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Financial Heterogeneity and Monetary Union

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Abstract

During the 2010–12 eurozone crisis, deviations of price and wage dynamics from those implied by canonical Phillips curves were systematically related to differences in financial strains across countries. Most notably, markups in financially "weak" (periphery) countries rose, while those in financially "strong" (core) countries declined. In a monetary union model, where financial frictions interact with the firms' pricing decisions because of customer-market considerations, firms in the periphery maintain cashflows in response to an adverse financial shock by raising markups in both domestic and export markets, while firms in the core reduce markups, undercutting their financially constrained competitors to gain market share. In this framework, a unilateral fiscal-devaluation-style policy by the periphery stabilizes the local economy by improving the condition of firm balance sheets and by boosting household demand—it does not, however, reverse the real exchange rate appreciation in the periphery.

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1 Introduction

In a monetary union, adjustments to country-specific financial shocks—absent labor mobility or common fiscal policy—have to take place primarily through the depreciation of the overvalued real exchange rate of the country hit by the shock vis-à-vis the other countries in the union. In the euro area, such adjustment occurred very slowly in response to the acute financial distress that emerged in March of 2010, when eurozone investors lost trust in the so-called periphery countries, precipitating a sharp pullback of private capital from the region.[1] Although the periphery subsequently endured notable disinflation, a considerable gap between the general level of prices in the core and periphery persisted during the ensuing sovereign debt crisis and its aftermath. As a result, real effective exchange rates in the periphery remained persistently above those of the core euro area countries, impeding the necessary economic adjustments.

What economic forces were responsible for such a slow adjustment in the price levels between the core and periphery, as the latter experienced a prolonged period of financial distress? Why were firms in the periphery, given the degree of resource underutilization in these economies, so slow to cut prices? By the same token, why were firms in the core reluctant to increase prices, despite a gradual improvement in the economic outlook and highly stimulative monetary policy? In fact, some prominent commentators argued that core countries "exported" deflationary pressures into the periphery, a dynamic contrary to that needed to reverse the real exchange rate appreciation that eroded the periphery's competitiveness (see Krugman, 2014).

To help answer these questions, this paper introduces financial frictions and customer markets—markets in which a customer base is "sticky" and thus an important determinant of firm's assets and its ability to generate profits—into the conventional international macroeconomic framework. Specifically, we augment the canonical two-country DSGE model featuring nominal price and wage rigidities, segmented labor markets, and incomplete risk sharing with two new assumptions: (*i*) firms operate in customer markets, both domestically and abroad; and (*ii*) foreign and domestic financial markets are subject to a differing degree of distortion.

We show that in such an environment firms from the core—that is, firms with a relatively unimpeded access to external finance—have a strong incentive to expand their market share at home and abroad by undercutting prices charged by their periphery competitors, especially when the latter are experiencing financial distress. By contrast, firms from the periphery have an incentive to increase markups in order to preserve internal liquidity, even though doing so means forfeiting some of their market share in the near term.

The notion that firms operating in customer markets and facing potential financing constraints set prices to actively manage current versus expected future demand is not new to macroeconomics (see Gottfries, 1991; Chevalier and Scharfstein, 1996). More recently, Gilchrist et al. (2017) have shown that the interaction of customer markets and financial frictions can fundamentally alter inflation and output dynamics in a closed-economy New Keynesian framework. In the international

[1] The paper uses the following definition of the euro area core and periphery. Core countries: Austria, Belgium, Finland, France, Germany, and Netherlands. Periphery countries: Greece, Ireland, Italy, Portugal, and Spain.

context, the pricing mechanism engendered by this interaction generates time-varying markups and import price dynamics that differ fundamentally from those in the standard literature.[2] Specifically, this literature shows that following an adverse exchange rate shock, firms do not fully pass the resulting cost increase into import prices, but instead absorb some of the shock in their profits by *lowering* markups. In our model, by contrast, financially constrained firms, when hit by adverse shocks, try to maintain their cashflows by *increasing* markups in both domestic and export markets, in effect trading off future market shares for current profits.

The interplay of customer markets and financial frictions thus helps explain several aspects of the eurozone financial crisis that are difficult to reconcile using standard models. Most importantly, the pricing mechanism implied by this interaction is consistent with our empirical evidence, which shows that the acute tightening of financial conditions in the euro area periphery between 2008 and 2013 significantly attenuated the downward pressure on prices arising from the emergence of substantial and long-lasting economic slack. Aggregate and sectoral data further show that the tightening of financial conditions during this period is strongly associated with a notable increase in markups in the eurozone periphery, which is exactly the pattern predicted by our model.

Our framework, therefore, can help explain why the periphery countries have managed to avoid a potentially devastating Fisherian debt-deflation spiral in the face of massive and persistent economic slack and high levels of indebtedness. It also helps us understand the chronic stagnation in the euro area periphery and how the "price war" between the core and periphery impeded the adjustment process through which the latter economies tried to regain external competitiveness. As such, the interaction of customer markets and financial frictions provides a complimentary economic mechanism to the work of Schmitt-Grohé and Uribe (2013, 2016), who emphasize the fact that nominal wages in the eurozone periphery failed to adjust downward after 2008 despite a significant increase in unemployment.

In terms of macroeconomic stabilization policy, the union's central bank—faced with divergent economic trajectories between the core and periphery in the wake of an asymmetric financial shock—faces a well-known dilemma: Because monetary policy cannot be targeted to just one region, the central bank is unable to stabilize the union-wide economy. In such situations, fiscal-devaluation-style policies, which overcome the "one-size-fits-all" feature of monetary policy, can offer an effective way to countervail the asymmetric effects of a financial shock. Most importantly, such policies can be implemented unilaterally by the periphery countries encountering economic weakness—for example, by providing a wage subsidy to financially distressed firms, financed in a revenue-neutral fashion with a value-added tax (VAT). In fact, these types of targeted policies received considerable attention during the eurozone crisis.[3]

In our setup, a unilateral fiscal-devaluation-style policy is also an effective macroeconomic stabilization tool, though it does not a induce nominal devaluation of the periphery vis-à-vis the core.

[2] See Dornbusch (1987); Yang (1997); Bergin and Feenstra (2001); Atkeson and Burstein (2008); Gopinath and Itskhoki (2010a,b); Burstein and Gopinath (2014); Auer and Schoenle (2016).

[3] Adao et al. (2009) and Farhi et al. (2014), for example, explore the stabilization properties of certain fiscal policy mixes intended to replicate the effects of a nominal depreciation in a fixed exchange rate regime.

Rather, the policy has two effects. First, the wage subsidy to financially distressed firms in the periphery alleviates the pressure on their balance sheets. The resulting improvement in internal liquidity causes firms in the periphery to increase markups and prices by significantly less, mitigating the loss of market shares domestically and abroad; at the same time, the imposition of the VAT to finance the wage subsidy increases prices charged by firms from the core in their export market, which lessens the effects of their "predatory" pricing behavior in the periphery. Second, consumption in the periphery declines less as the wage subsidy—by stabilizing hours worked—supports household income. In combination, the two effects limit the economic contraction in the periphery, while also causing the real exchange rate of the periphery vis-à-vis the core to appreciate. The latter result is consistent with Erceg et al. (2023), who analyze the short-term macroeconomic effects of trade policies in the standard New Keynesian open-economy framework.

Finally, a fiscal-devaluation-style policy turns out to have a new, desirable feature from a political economy angle. In particular, such a policy can be desirable not only from the periphery's perspective, but also from that of the core because it forces foreign firms to take into account the adverse effect of their pricing behavior on aggregate demand. In general, as shown by Farhi and Werning (2016), distortionary taxation can help agents internalize such externalities. In our model, fiscal devaluations provide an effective means of achieving this goal.

2 Financial Conditions, Prices, Wages, and Markups

This section documents how changes in financial conditions influenced the dynamics of prices, wages, and markups in the eurozone core and periphery during the 2008–2013 period.

We begin by showing that price and wage inflation forecast errors implied by the canonical Phillips curve relationships during this period are systematically related to differences in the tightness of financial conditions between the two regions. We do so in two steps. First, we use a panel of euro area countries to estimate the following two Phillips curve specifications:

$$\pi_{i,t} = \alpha_i + \rho\pi_{i,t-1} + \lambda(u_{i,t} - \bar{u}_{i,t}) + \phi\Delta\text{VAT}_{i,t} + \mathbb{1}[i \in €] + \epsilon_{i,t}; \quad (1)$$

$$\pi^w_{i,t} = \alpha_i + \rho\pi_{i,t-1} + \lambda(u_{i,t} - \bar{u}_{i,t}) + \phi\Delta\tilde{z}_{i,t} + \mathbb{1}[i \in €] + \epsilon_{i,t}, \quad (2)$$

where i indexes countries and t represents time (in years).[4] In terms of notation, $\pi_{i,t}$ denotes price inflation measured by the log-difference of the GDP price deflator, while $\pi^w_{i,t}$ denotes wage inflation measured by the log-difference of nominal compensation per employee.

These two specifications are the textbook price and wage Phillips curves, which assume that inflation expectations are proportional to past inflation and where labor market tightness—measured by the difference of the unemployment rate $u_{i,t}$ from its corresponding natural rate $\bar{u}_{i,t}$—is a fun-

[4]The panel includes six core countries (Austria, Belgium, Finland, France, Germany, and Netherlands) and five periphery countries (Greece, Ireland, Italy, Portugal, and Spain); together, these 11 countries account for about 95 percent of the eurozone's total economic output. The annual macroeconomic data for these countries were obtained from the AMECO database maintained by the European Commission.

damental determinant of price and wage dynamics.[5] As a robustness check, we also consider a New Keynesian variant of the Phillips curve (NKPC), which incorporates into the process of price inflation determination both rational expectations as well as more explicit microfoundations (see Galí and Gertler, 2000; Galí et al., 2001). In that case, we estimate,

$$\pi_{i,t} = \alpha_i + \beta_f E_t \pi_{i,t+1} + \beta_b \pi_{i,t-1} + \lambda \widehat{mc}_{i,t} + \phi \Delta \text{VAT}_{i,t} + \mathbb{1}[i \in €] + \epsilon_{i,t}, \tag{3}$$

where $\widehat{mc}_{i,t}$ denotes a proxy for marginal cost. In the baseline specifications, the coefficients of all three Phillips curves are allowed to differ between the periphery and core countries. For specifications (1) and (2), we also consider an alternative specification in which the coefficient on the unemployment gap (λ) is allowed to differ across countries.

