21] 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 $\beta^{(0)} = \left\{\hat{\beta}_1, \hat{\beta}_2, \ldots, \hat{\beta}_N\right\}$, 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

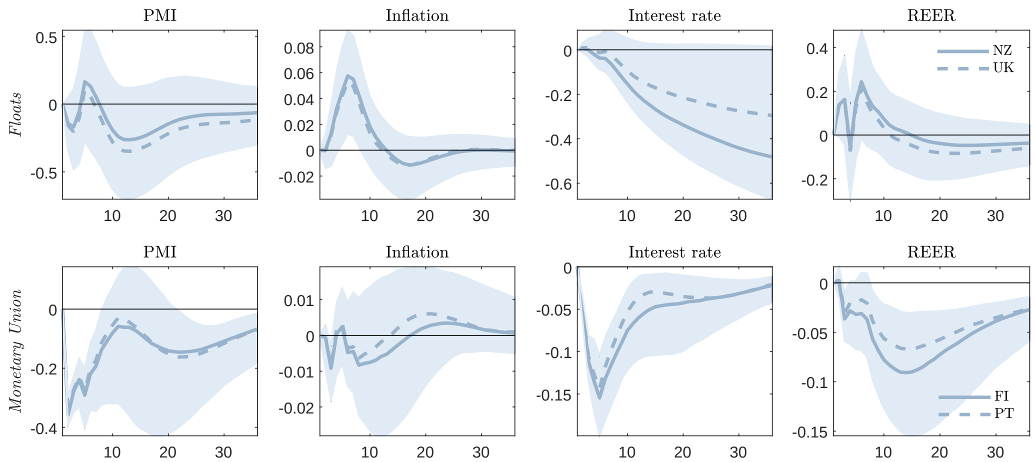
$$\tilde{S}_j = \left(Y_j - X_j B_j^{(n)} \right)' \left(Y_j - X_j B_j^{(n)} \right).$$

This concludes the algorithm.

C Heterogeneous effects across countries

Figure 1 summarize the countries' IRFs to a risk premium shock by using the mean model for each panel. While the dynamics with respect to a risk premium shock are similar across countries within each panel, country risk premium shocks were more important in explaining PMI dynamics in some countries relative to others as shown in the historical decomposition of Table 2. To highlight this cross-country heterogeneity in the responses, 9 shows the IRFs to a country risk premium shock for the two countries of each panel with, respectively, the lowest (solid) and highest (dashed) relevance of risk premium shocks in the historical decomposition of PMI. These countries are Finland and Portugal for the monetary union, and New Zealand and the UK for the floats. As evident from the Figure, the responses to a risk premium shock are very similar across countries within each panel, highlighting that the differences in relevance across countries was triggered by the magnitude of the shocks rather than their amplification.

Figure 9: Impulse responses to a positive risk premium shock



Note: The figures show the posterior median impulse response functions of the country with the lowest (solid) and highest (dashed) historical relevance of risk premium shocks in explaining real activity to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis Germany in case of a monetary union and the US for the floats, respectively. The shaded area reflects the 5%-95% credibility intervals of the panel model.