Our interest is not in the details of the Phillips curve estimates per se (see Table A-1 of Appendix A). Rather, we are interested in whether deviations of actual price and wage inflation from the trajectories implied by these relationships are systematically related to differences in the tightness of financial conditions across countries during the crisis. To test this hypothesis, we use spreads on sovereign credit default swap (CDS) contracts to measure the degree of financial strain in each country.[6]

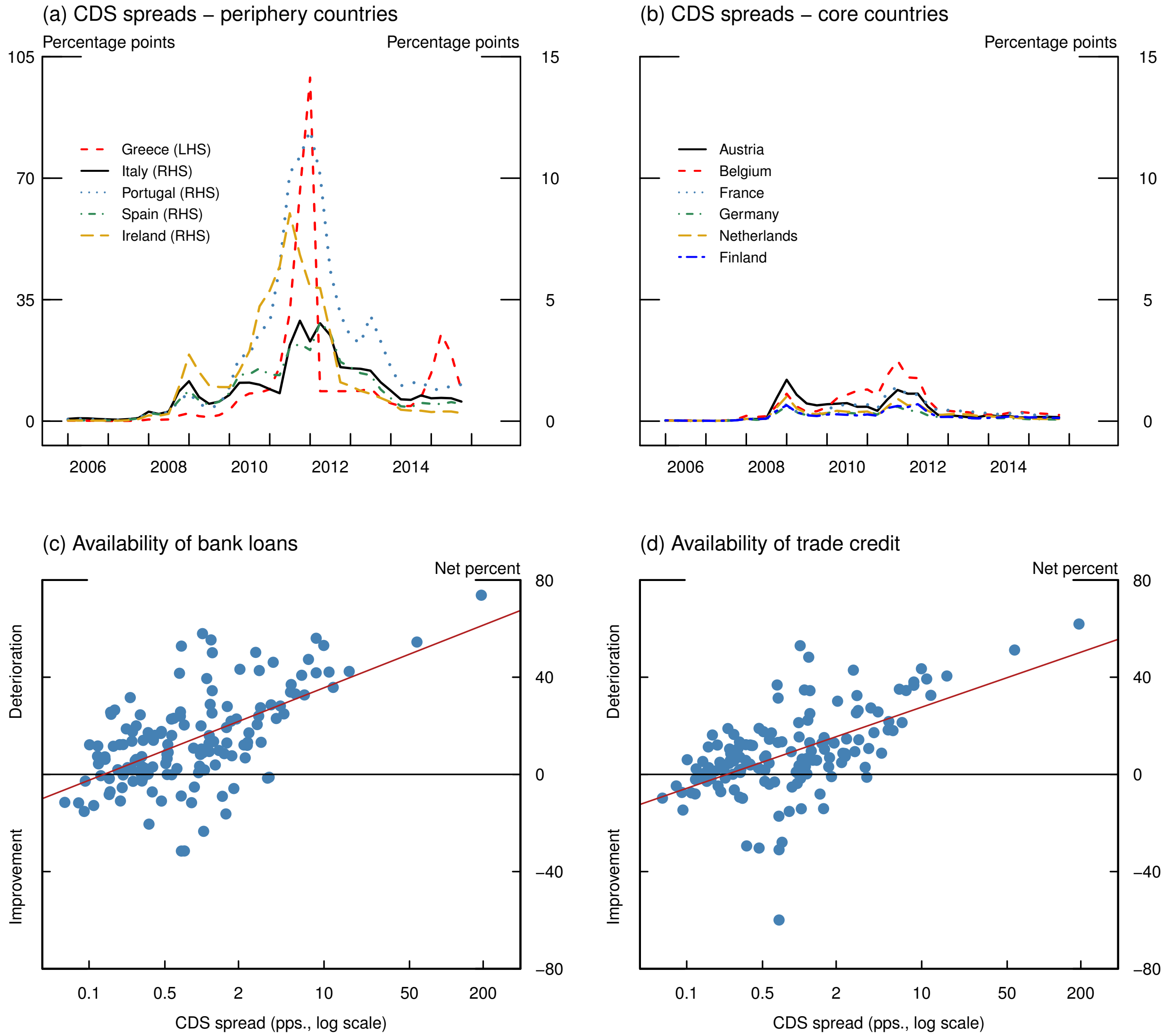
Panels (a) and (b) of Figure 1 show the evolution of five-year sovereign CDS spreads—the most liquid segment of the credit derivatives market—in the euro area from 2006 to 2015. Clearly evident is the massive tightening of financial conditions in the eurozone periphery (panel (a)) compared with the core (panel (b)): First in 2008, as the escalating financial turmoil in the U.S. led to investors' widespread reassessment of risks globally; and then again in 2010, when a growing recognition of an unsustainable fiscal situation in Greece led to a massive outflow of private capital from the periphery.

Panels (c) and (d) show that during the crisis, sovereign CDS spreads were highly informative of the tightness of credit conditions faced by nonfinancial firms in the eurozone. Using results from the ECB's firm-level Survey on the Access to Finance by Enterprises (SAFE) for the same 11 countries, we find a strong positive association between sovereign CDS spreads and the net percentage of respondent firms that indicated that the availability of financing through banks or trade credit has deteriorated over the subsequent six months. These findings are consistent with the evidence of Gilchrist and Mojon (2018), who document a strong relationship between sovereign risk and credit spreads on bonds issued by financial institutions in the euro area countries; they are also consistent

[5] In addition to a country fixed effect α_i, the two specifications also include $\mathbb{1}[i \in €]$, a 0/1-indicator that equals one when country i adopts the euro and thereafter. The price Phillips curve (1) also controls for the pass-through of changes in the effective VAT rate ($\Delta\text{VAT}_{i,t}$) to aggregate price inflation. The wage Phillips curve (2) includes the growth rate of trend labor productivity ($\Delta\tilde{z}_{i,t}$), thereby allowing for a link between real wage bargaining and labor productivity (see Blanchard and Katz, 1999); trend labor productivity is estimated by regressing the log of labor productivity on a constant and a third-order polynomial in time.

[6] As emphasized by Lane (2012), the European sovereign debt crisis originated over concerns related to the solvency of national banking systems in the periphery. Accordingly, sovereign CDS spreads provide an accurate gauge of pressures faced by the national banking systems in the eurozone during the crisis. Given the bank-centric nature of the euro area, variation in CDS spreads should thus reflect differences in the tightness of financial conditions faced by businesses and households in different countries.

Figure 1: Sovereign CDS Spreads and Credit Conditions in the Euro Area



Note: Panels (a) and (b) depict sovereign (5-year) CDS spreads on euro-denominated contracts; each series is a quarterly average of the available daily quotes. Panels (c) and (d) show the relationship between sovereign CDS spreads and the net percentage of survey respondents in our sample of 11 countries, indicating that the availability of financing (through banks or trade credit) has improved/deteriorated over the subsequent six months. Country-specific survey results are available at a semi-annual (March and October) frequency, starting in October 2009.

with evidence of a direct transmission of sovereign risk to corporate borrowing costs during the eurozone sovereign debt crisis provided by Augustin et al. (2018).

To gauge the effects of these financial strains on price and wage dynamics, we first use the estimated Phillips curves to generate price and wage inflation prediction errors from 2008 to 2013. In the second step, we estimate the following regression:

$$\hat{\epsilon}_{i,t} = \theta_0 + \theta_1 \ln \mathrm{CDS}_{i,t-1} + \theta_2 \big[\ln \mathrm{CDS}_{i,t-1} \times \mathbb{1}[i \in \mathrm{P}] \big] + \mathbb{1}[i \in \mathrm{P}] + u_{i,t}, \tag{4}$$

Table 1: Financial Conditions and Phillips Curve Prediction Errors

PC Specification	θ_1	θ_2	R^2
(a) *w/o time fixed effects*			
1. Prices (baseline)	0.064	0.423	0.139
	$[-0.128, 0.256]$	$[0.062, 0.785]$	
2. Prices (alternative)	0.199	0.644	0.289
	$[0.027, 0.371]$	$[0.232, 1.057]$	
3. Hybrid NK	0.050	0.381	0.184
	$[-0.069, 0.168]$	$[0.120, 0.642]$	
4. Wages (baseline)	0.001	-0.936	0.157
	$[-0.208, 0.210]$	$[-1.578, -0.293]$	
5. Wages (alternative)	0.002	-1.266	0.203
	$[-0.219, 0.263]$	$[-2.065, -0.486]$	
(b) *w/ time fixed effects*			
1. Prices (baseline)	0.004	0.302	0.267
	$[-0.239, 0.247]$	$[-0.045, 0.649]$	
2. Prices (alternative)	0.681	0.320	0.450
	$[0.330, 1.033]$	$[0.080, 0.559]$	
3. Hybrid NK	0.229	0.252	0.266
	$[0.033, 0.424]$	$[0.025, 0.479]$	
4. Wages (baseline)	-1.463	-0.616	0.273
	$[-2.183, -0.743]$	$[-1.436, 0.207]$	
5. Wages (alternative)	-1.773	-0.852	0.339
	$[-2.462, -1.085]$	$[-1.847, 0.143]$	

Note: Annual data from 2008 to 2013; No. of countries = 11; Obs. = 66. The dependent variable is $\hat{\epsilon}_{i,t}$, a price or wage inflation prediction error of country i in year t implied by the specified Phillips curve (see the text and Appendix A for details). The entries denote the OLS estimates of the coefficients θ_1 and θ_2 from specification (4). All specifications include a constant and $\mathbb{1}[i \in \text{P}]$, an indicator for whether country i is in the euro area periphery (not reported). The 95-percent confidence intervals reported in brackets are based on the empirical distribution of coefficients across 5,000 replications, using the wild bootstrap clustered in the time dimension (see Cameron et al., 2008).

where $\hat{\epsilon}_{i,t}$ denotes a residual from one of the estimated Phillips curves and $\mathbb{1}[i \in P]$ is a 0/1-indicator variable that equals one if country i is in the periphery and zero otherwise. The parameters θ_1 and θ_2 thus measure the extent to which differences in financial conditions between the core and periphery countries during the crisis can explain deviations of price and wage inflation trajectories from those implied by the various Phillips curve specifications.

As shown in panel (a) of Table 1, differences in financial conditions across the euro area during this period are systematically related to the deviations of price and wage inflation from the dynamics implied by canonical Phillips curve-type relationships. Turning first to prices (rows 1, 2, and 3), the positive estimates of θ_2, the coefficient on the interaction term $\ln \text{CDS}_{i,t-1} \times \mathbb{1}[i \in \text{P}]$, imply that a widening of sovereign CDS spreads in the eurozone periphery is associated with subsequent inflation rates that exceed those predicted by the various estimated Phillips curves. With regards to wages (rows 4 and 5), on the other hand, negative estimates of θ_2 imply that increased sovereign risk in the periphery leads to subsequent wage growth that is below that predicted by the estimated Phillips curves. The 95-percent confidence intervals bracketing the point estimates of θ_2 indicate that these relationships are statistically significant at conventional levels.

In panel (b), we repeat the same exercise, except we add time fixed effects to specification (4), so that θ_1 and θ_2 are identified using only variation between countries. The same results continue to hold: An increase in sovereign CDS spreads in the eurozone periphery is associated with rates of price inflation that lie systematically above those predicted by the estimated Phillips curves, whereas such tightening of financial conditions leads to rates of wage inflation that run systematically below those implied by the corresponding estimated wage Phillips curve. Taken together, these findings indicate that the deterioration in financial conditions may have significantly influenced price-cost margins and hence the behavior of markups in the periphery.

Figure 2 explores this conjecture by showing the evolution of price markups in the eurozone periphery and core, both at the aggregate level and using sectoral data.[7] According to panels (a) and (b), the divergence in aggregate markups between the core and periphery during the crisis is striking: The median markup in the periphery increased about 5 percentage points between 2009 and 2013, while in the core, the median markup fell about the same amount during this period. As shown in panels (c) through (f), this divergence in markups is pervasive across broad sectors of the economy.