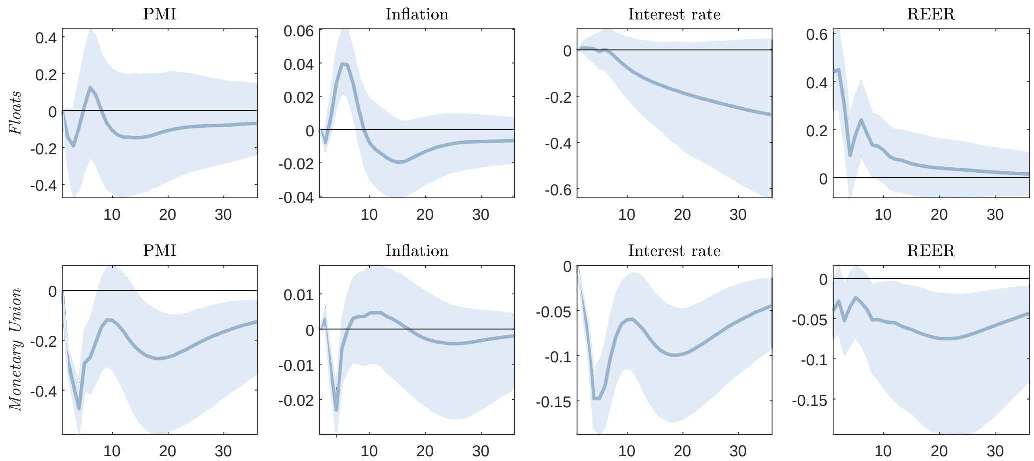
D Robustness of the empirical results

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 of Industrial Production as an alternative measure of economic activity to PMI, 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.

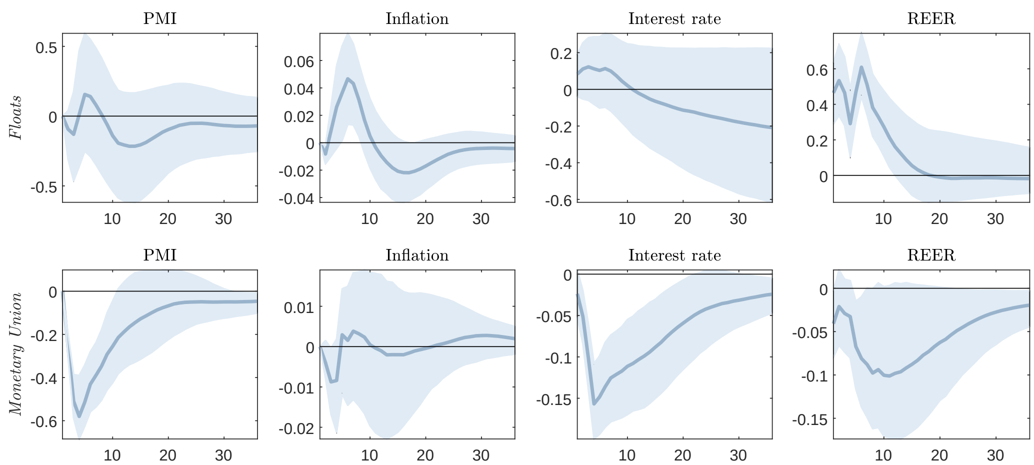
First, we *change the order of the variables* in the model. In Figure 10, panel *a*, we place the risk premium *fourth*, rather than last as in the baseline, and the REER last, while we keep the−arguably less controversial−order for output, inflation and the short-term interest rate unaltered. For the 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 10: Impulse responses to a risk premium shock: different ordering of variables

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



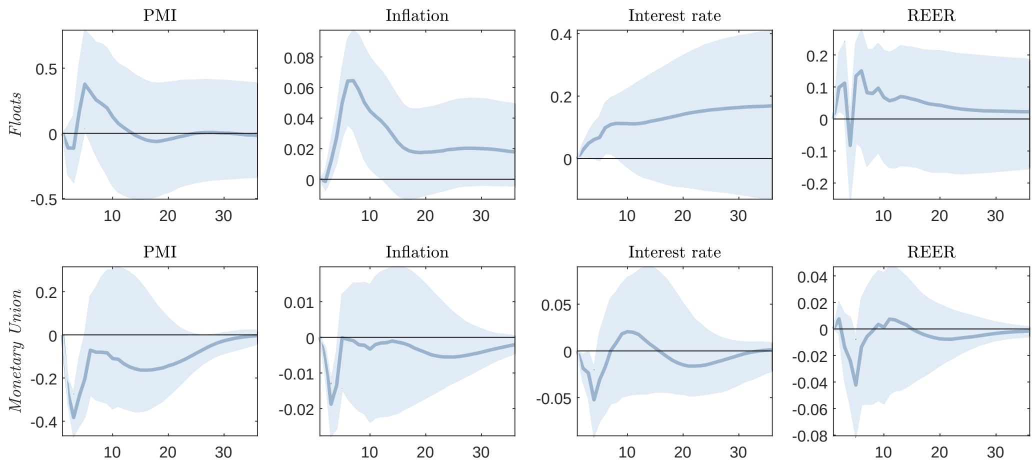
b Ordering: $\tilde{y}_t$, $\tilde{\pi}_t$, ξ_t, R_t and $\tilde{q}_t$