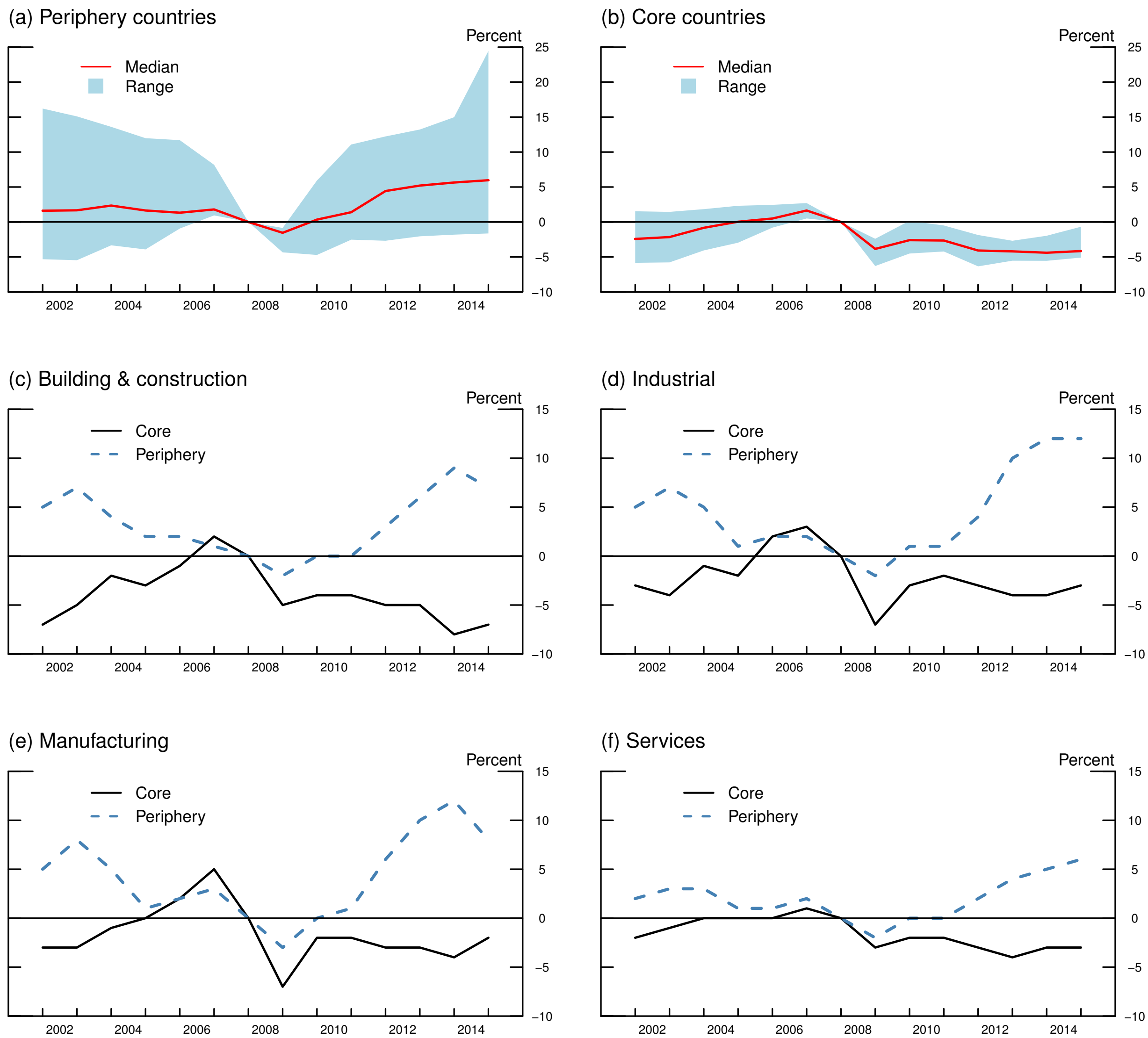
To establish more formally that differences in financial strain across countries affected the behavior of markups in the euro area during the crisis, we re-estimate regression (4) using the change in markups as the dependent variable. As indicated in panel (a) of Table 2, a widening sovereign CDS spreads in the periphery is associated with a statistically significant subsequent increase in aggregate markups, whereas in the euro area core, such a tightening of financial conditions has no effect on markups; note that this effect is robust to the inclusion of time fixed effects. In panel (b), we improve on the power of this test by considering changes in markups at the sectoral level. Adding this dimension to our data further strengthens the relationship between financial conditions and subsequent changes in price markups. Using the "between" estimates in row two as a benchmark, a periphery country with CDS spreads at the 90th percentile of the distribution would see its markups increase more than 5.5 percentage points, compared with a country whose CDS spreads are at the 10th percentile of the distribution.

The above results add to the growing empirical evidence, which supports the notion that financial conditions of firms in the euro area affected their pricing decisions during the global financial crisis and its aftermath.[8] Combining the theory of customer markets with financial frictions provides a natural way to understand these new findings. In fact, using model simulations, we show that this framework yields quantitative predictions that accord quite well with the observed differences in output growth and inflation between the eurozone core and periphery during the sovereign debt

[7] As shown by Galí et al. (2007), the price markup can, under reasonable assumptions, be measured (up to an additive constant) as minus the log of real unit labor costs.

[8] See Montero and Urtasun (2014); Antoun de Almedia (2015); Montero (2017); Duca et al. (2017)

Figure 2: Price Markups in the Euro Area



Note: In panels (a) and (b), the solid lines depict the cross-country medians of aggregate price markups, while the shaded bands denote the corresponding (max–min) ranges. In panels (c), (d), (e), and (f), the lines depict the cross-country weighted-averages of sector-specific markups, with weights equal to value-added output. In all cases, the price markup is defined as minus (100 times) the log of real unit labor costs (2008 = 1).

crisis. Before moving on to these quantitative exercises, we first delineate how differences in financial strains between the eurozone core and periphery relate to the differential dynamics of inflation and output between the two regions, as these empirical relationships guide the calibration strategy adopted below.

To measure the asymmetric financial shock in the periphery, we exploit market prices of the so-called CDS quanto derivatives, a type of derivative in which the underlying event is denominated in one currency (e.g., euros), but the instrument itself is settled in another currency at some rate

TABLE 2: Financial Conditions and Price Markups

Specification	θ_1	θ_2	R^2
(a) *Aggregate markups*[a]			
1. w/o time fixed effects	-0.205	1.378	0.256
	$[-0.944, 0.534]$	$[0.557, 2.220]$	
2. w/ time fixed effects	-0.312	1.148	0.681
	$[-0.528, -0.095]$	$[0.926, 1.372]$	
(b) *Sectoral markups*[b]			
1. w/o time fixed effects	-0.442	2.556	0.057
	$[-2.135, 1.252]$	$[0.913, 4.198]$	
2. w/ time fixed effects	-0.331	1.974	0.152
	$[-1.915, 1.254]$	$[1.244, 2.704]$	

NOTE: In panel (a), the dependent variable is the change in the aggregate price markup in country i, while in panel (b) the dependent variable is the change in the country-specific sectoral price markup. The entries denote the OLS estimates of the coefficients θ_1 and θ_2 from specification (4). All specifications include a constant and $\mathbb{1}[i \in \text{P}]$, an indicator for whether country i is in the euro area periphery (not reported); specifications in panel (b) also include sector fixed effects. The 95-percent confidence intervals reported in brackets are based on the empirical distribution of coefficients across 5,000 replications, using the wild bootstrap clustered in the time dimension (see Cameron et al., 2008).

[a] Annual data from 2008 to 2013; No. of countries = 11; Obs. = 66.

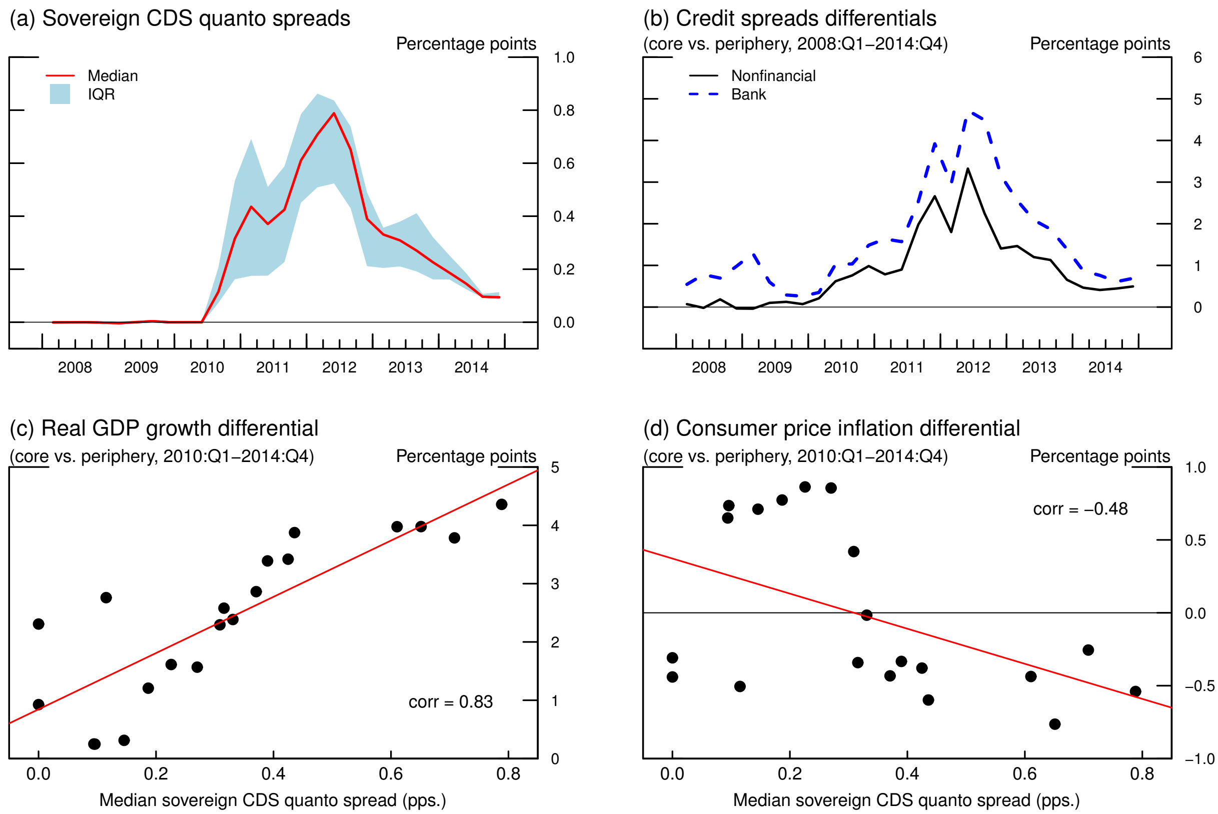
[b] Annual data from 2008 to 2013; No. of countries = 11; No. of sectors = 5 (Agriculture, Forestry & Fishing; Building & Construction; Industrial; Manufacturing; and Services); Obs. = 328.

(e.g., USD). Specifically, for each country in our panel, we construct a sovereign CDS quanto spread as the difference between a sovereign CDS premium implied by contracts denominated in euros and the corresponding premium implied by contracts denominated in U.S. dollars. As documented by Augustin et al. (2020), quanto spreads are informative of how financial markets view the interaction between a country's likelihood of default and the associated currency devaluation. In our context, they capture the financial market's perception of the risk that a eurozone periphery country would default on its sovereign obligations and in the process exit the monetary union.

Panel (a) of Figure 3 shows the median (5-year) CDS quanto spread across our sample of 11 countries, along with the corresponding inter-quartile range. Note that before mid-2010, sovereign CDS quanto spreads were essentially zero in all 11 countries. In mid-2010, when a growing recognition of an unsustainable fiscal situation in Greece sparked a capital flight from the periphery, financial markets suddenly re-assessed the likelihood of a sovereign default and a break-up of the eurozone: The median CDS quanto spread increased sharply, peaking at about 80 basis points at the nadir of the crisis in mid-2012. As shown in panel (b), the run-up in quanto spreads is strongly associated with the asymmetric tightening of financial conditions between the core and periphery, as credit spreads for both nonfinancial corporations and banks increased significantly more in the latter than in the former.

Panels (c) and (d) explore the implication of this asymmetric tightening of financial conditions for the differential behavior of output and prices, respectively. According to panel (c), the peak

Figure 3: Asymmetric Financial Shock in the Euro Area



Note: The solid line in panel (a) depicts the cross-country median of (5-year) sovereign CDS quanto spreads, while the shaded band denotes the corresponding inter-quartile range (see the text for details). Panel (b) depicts the credit spread differentials between selected periphery (Italy and Spain) and core (France and Germany) countries; credit spreads on corporate bonds issued by nonfinancial companies (solid line) and banks (dashed line) are measured relative to comparable-maturity German bunds. Panel (c) and (d) depict the relationships between the median sovereign CDS quanto spread and the difference between the four-quarter growth in real GDP and the four-quarter growth in the CPI between core and periphery, respectively.

in the median CDS quanto spread in mid-2012 is associated with a *positive* differential of about four percentage points in real GDP growth between the core and periphery; at the same time, it is also associated with a *negative* inflation differential of about 0.5 percentage points (panel (d)). In other words, during the eurozone sovereign debt crisis, the periphery exhibited—relative to the core—a persistently lower output growth and a persistently higher inflation. Moreover, during this period, the output growth and inflation differentials are systematically related to movements in the sovereign CDS quanto spreads. In the quantitative analysis below, our asymmetric financial shock in the periphery is calibrated to deliver similar differential responses.