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 11 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 11: Impulse responses to a risk premium shock: including additional controls

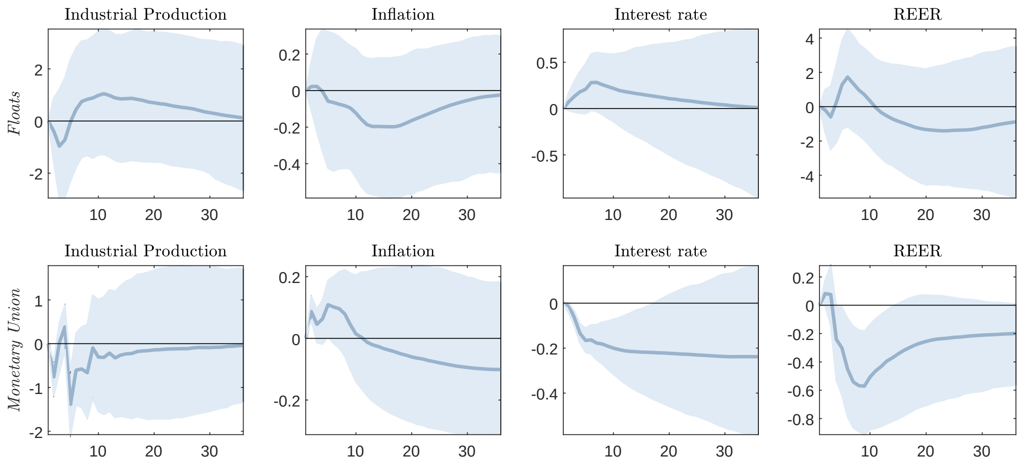


Note: The figure shows the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the US (top row) or Germany (bottom row). In the figure, the top row shows the responses for the floats, while the bottom row shows 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.

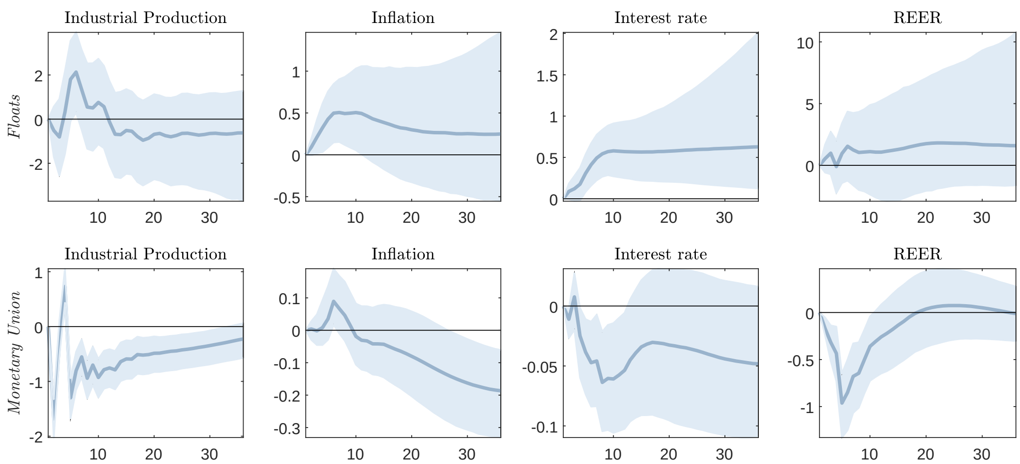
Next, Figure 12 shows the impulse responses when using year-on-year growth rates of *Industrial Production* as alternative measures for economic activity. Despite a somewhat larger estimation uncertainty, the impulse responses confirm our previous results that a risk premium shock is contractionary only under monetary union.

Figure 12: Impulse responses to a risk premium shock: using Industrial Production

a Base country = Germany



b Base country = US

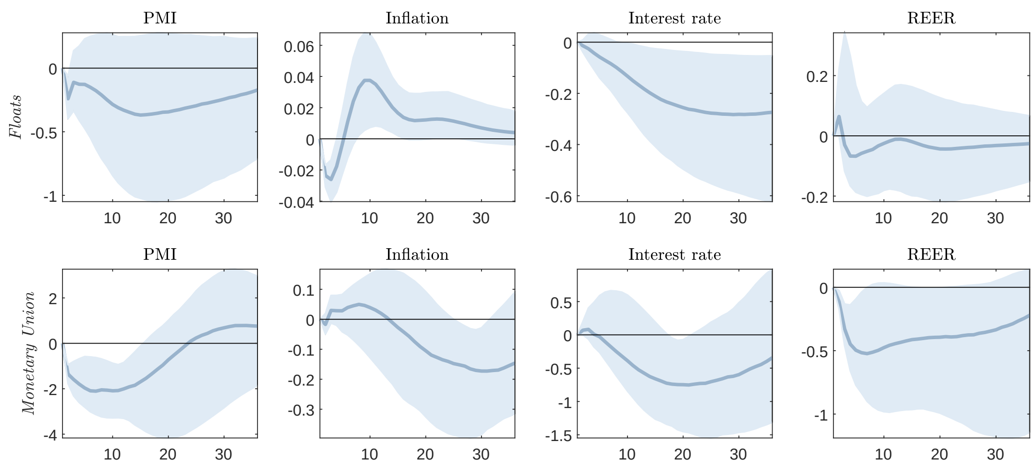


Note: The figures show the posterior median impulse response functions of the mean model to a 100 basis points increase in the long-term sovereign bond spread vis-à-vis the Germany (top panel) and the US (bottom panel). Industrial production, CPI inflation and the REER are measured as year-on-year growth rates. The shaded area reflects the 5%-95% credibility intervals.

One may wonder whether our results are solely driven by the euro area sovereign debt crisis episode during which risk premia were above average. Figure 13, 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.[22]

[22]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.

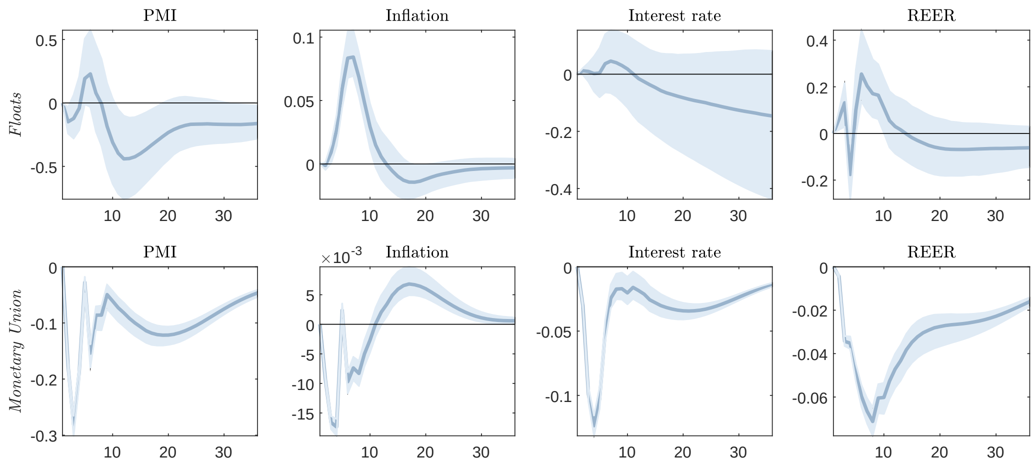
Figure 13: Impulse responses to a risk premium shock: shorter sample, excluding the Great Recession and sovereign debt crisis



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 the 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.