3 Key Elements of the Model

This section presents the key elements of the closed-economy DSGE model of Gilchrist et al. (2017) (GSSZ hereafter), extended to an open-economy setting (see Appendix B for additional details). The key difference from canonical open-economy DSGE models is that firms in the GSSZ setup trade off future market shares against current profits. In particular, financially constrained firms, when hit by an adverse shock, try to maintain cashflows by increasing markups, even though doing so means losing market share in the near term. As shown through simulations below, this pricing behavior helps to rationalize the empirical facts documented above.

The model economy consists of two countries—referred to as home (h) and foreign (f)—and where foreign country variables carry a superscript "*". The reader should think of home and foreign countries as representing the periphery and core regions of the euro area, respectively.

3.1 Preferences and Technology

In each country, there exists a continuum of households indexed by $j \in N_c = [0, 1]$, $c = h, f$. Each household consumes two types (h and f) of differentiated varieties of consumption goods, indexed by $i \in N_h = [0, 1]$ in the home country and by $i \in N_f = [1, 2]$ in the foreign country. Consistent with the standard assumption used in international macroeconomics, the home country only produces the h-type goods, while the foreign country only produces the f-type goods. In this two-country setting, $c^j_{i,f,t}$ denotes the consumption of product i of type f by a home country household j, while $c^{j*}_{i,f,t}$ denotes its foreign counterpart—that is, the consumption of product i of type f by a foreign country household j. Due to the symmetric structure of the two countries, generally all relevant foreign country analogues can be expressed simply by adding a superscript "*" to each variable.

The preferences of household j in the home country are given by

$$\mathbb{E}_t \sum_{s=0}^{\infty} \delta^s U(x^j_{t+s}, h^j_{t+s}) \quad (0 < \delta < 1). \tag{5}$$

The household's per-period utility function $U(\cdot, \cdot)$ is strictly increasing and concave in the consumption bundle x^j_t and strictly decreasing and concave in hours worked h^j_t.[9]

Standard open-economy models allow for home bias in consumption by combining Dixit-Stiglitz preferences with an Armington aggregator of home and foreign goods. In line with GSSZ, we introduce into this framework a sticky customer base via the "deep habits" preference structure of Ravn et al. (2006). As shown by Drozd and Nosal (2012), the introduction of customer capital into such models has the potential to resolve a number of international pricing puzzles. Our analysis additionally highlights the important role financial market frictions can play in such a framework.

[9] For simplicity it is assumed that labor is immobile, which is consistent with the evidence that Europe is still to a large extent a "stay-at-home" place (see auf dem Brinke and Dittrich, 2016).

The deep habits preference structure yields the consumption/habit aggregator

$$x_t^j \equiv \left[\sum_{k=h,f} \Xi_k \left[\int_{N_k} (c^j_{i,k,t}/s^{\theta}_{i,k,t-1})^{1-1/\eta} di \right]^{\frac{1-1/\varepsilon}{1-1/\eta}} \right]^{\frac{1}{1-1/\varepsilon}},$$

where $\eta > 1$ and $\varepsilon > 1$ are the elasticities of substitution *within* a type of goods produced in a given country and *between* the two types of goods, respectively. The parameter $\Xi_k > 0$ governs the degree of home bias in the household's consumption basket in the steady state, with $\Xi_h^{\varepsilon} + \Xi_f^{\varepsilon} = 1$.

Let $c_{i,k,t} = \int_0^1 c^j_{i,k,t} dj$ denote the average level of consumption of good i in country k. And as in Ravn et al. (2006), let $s_{i,k,t}$ denote the *good-specific* habit, which evolves according to

$$s_{i,k,t} = \rho s_{i,k,t-1} + (1-\rho) c_{i,k,t}; \quad k = h, f \quad (0 < \rho < 1).$$

In the above formulation, habits are external to the household and country specific. When $\theta < 0$, the stock of habit formed by past consumption of the average household has a positive effect on the utility derived from today's consumption, making the household desire more of the same good.

In equilibrium, all households within a given country choose the same consumption basket. Going forward, we thus omit the household index j. The cost minimization associated with equation (5) implies the following demand function for good i (of type h or f) in the home country:

$$c_{i,k,t} = \left(\frac{P_{i,k,t}}{\tilde{P}_{k,t}} \right)^{-\eta} s^{\theta(1-\eta)}_{i,k,t-1} x_{k,t}; \quad k = h, f,$$

where the habit-adjusted price index $\tilde{P}_{k,t}$ and consumption bundle $x_{k,t}$ are given by

$$\tilde{P}_{k,t} = \left[\int_{N_k} (P_{i,k,t} s^{\theta}_{i,k,t-1})^{1-\eta} di \right]^{\frac{1}{1-\eta}};$$

and

$$x_{k,t} = \left[\int_{N_k} (c_{i,k,t}/s^{\theta}_{i,k,t-1})^{1-1/\eta} di \right]^{\frac{1}{1-1/\eta}}.$$

In equilibrium, the consumption/habit basket $x_{k,t}$, $k = h, f$, is equal to

$$x_{k,t} = \Xi_k^{\varepsilon} \left(\frac{\tilde{P}_{k,t}}{\tilde{P}_t} \right)^{-\varepsilon} x_t, \quad \text{where} \quad \tilde{P}_t = \left[\sum_{k=h,f} \Xi_k \tilde{P}_{k,t}^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}} \tag{6}$$

is the aggregate price index of the home country.[10]

On the production side, we abstract from capital and assume that labor is the only input. The

[10] In this setup, the consumer price index (CPI) of the home country—denoted by P_t—is given by $P_t = \left[\sum_{k=h,f} \Xi_k P_{k,t}^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}$, where $P_{k,t} = \left[\int_{N_k} {P_{i,k,t}}^{1-\eta} di \right]^{\frac{1}{1-\eta}}$ denotes the CPI corresponding to a k-type category of goods.

technologies in the home and foreign countries are given by

$$y_{i,t} = \left(\frac{A_t}{a_{i,t}} h_{i,t}\right)^{\alpha} - \phi \quad \text{and} \quad y^*_{i,t} = \left(\frac{A^*_t}{a^*_{i,t}} h^*_{i,t}\right)^{\alpha} - \phi^* \quad (0 < \alpha \leq 1),$$

where $\phi, \phi^* > 0$ denote fixed operating costs; A_t and A^*_t are the country-specific aggregate technology shocks, and $a_{i,t}$ and $a^*_{i,t}$ are the idiosyncratic "cost" shocks affecting home and foreign firms, respectively. The idiosyncratic cost shocks are distributed according to a log-normal distribution: $\ln a_{i,t}, \ln a^*_{i,t} \overset{iid}{\sim} N(-0.5\sigma^2, \sigma^2)$, with the CDF denoted by $F(a)$.

3.2 The Firm's Problem

The firm's objective is to maximize the present discounted value of its dividends, $\mathbb{E}_t\left[\sum_{s=0}^{\infty} m_{t,t+s} d_{i,t+s}\right]$, where $d_{i,t} = D_{i,t}/P_t$ is the real dividend payout when positive and real equity issuance when negative. Firms are owned by households, and they discount future cashflows using the stochastic discount factor ($m_{t,t+s}$) of the representative household in their respective country. (The formal Lagrangian associated with the firm's problem can be found in Appendix B.)

Financial frictions play a critical role in the firm's problem and the implied pricing behavior. The basic underlying structure why financial frictions matter parallels the structure in GSSZ: (i) firms set prices and production in advance of the realization of an idiosyncratic cost shock; and (ii) firms face a fixed cost of production. Hence ex post profits may not be large enough to cover the fixed cost in the absence of corporate savings. Firms, therefore, may ex post need to secure external funds by issuing equity. Issuing equity, however, is costly because of financial frictions, and a cost of doing differs between home and foreign countries. As a result, firms face a "cost shock threshold" above which they need to issue equity.

More formally, a home country firm maximizes the present discounted value of real dividends, subject to a flow-of-funds constraint:

$$\begin{aligned} d_{i,t} = {} & p_{i,h,t} p_{h,t} c_{i,h,t} + q_t p^*_{i,h,t} p^*_{h,t} c^*_{i,h,t} - w_t h_{i,t} + \varphi \min\{0, d_{i,t}\} \\ & - \frac{\gamma_p}{2}\left(\frac{p_{i,h,t}}{p_{i,h,t-1}} \pi_{h,t} - 1\right)^2 c_t - \frac{\gamma_p}{2} q_t \left(\frac{p^*_{i,h,t}}{p^*_{i,h,t-1}} \pi^*_{h,t} - 1\right)^2 c^*_t, \end{aligned}$$

where $w_t = W_t/P_t$ is the real wage, $q_t = Q_t P^*_t/P_t$ is the real exchange rate, and $\pi_{h,t} = P_{h,t}/P_{h,t-1}$ and $\pi^*_{h,t} = P^*_{h,t}/P^*_{h,t-1}$ are the market-specific (gross) inflation rates faced by firms in the home country. The flow-of-funds constraint takes into account both the domestic and foreign demand and quadratic price adjustment costs. The firm charges prices $p_{i,h,t}$ and $p^*_{i,h,t}$ in the home and foreign markets, respectively, where both prices are measured relative to the average price level prevailing in that market.[11]

[11] Note that individual product prices relative to the CPIs in home and foreign countries can be written as $\frac{P_{i,h,t}}{P_t} = \frac{P_{i,h,t}}{P_{h,t}} \frac{P_{h,t}}{P_t} \equiv p_{i,h,t} p_{h,t}$ and $\frac{P^*_{i,h,t}}{P^*_t} = \frac{P^*_{i,h,t}}{P^*_{h,t}} \frac{P^*_{h,t}}{P^*_t} \equiv p^*_{i,h,t} p^*_{h,t}$. That is, $p_{i,h,t}$ and $p^*_{i,h,t}$ are prices charged by home country firm i relative to the average price level chosen by the home country firms in the home and foreign markets, respectively, whereas $p_{h,t}$ and $p^*_{h,t}$ are the average price levels relative to the CPI in the home and foreign markets,

Imposing the relevant (symmetric) equilibrium conditions, the firm's internal funds are given by revenues less production costs:

$$p_{h,t}c_{h,t} + q_t p^*_{h,t}c^*_{h,t} - w_t \frac{a_{i,t}}{A_t}\left(\phi + c_{h,t} + c^*_{h,t}\right)^{\frac{1}{\alpha}}.$$

In this open-economy setting, both foreign and home market conditions, $c_{h,t}$ and $c^*_{h,t}$, are related to domestic fixed operating costs ϕ and idiosyncratic costs $a_{i,t}$. The firm resorts to costly external finance—that is, issues new shares—if and only if

$$a_{i,t} > a^E_t \equiv \frac{A_t}{w_t}\left[\frac{p_{h,t}c_{h,t} + q_t p^*_{h,t}c^*_{h,t}}{\left(\phi + c_{h,t} + c^*_{h,t}\right)^{\frac{1}{\alpha}}}\right]. \tag{7}$$

Using the above definition of the equity issuance threshold a^E_t, one can express the first-order conditions for dividends as follows:

$$\xi_{i,t} = \begin{cases} 1 & \text{if } a_{i,t} \leq a^E_t; \\ 1/(1-\varphi) & \text{if } a_{i,t} > a^E_t, \end{cases}$$

which states that because of costly external financing, the shadow value of internal funds, $\xi_{i,t}$, jumps from one to $1/(1-\varphi) > 1$ when the realization of the idiosyncratic cost shock $a_{i,t}$ exceed the threshold value a^E_t.

3.3 Equilibrium Inflation Dynamics

As in GSSZ, we define the markup—denoted by $\tilde{\mu}_t$—as the inverse of real marginal cost inclusive of financing costs:

$$\tilde{\mu}_t = \left[\frac{\mathbb{E}^a_t[a_{i,t}\xi_{i,t}]}{\mathbb{E}^a_t[\xi_{i,t}]}\frac{w_t}{\alpha A_t}\left(\phi + c_{h,t} + c^*_{h,t}\right)^{\frac{1-\alpha}{\alpha}}\right]^{-1},$$

where the fact that

$$\frac{\mathbb{E}^a_t[a_{i,t}\xi_{i,t}]}{\mathbb{E}^a_t[\xi_{i,t}]} = 1 + \frac{\text{Cov}[a_{i,t}, \xi_{i,t}]}{\mathbb{E}^a_t[\xi_{i,t}]} = \frac{1 - \varphi\Phi(z^E_t - \sigma)}{1 - \varphi\Phi(z^E_t)} > 1$$

follows from properties of the log-normal distribution.[12]

Relegating the detailed optimality conditions to Appendix B, we show below how financial frictions and customer markets modify the well-known, log-linearized domestic-economy Phillips curve. In addition, we show how markups react differently to shocks than in the conventional open-economy framework.

respectively, and as such are taken as given by individual firms.

[12]The random variable z^E_t is the standardized value of the threshold value a^E_t (i.e, $z^E_t = (\ln a^E_t + 0.5\sigma^2)/\sigma$) and Φ is the standard normal CDF.

We begin by expressing the log-linearized dynamics of national CPIs as

$$\hat{\pi}_t = \Xi_h p_h(\hat{p}_{h,t-1} + \hat{\pi}_{h,t}) + \Xi_f p_f(\hat{p}_{f,t-1} + \hat{\pi}_{f,t}); \tag{8}$$

$$\hat{\pi}^*_t = \Xi^*_h p^*_h(\hat{p}^*_{h,t-1} + \hat{\pi}^*_{h,t}) + \Xi^*_f p^*_f(\hat{p}^*_{f,t-1} + \hat{\pi}^*_{f,t}), \tag{9}$$

where the variables with the "hat" denote log-linearized deviations from their respective steady-state values, which correspond to variables without the time subscript. Equations (8) and (9) illustrate how import prices affect the inflation dynamics of national CPIs. A full characterization of these dynamics requires a construction of Phillips curves for $\hat{\pi}_{h,t}$, $\hat{\pi}_{f,t}$, $\hat{\pi}^*_{h,t}$, and $\hat{\pi}^*_{f,t}$. For the sake of space, we focus on the first and the third, namely, Phillips curves characterizing the inflation dynamics of home firms selling domestically and abroad.

The log-linearization of first-order conditions for $p_{i,h,t}$ and $p^*_{i,h,t}$ implies:

$$\hat{\pi}_{h,t} = \frac{1}{\gamma_p}\frac{p_h c_h}{c}\left[\hat{p}_{h,t} - (\hat{\nu}_{h,t} - \hat{\xi}_t)\right] + \delta\mathbb{E}_t[\hat{\pi}_{h,t+1}]; \tag{10}$$

$$\hat{\pi}^*_{h,t} = \frac{1}{\gamma_p} q p^*_h \frac{c^*_h}{c^*}\left[\hat{q}_t + \hat{p}^*_{h,t} - (\hat{\nu}^*_{h,t} - \hat{\xi}_t)\right] + \delta\mathbb{E}_t[\hat{\pi}^*_{h,t+1}], \tag{11}$$

where $\hat{\nu}_{h,t}$, $\hat{\nu}^*_{h,t}$, and $\hat{\xi}_t$ denote the log-deviations of $\mathbb{E}^a_t[\nu_{i,h,t}]$, $\mathbb{E}^a_t[\nu^*_{i,h,t}]$, and $\mathbb{E}^a_t[\xi_{i,t}]$ from their respective steady-state values.[13] In the absence of customer markets (i.e., $\nu_{i,h,t} = \nu^*_{i,h,t} = 0$), the terms in brackets are exactly equal to the log-deviation of the financially adjusted real marginal cost $\tilde{\mu}_t^{-1}$. As a result, we recover a conventional forward-looking Phillips curve for each market in which home firms operate and which takes into account financing costs through the adjusted markup.

With customer markets, however, inflation dynamics become substantially richer. Substituting the log-linear dynamics of $\hat{\nu}_{h,t} - \hat{\xi}_t$ and $\hat{\nu}^*_{h,t} - \hat{\xi}_t$ into equations (10) and (11), respectively, yields the following Phillips curve for the domestic market sales of home firms:

$$\hat{\pi}_{h,t} = \frac{1}{\gamma_p}\frac{p_h c_h}{c}\left[\hat{p}_{h,t} - \eta\left(\hat{p}_{h,t} + \frac{\hat{\mu}_t}{p_h\tilde{\mu}}\right) - \eta\chi\mathbb{E}_t\sum_{s=t+1}^{\infty}\tilde{\delta}^{s-t}\left(\hat{p}_{h,s} + \frac{\hat{\mu}_s}{p_h\tilde{\mu}}\right)\right]$$
$$+ \frac{\eta\chi}{\gamma_p}\frac{p_h c_h}{c}\left(1 - \frac{1}{p_h\tilde{\mu}}\right)\mathbb{E}_t\sum_{s=t+1}^{\infty}\tilde{\delta}^{s-t}\left[(\hat{\xi}_t - \hat{\xi}_s) - \hat{\beta}_{h,t,s}\right] + \delta\mathbb{E}_t[\hat{\pi}_{h,t+1}];$$

[13] Variables $\nu_{i,h,t}$ and $\nu^*_{i,h,t}$ are the Lagrange multipliers associated with the domestic and foreign demand constraints—arising from the presence of customer markets—in the firm's optimization problem (see Appendix B for details).

while their pricing behavior in the foreign market implies that

$$\hat{\pi}^*_{h,t} = \frac{1}{\gamma_p} q p^*_h \frac{c^*_h}{c^*} \Bigg[\hat{q}_t + \hat{p}^*_{h,t} - \eta \bigg((\hat{q}_t + \hat{p}_{h,t}) + \frac{\hat{\mu}_t}{q p^*_h \tilde{\mu}} \bigg) + \eta \chi \mathbb{E}_t \sum_{s=t+1}^{\infty} \tilde{\delta}^{s-t} \bigg((\hat{q}_s + \hat{p}^*_{h,s}) + \frac{\hat{\mu}_s}{q p^*_h \tilde{\mu}} \bigg) \Bigg] + \frac{\eta \chi}{\gamma_p} q p^*_h \frac{c^*_h}{c^*} \bigg(1 - \frac{1}{q p^*_h \tilde{\mu}} \bigg) \mathbb{E}_t \sum_{s=t+1}^{\infty} \tilde{\delta}^{s-t} \big[(\hat{\xi}_t - \hat{\xi}_s) - \hat{\beta}^*_{h,t,s} \big] + \delta \mathbb{E}_t [\hat{\pi}^*_{h,t+1}],$$

where $\chi = (1-\rho)\theta(1-\eta)$ and $\tilde{\delta} = \delta(\rho + \chi)$.

First note that because $\chi > 0$, a firm's heightened concern about its current liquidity position, as manifested by the fact that $\hat{\xi}_t - \hat{\xi}_s > 0$, will result in higher inflation in both markets. Second, the increased importance of future market shares at home and abroad, as captured by the growth-adjusted, compounded discount factors $\hat{\beta}_{h,t,s} > 0$ and $\hat{\beta}^*_{h,t,s} > 0$, leads to lower inflation in both markets. The terms $(\hat{\xi}_t - \hat{\xi}_s) - \hat{\beta}_{h,t,s}$ and $(\hat{\xi}_t - \hat{\xi}_s) - \hat{\beta}^*_{h,t,s}$, therefore, capture the fundamental tension between the maximization of current profits and the maximization of long-run market shares.

Not only does this tension affect the dynamics of goods prices in both home and foreign markets. The pricing mechanism engendered by the underlying interaction also generates price dynamics that differ fundamentally from those in the standard literature. Specifically, following an adverse exchange rate shock, firms in the conventional open-economy framework do not fully pass the resulting cost increase into import prices, but instead absorb some of this cost shock in their profits by *lowering* markups. In our setup, by contrast, financially constrained firms, when hit by adverse shocks, try to maintain their cashflows by increasing markups in both the domestic and export markets, in effect trading off future market shares for current profits.

To close the model, we need to specify the optimization problems of the representative households in the home and foreign countries and the behavior of the respective monetary authorities. When it comes to the main mechanism of the model, the optimization problem of the representative household in the open-economy setup differs inconsequentially from that in the closed-economy setup of GSSZ. We therefore relegate the details of the household's optimization problem to Appendix B, where for clarity of exposition, we first formulate this problem in an environment of flexible exchange rates and independent central banks in home and foreign countries. We then impose the necessary restrictions that deliver the baseline model of a monetary union with a single central bank.

4 Calibration

There are three sets of parameters in the model: (*i*) parameters related to preferences and technology; (*ii*) parameters governing the strength of nominal rigidities and the conduct of monetary policy; and (*iii*) parameters determining the degree of financial market distortions. In setting their values, our calibration strategy closely follows GSSZ, while expanding the set of parameters to the international environment. Our strategy for the latter step entails choosing parameters governing the strength of financial frictions in home and foreign countries, such that the model-implied responses match the observed differential behavior of output and prices between the core and periphery during the European sovereign debt crisis.

When it comes to parameters related to preferences and technology, we set the time discount factor $\delta = 0.99$, in line with a quarterly model. The CRRA parameter (γ_x) in the household's utility function is set equal to 2. As we explain below, we specify the same degree of persistence (0.90) for all exogenous shock processes (i.e., aggregate technology shocks and financial shocks). We then adjust the volatilities of shocks to match the variance-decomposition shares of output fluctuations.

The deep habit parameter θ is set to -0.86, a value similar to that used by Ravn et al. (2006). The key tension between the maximization of a long-run market share and the maximization of current profits does not exist when $\theta = 0$. In such an environment, the financial shock we consider has a considerably smaller effect on economic outcomes. It is in this sense that our model owes a lot to customer-market considerations as captured by deep habits. Consequently, we follow Ravn et al. (2006) and choose a fairly persistent habit-formation process, so that only 15 percent of the habit stock depreciates in a given quarter ($\rho = 0.85$), a choice that highlights firms' incentives to compete for market share.

The elasticity of substitution η is a key parameter in the customer-markets model because the greater the firm's market power, the greater the incentive to invest in customer base. We set $\eta = 2$, a value consistent with Broda and Weinstein (2006), who provide a range of estimates of η for the U.S. economy; their estimates lie between 2.1 and 4.8, depending on the characteristics of products (commodities vs. differentiated goods) and sub-samples (before 1990 vs. after 1990). Our choice is close to the median value of the estimated elasticities for differentiated goods for the post-1990 period, a class of products that is most relevant for the deep habits framework.[14]

Regarding Ξ_h and Ξ_f (and Ξ_f^* and Ξ_h^*), the weights of home and foreign goods in the household's utility function, we choose their values so that the share of imported goods in the steady-state consumption basket is equal to 0.4 in both countries, a value in the middle of the range of the import-to-GDP ratios for the Euro area countries since 2000.[15] As for the Armington elasticity, we set ε equal to 1.5, in order to stay close to the near-unit elasticity estimated by Feenstra et al. (2014).[16]

In choosing parameters governing the strength of nominal rigidities and the conduct of monetary policy, we set γ_p, the quadratic adjustment costs of nominal prices, equal to 14.5 in both countries. This choice adopts the point estimate obtained by Ravn et al. (2010), who show that deep habits

[14] It is also broadly consistent with Ravn et al. (2010), who estimate η equal to 2.48 within a context of the deep habits model.