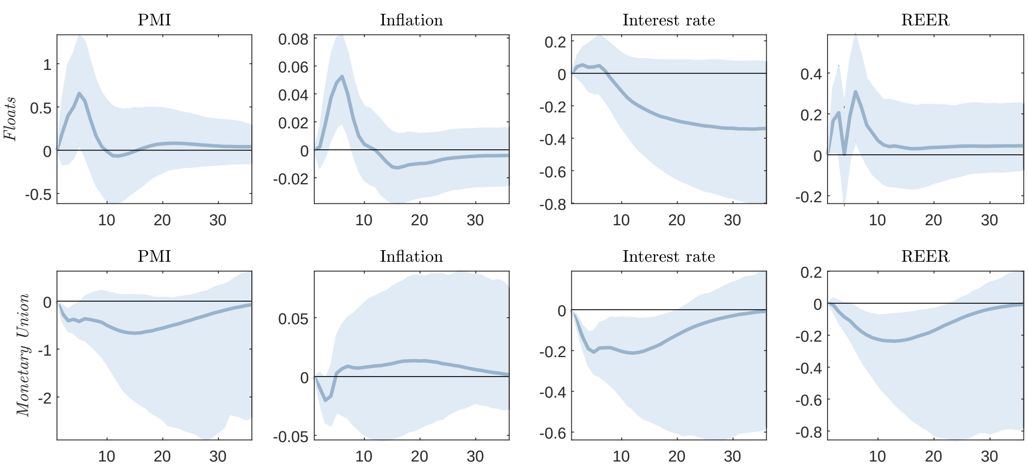
The impulse responses of the two extreme cases of our model are shown in Figures 14 and 15. In particular, Figure 14 plots the responses of a *homogeneous panel*, i.e. $\lambda_1 = 0$, while Figure 15 plots the mean responses of *country-by-country regressions*. Comparing both figures illustrates the 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 14, 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 14: 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.

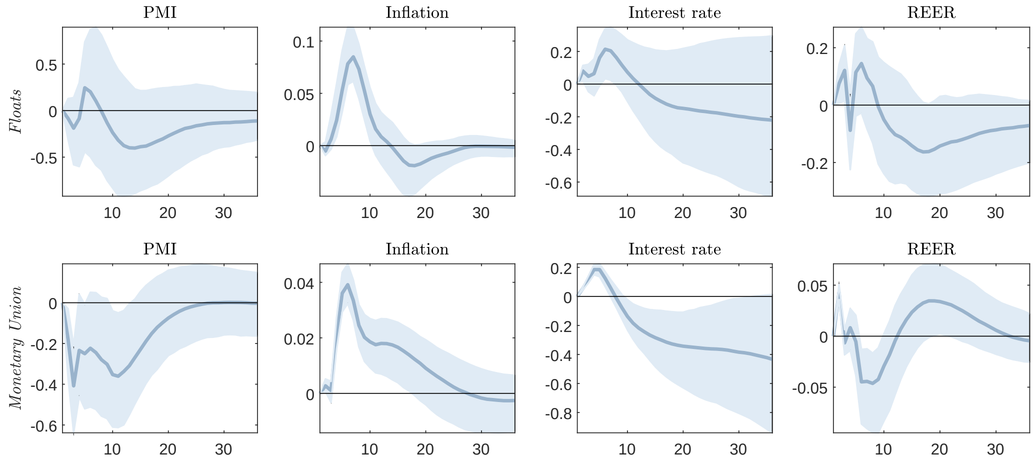
Figure 15: IRFs to a risk premium shock: Mean response of country-by-country regressions



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, the impulse responses are not biased by the ELB either. Specifically, when we include the shadow rates estimated by Krippner (2013) instead of the short-term interest rates for the euro area, Japan, the UK and the US, we continue to find a contractionary effect of risk premium shocks

Figure 16: IRFs to a risk premium shock: Using shadow rates



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 the figure, the top row shows the responses for the floats, while the bottom row shows the responses for monetary union. Krippner (2013) shadow rates are used for the euro area, Japan, the US and the UK. The shaded area reflects the 5%-95% credibility intervals.

only under monetary union as shown in Figure 16.

E 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:

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

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

$$P_{H,t} = \left(\frac{1}{s} \int_{0}^{s} P_{H,t}(h)^{1-\epsilon}\, dh\right)^{\frac{1}{1-\epsilon}}, \qquad P_{F,t} = \left(\frac{1}{1-s} \int_{s}^{1} P_{F,t}(f)^{1-\epsilon}\, df\right)^{\frac{1}{1-\epsilon}}.$$