[15] Note that Ξ_f itself is not equal to the share of imported goods in the GDP of the home country; rather Ξ_f is chosen such that $\Xi_f^{\varepsilon} = p_f c_f / \sum_{k=h,f} p_k c_k = 0.4$.

[16] As long as $\varepsilon > 1$, a value lower than 1.5 does not affect our main results. For example, setting ε close to 1 reduces the impact of a financial shock on aggregate output in a monetary union to two-thirds of that implied by our baseline calibration. This is because the lower elasticity of cross-border substitution implies a less intense price war between firms of the two countries. However, even in this extreme case, the qualitative features of the equilibrium remain the same.

substantially enhance the persistence of inflation without the need to impose an implausibly large degree nominal price stickiness. The labor supply elasticity (ζ) is set equal to 3, in the middle of estimates used in the macro literature (see Chetty et al., 2011).[17] Regarding monetary policy, we assume that it is conducted using an interest-rate rule proposed by Taylor (1999). We abstract from interest-rate smoothing and assume that the nominal interest rate systematically responds to inflation with a parameter $\psi_\pi = 1.5$ and to output gap with a parameter $\psi_y = 1$.

The last set of parameters determine the degree of financial market distortions. Among these parameters, the fixed operating costs ϕ and ϕ^* are two key parameters for the model. We set $\phi = \phi^*$, which implies that differences in the degree of financial distortions are the sole source of heterogeneity between the two countries. We calibrate ϕ in conjunction with the returns-to-scale parameter α. Specifically, we set α first and then choose ϕ so that the dividend-payout ratio (relative to operating income) hits 2.5 percent, the mean of this ratio in the U.S. since 1945, which is close to the average dividends-and-buyback ratio of 3 percent for the European OECD countries during the 2002–15 period.

Following the international macroeconomics literature, we set $\alpha = 1$; in turn, this implies that $\phi = 0.1$. With $\alpha = 1$, $\phi = 0.1$, and $\eta = 2$, the average short-run gross markup in the model comes out at 1.19, while the long-run gross markup is equal to 1.07.

In calibrating the degree of financial distortions faced by domestic firms, we set the equity dilution cost parameter φ equal to 0.2, a value that lies in the middle of the range typically found in the corporate finance literature (see Cooley and Quadrini, 2001; Hennessy and Whited, 2007). An additional calibration step involves setting parameters for the foreign country. We do so by simulating an adverse financial shock in the home country as described in the next section and targeting the observed differential paths of (detrended) real GDP and CPI between the core and periphery during the crisis (see Figure 6 and related discussion below). This leads us to choose a degree of financial frictions faced by foreign firms φ^* to be one-tenth of φ (i.e., $\varphi^* = 0.1\varphi$), implying a considerably more accommodative financial conditions for foreign country firms in the steady state.

The same targeting exercise also leads us to set the volatility of the idiosyncratic cost shock σ to 0.2 at a quarterly frequency. With $\varphi = 0.2$ and $\phi = 0.1$, this level of idiosyncratic volatility implies that the expected shadow value of internal funds equals 1.12 for home country firms in the steady state, a value in line with the linear component of equity issuance costs for small firms estimated by Hennessy and Whited (2007). Table C-1 of Appendix C conveniently summarizes our baseline calibration.

[17] As in GSSZ, we allow for nominal wage rigidities by assuming market power for households supplying labor to firms and a quadratic cost of adjusting nominal wages (see Appendix B). Following Ravn et al. (2010) and in keeping with our symmetric assumptions regarding nominal price rigidities, we set elasticity of substitution between differentiated labor (η_w) equal to 2 and quadratic wage adjustment costs (γ_w) equal to 41 in both countries.

5 Model Simulations

This section uses the calibrated model to analyze quantitatively the macroeconomic implications of home and foreign countries forming a monetary union—that is, adopting a common currency and hence common monetary policy—in an environment of asymmetric financial shocks. We show that the simulated dynamics following an adverse shock originating in the periphery match well the differential dynamics of inflation and output between core and periphery observed during the European sovereign debt crisis.

5.1 The Impact of an Asymmetric Financial Shock

To analyze the effects of financial instability under various currency regimes, we posit an external asymmetric financial shock, which temporarily raises the cost of outside equity capital for firms in the two countries. Specifically, the cost of issuing new shares for home country firms is assumed to be subject to a "cost-of-capital" shock of the form:

$$\varphi_t = \varphi f_t; \quad \text{where } \ln f_t = \rho_f \ln f_{t-1} + \epsilon_{f,t}, \text{ with } \epsilon_{f,t} \sim N(-0.5\sigma_f^2, \sigma_f^2).$$

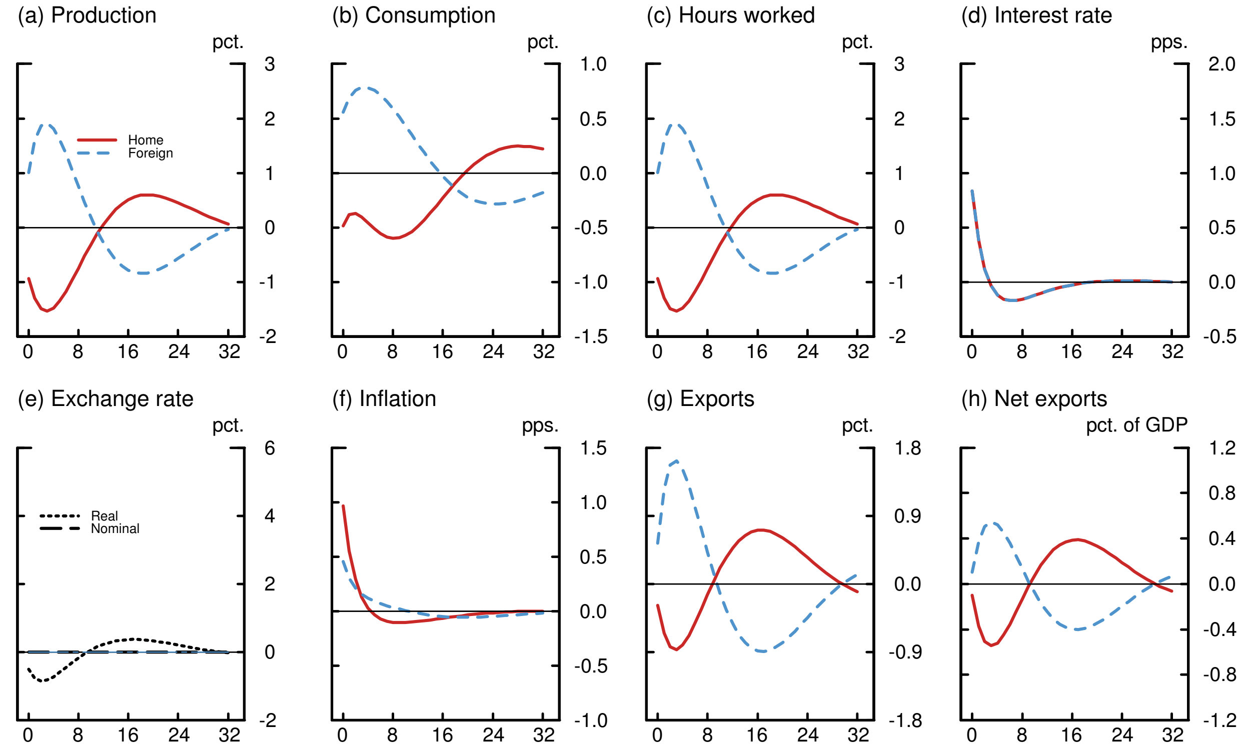
We solve the model using linear perturbation techniques, calibrating the size of the shock $\epsilon_{f,t}$ such that φ_t jumps to 1.5φ upon impact and then returns to its normal level of $\varphi = 0.2$, according to the autoregressive dynamics specified above.

Because our calibration assumes that $\varphi^* = 0.1\varphi$, the above formulation results in asymmetric financial conditions between the two countries, with home country firms facing a significantly higher cost of external finance. To further underscore the effects of differences in financial conditions faced by domestic and foreign firms, we keep the cost of external equity capital in the foreign country at $\varphi_t^* = 0.1\varphi$, for all t. Our focus on such asymmetric financial shocks—as opposed to common demand shocks, for instance—is motivated by the fact that the eurozone sovereign debt crisis was sparked by concerns related to the solvency of national banking systems in the periphery, which led to a differential tightening of financial conditions across the euro area. As shown below, this calibration of a financial shock generates differential output and inflation responses between home and foreign countries that accord quite well with the actual differences in the dynamics of output and inflation between the core and periphery during the crisis.

In this experiment, the financial shock increases the expected shadow value of internal funds for firms in the home country from 1.12 to 1.28 upon impact. Figure 4 displays the macroeconomic effects of such an asymmetric financial shock when the two countries share a common currency. As shown in panel (f), home country firms raise prices significantly in response to an adverse financial shock. Foreign inflation also increases somewhat because of the increase in import prices. At the same time, the burst of inflation in the home country is accompanied by an economic slump: Production declines notably in the immediate aftermath of the shock (panel (a)), as does consumption (panel (b)) and hours worked (panel (c)).

Because the nominal exchange rate is unable to respond to the shock, the differential behavior

Figure 4: Asymmetric Financial Shock – Macroeconomic Implications



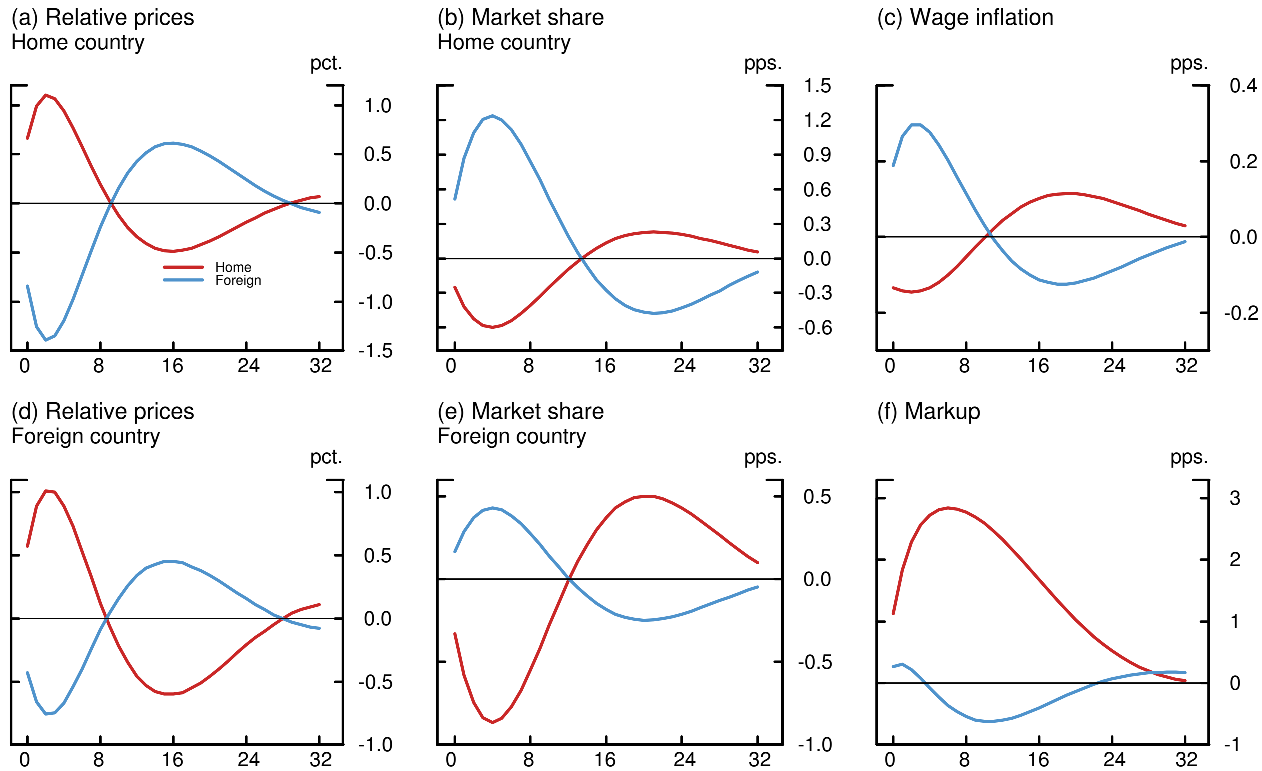
Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0. Unless noted otherwise, the solid red lines show responses of variables in the home country, while the dashed blue lines show those of the foreign country. Exchange rates (panel (e)) are expressed as home currency relative to foreign currency.

of inflation in the two countries implies a notable appreciation of the real exchange rate (panel (e)). As a result, exports from the home country drop (panel (g)), and the home country registers a notable trade deficit in the near term (panel (h)). Strikingly, the downturn in the home country is accompanied by a boom in the foreign country: Production, consumption, hours worked, and exports all increase significantly, and the foreign country's trade balance improves significantly.[18]

These dynamics are a direct result of the interaction between financial frictions and customer-market considerations in our two-country setup. Because firms in the home country optimally choose higher markups and relative prices in response to the tightening of financial conditions, the real exchange rate appreciates substantially, and production and exports by home country firms drop sharply. The real exchange rate reflects the terms of trade, and differences in inflation rates

[18] As it is well known, the pattern of international macroeconomic adjustment in response to such a shock looks very different when the two countries have their own currencies and are able to pursue independent monetary policies, responding to their respective domestic economic developments. In that case, according to Figure D-1 in Appendix D, home country firms also raise prices in response to an adverse financial shock (panel (f)), and foreign inflation rises slightly, reflecting the pass-through of higher import prices. With flexible exchange rates, however, the nominal exchange rate strongly depreciates (panel (e)). In fact, the depreciation is so large that the real exchange rate also depreciates, despite the inflation differential moving in the "wrong" direction.

Figure 5: Asymmetric Financial Shock – Relative Prices, Wages, and Markups



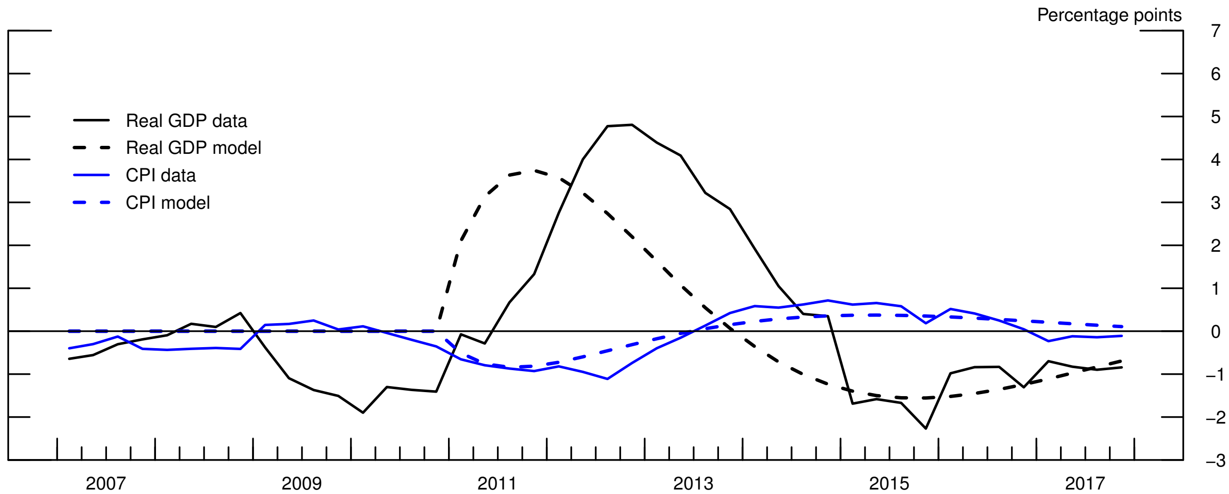
Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0. The solid red lines show responses of firms in the home country, while the solid blue lines show responses of firms in the foreign country.

translate directly into movements in the real exchange rate. In comparison, the decline in consumption is noticeably less severe because international borrowing—while subject to costly portfolio rebalancing—allows consumers in the home country to smooth the effects of the financial shock to a certain extent. The foreign economic boom is simply a mirror image of the home country's economic plight and is reminiscent of the dichotomy in economic outcomes between the eurozone core and periphery during the recent financial crisis.[19]

As shown in panels (a) and (d) of Figure 5, the financial shock in the home country induces a significant dispersion in relative prices in both countries. The increase in the cost of external finance causes home country firms to raise relative prices in both their domestic and export markets (panels (a) and (d)). Foreign country firms, in contrast, optimally follow the opposite strategy and lower relative prices in both markets in order to steal market share from their financially constrained

[19]It is important to note that these results are driven primarily by the interaction of customer markets and financial frictions. As shown in Figure D-2 in Appendix D, reducing the strength of the deep-habit mechanism significantly dampens the macroeconomic effects of an adverse financial shock in the home country. At the same time, it is also worth noting that the addition of nominal wage rigidities, while certainly strengthening the pricing mechanism implied by the interaction of customer markets and financial frictions, does not change the qualitative nature of our main results (see Figures D-3 and D-4).

Figure 6: Model vs. Data



Note: The solid black and purple lines depict the real GDP and CPI differentials between between core and periphery, respectively. The log-levels of real GDP and CPI for the core and periphery have been detrended using the modified Hamilton filter (see Quast and Wolters, 2022). The dashed black and purple lines depict the model-implied corresponding responses to an asymmetric financial shock in the home country, assuming that period 0—the time of the shock—is equal to 2011:Q1 (see the text for details).

home country counterparts (panels (b) and (e)). This "predatory" price war is a notable feature of our setup. Unlike in a conventional open-economy setup, financial distress leads to a strongly countercyclical markup in the home country (panel (f)).

These model-implied dynamics of markups in the home country in response to a financial shock help make sense of the behavior of price markups in the eurozone periphery observed during the recent financial crisis and its aftermath (see Figure 2).[20] They also help generate differences in inflation and output dynamics between the core and periphery that are quantitatively in line with those during the European sovereign debt crisis. Figure 6 illustrates this result by plotting paths of output and CPI levels based on the model (dashed lines) and the data (solid lines). The differential model-implied responses to an asymmetric financial shock in the home country—the dashed black and purple lines—correspond to the difference in responses from Figure 4 (with the inflation response cumulated to the CPI level) and assume that period 0 equals 2011:Q1. The solid black and purple lines, on the other hand, depict the observed (detrended) real GDP and CPI differentials between between the eurozone core and periphery, respectively. The model and actual output differentials show similar dynamics and comparable peak differentials in the order of three to four percentage points. Similarly, the model-implied differential CPI response closely tracks that observed in the actual data, both in terms of dynamics and magnitude.

[20] As shown in panels (b) and (e) of Figure 5, an important prediction of the model concerns the relative behavior of market shares during the financial crisis. Figure D-5 in Appendix D shows that these model-implied dynamics are in fact consistent with the available data.

5.2 Fiscal Devaluations and Firm Balance Sheet Concerns

What macroeconomic policies can stabilize the periphery's economy in the currency union in the wake of an adverse asymmetric financial shock? As it is well known, a one-size-fits-all monetary policy cannot achieve this goal. Instead, a frequently advocated policy option in response to country-specific shocks in a currency union has been a so-called fiscal devaluation, a policy intended to replicate a nominal exchange rate depreciation in the affected country.[21]

In the presence of financial frictions, a fiscal-devaluation-style policy works differently, though it still achieves the goal of stabilizing economic conditions in the periphery. As shown below, the policy does so through a consumption channel as well as a novel firm balance sheet channel. Because it mitigates predatory pricing by foreign firms and increases aggregate demand in the home country, the policy could also be desirable from a political economy angle in both countries. The firms' balance sheet concerns also explain why, unlike in a conventional fiscal devaluation, the policy does not eliminate the home country's real exchange rate appreciation (see Erceg et al., 2023), which persists despite the stabilizing macroeconomic effects of the policy.

To examine qualitatively the efficacy of a fiscal-devaluation-style policy in the presence of firm balance sheet concerns, we consider a scenario in which the home country introduces a payroll subsidy (ς_t^P) that is financed by a VAT (τ_t^V).[22] This combination of fiscal measures—a reduction in employers' social security contributions, coupled with an increase in the VAT rate imposed in a revenue-neutral manner—received considerable attention in policy circles during the European sovereign debt crisis (see Puglisi, 2014).

Under such policy, the marginal revenue of a home country firm selling its product in the domestic market becomes $(1 - \tau_t^V)p_{h,t}$, while its marginal labor cost is equal to $(1 - \varsigma_t^P)w_t$. We assume that the home country firms are not subject to the same VAT in the foreign country and that the foreign country does not retaliate in response to the unilateral adoption of these fiscal measures by the home country. In addition, we assume that the home government implements these measures to stabilize the economy using the following Taylor-type fiscal rule:

$$\tau_t^V = \frac{\Delta_t}{1 + \Delta_t}, \quad \text{with } \Delta_t = -\alpha^{FD} \ln\left(\frac{y_t}{y}\right),$$

and where $\alpha^{FD} > 0$ is the fiscal reaction coefficient.

[21] Farhi et al. (2014) provide an in-depth analysis of various fiscal policy mixes that can under various asset market conditions replicate these effects. As shown recently by Erceg et al. (2023), the results in Farhi et al. (2014) are more nuanced and depend importantly on how such a policy is assumed to pass through to prices. In particular, a fiscal-devaluation-style policy may lead to a real exchange rate appreciation and not a depreciation. In principle, a complete risk-sharing arrangement, which would also improve the union's overall welfare, could be achieved by forming a fiscal union, a point emphasized by Farhi and Werning (2017). However, the formation of such a union tends to involve large state-contingent transfers of wealth from the foreign country to the home country. In combination with the eurozone's institutional setup, this result underscores the elusive goal of further European integration, as such transfers are unlikely to enjoy broad public support.

[22] We stress the qualitative nature of this exercise because the effectiveness of a fiscal devaluation depends on a variety of country-specific factors: the degree of price/wage rigidities, the degree of price pass-through, the elasticity of labor supply, the size of the economy, its trade openness, and the share of labor as variable production input.

To pin down the level of the payroll subsidy ς_t^P, we impose the following revenue-neutrality constraint:

$$\varsigma_t^P w_t h_t = \tau_t^V (p_{h,t} c_{h,t} + p_{f,t} c_{f,t}),$$

where the left side represents the home government's payroll subsidy expenditures, and the right side is the revenue generated by the VAT. When the home country enters a recession, $\Delta_t > 0$, which makes the export sales of foreign country firms and the domestic sales of the home country firms subject to a VAT rate of $\tau_t^V > 0$. At the same time, the revenue-neutrality constraint implies a payroll subsidy $\varsigma_t^P > 0$, which lowers the marginal labor cost for home country firms to a fraction $1 - \varsigma_t^P$ of the level that prevailed before the implementation of these measures.

In this setting, stabilization is achieved through two channels. First, through a novel firm balance sheet channel that affects both home and foreign firms. And second, through a stabilization of household income and demand. To understand how the first channel affects the pricing behavior of firms, it is useful to consider how such a policy modifies the equity issuance threshold a_t^E, given in equation (7); recall that the higher this threshold, the lower is the likelihood that home country firms will have to issue new equity. With the fiscal-devaluation- style policy, the threshold for home-country firms becomes

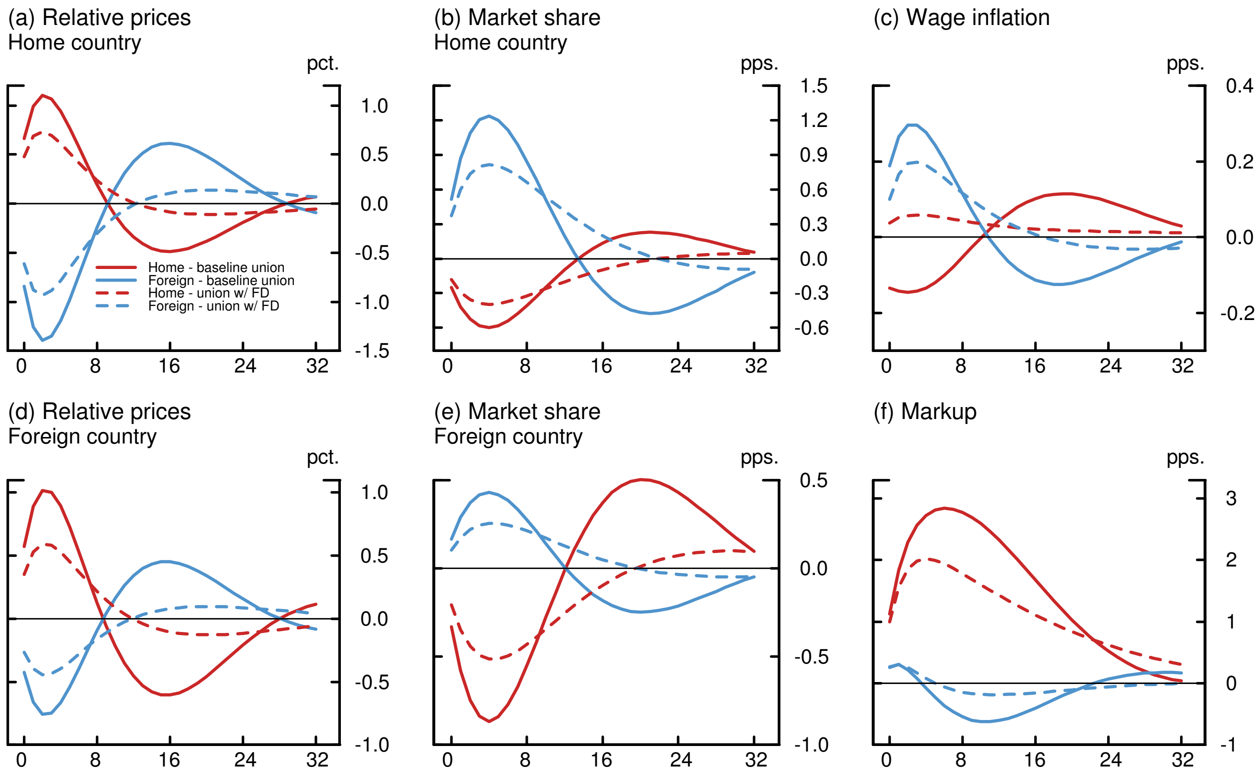
$$a_t^E = \frac{A_t}{(1 - \varsigma_t^P) w_t} \left[\frac{p_{h,t}(1 - \tau_t^V) c_{h,t} + q_t p_{h,t}^* c_{h,t}^*}{(\phi + c_{h,t} + c_{h,t}^*)^{\frac{1}{\alpha}}} \right].$$

An increase in the payroll subsidy ς_t^P improves the internal liquidity positions of home country firms, while raising the VAT rate τ_t^V worsens their liquidity positions. However, because the VAT is applied only to the domestic sales, whereas the payroll subsidy affects the entire wage bill, the improvement in the firms' financial conditions resulting from the payroll subsidy outweighs the negative impact of the VAT. As a result, home country firms do not have to raise relative prices as much as they are forced to do in the baseline monetary union case without a fiscal-devaluation-style policy.[23] A similar threshold applies to foreign firms. However, because foreign firms do not receive a payroll subsidy, but are subject to a VAT on their export sales, their threshold may fall. As a result, they lower their export prices by less than in the absence of the policy.

We illustrate the associated pricing behavior of firms both in the home and the foreign countries in Figure 7. The figure shows the price responses to an asymmetric shock in the home country, while allowing for a fiscal-devaluation-style policy response ($\alpha^{FD} = 3$). As shown by the solid lines in panels (a) and (d), home country firms, in response to the pricing behavior of foreign firms, raise relative prices to maintain cashflows, thus sacrificing their market share at home and abroad (panels (b) and (e)). However, to the extent that the policy improves the financial condition of home country firms, such "defensive" price hikes are now less pronounced in both the domestic and export markets, as evidenced by the corresponding dashed lines. As a result, the loss in the corresponding

[23] If this mix of fiscal policies is not constrained by revenue neutrality and the home country can run a temporary budget deficit, such a unilateral fiscal-devaluations-style policy can provide even greater liquidity support to home country firms.

Figure 7: Fiscal Devaluation – Relative Prices, Wages, and Markups



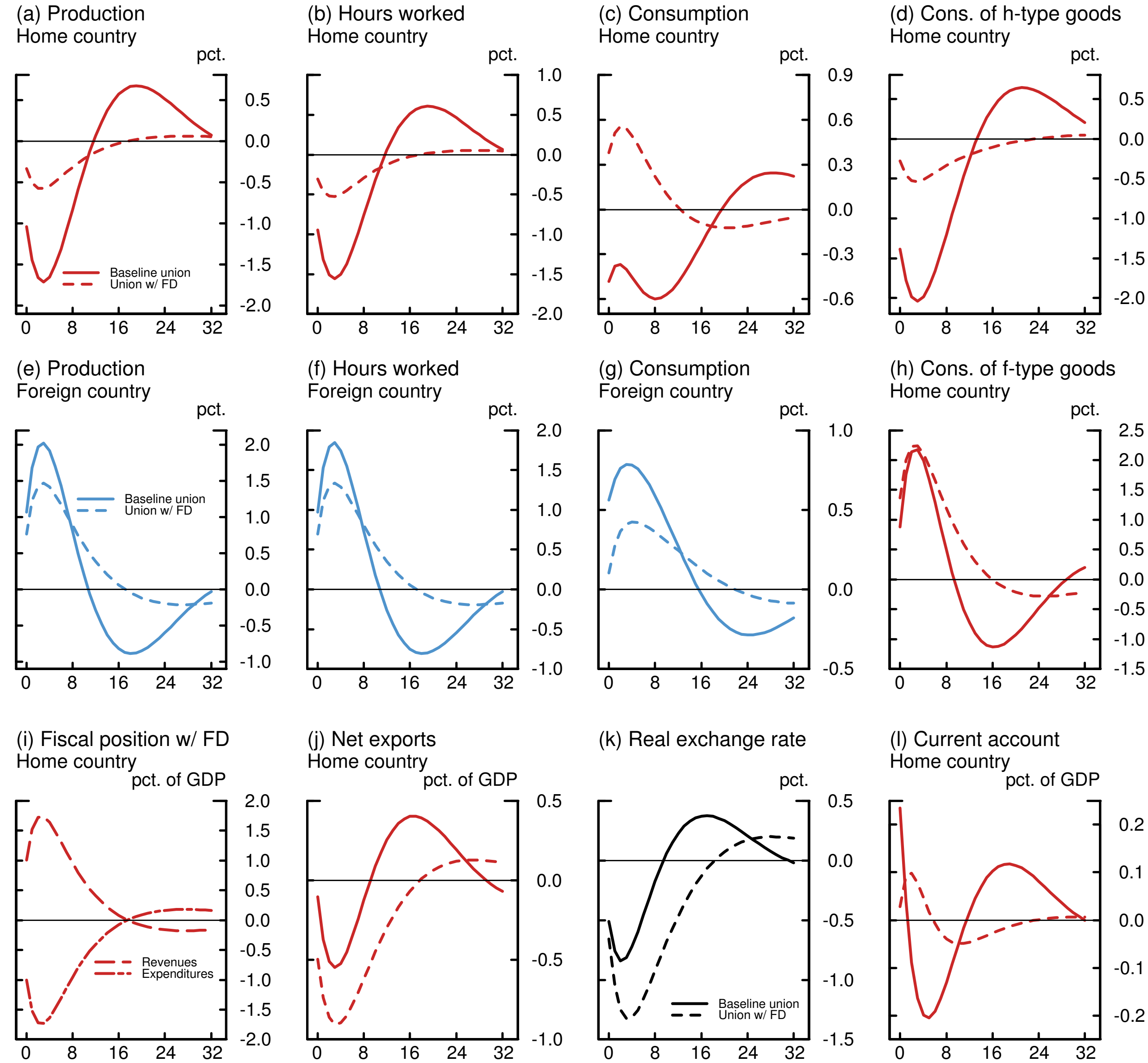
Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0, when the two countries are in a monetary union. The solid red and blue lines show responses from the baseline monetary union case (see Figure 5). The dashed red and blue lines show the corresponding responses when the home country pursues a unilateral fiscal devaluation, with the fiscal reaction coefficient $\alpha^{FD} = 3$ (see the text for details).

market shares is noticeably less severe for home firms. Furthermore, foreign firms do not lower relative prices as much as in the baseline case because such actions would reduce their after-tax revenue too much. These differences in price dynamics are also reflected in the differential behavior of markups: Home country firms set lower markups, while their foreign counterparts choose higher markups than in the baseline case (panel (f)).[24]

The second channel that helps stabilize economic conditions in the home country involves the household side. According to panels (a) and (b) of Figure 8, the policy is very effective at stabilizing production and hours worked in the home country, relative to the baseline monetary union case. In line with these beneficial effects, the payroll subsidy provides further stabilization gains because it increases domestic employment and wages, the most important source of income in the steady

[24]The fact that home country firms choose lower markups does not imply that they also set lower prices in absolute terms. The imposition of the VAT implies that a part of the tax is paid by the representative home country household. This means that the actual price level in the home country can be higher under the fiscal-devaluation-style intervention compared with the baseline monetary union case; and indeed, the initial response of inflation in the home country is slightly greater than in the baseline case.

Figure 8: Fiscal Devaluation – Macroeconomic Implications



Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0, when the two countries are in a monetary union. Unless noted otherwise, the solid red and blue lines show responses from the baseline monetary union case (see Figure 4), while the dashed red and blue lines show the corresponding responses when the home country pursues a unilateral fiscal devaluation, with the fiscal reaction coefficient $\alpha^{FD} = 3$ (see the text for details). The real exchange rate (panel (k)) is expressed as home currency relative to foreign currency.

state. Importantly, the payroll subsidy is paid for by an increase in the VAT rate, which is only partially financed by domestic consumers.

Panel (i) shows that under revenue neutrality, fiscal expenditures due to the payroll subsidy (expressed as negative cashflow for the home country's government) are exactly offset by an increased revenue from the introduction of the VAT. Given the small degree of home bias in our baseline calibration, roughly one-half of the revenue raised by the VAT is paid for by domestic consumers, with the other half being paid for by foreign firms. On balance, therefore, the combination of the payroll subsidy and VAT results in a positive income shock in the home country—the unilateral fiscal-devaluation-style intervention by the home country is akin to an *expansionary* domestic fiscal policy under a *balanced budget* trajectory.

As shown in panel (c), this expansionary fiscal policy provides a significant stimulus to home consumption. Aggregate consumption now increases, while in the monetary union without the fiscal-policy intervention, it falls. This response reflects two forces. First, despite the imposition of the VAT, the decline in consumption of domestically produced (i.e., h-type) goods is considerably attenuated relative to the baseline case. Second, the consumption of imported (i.e., f-type) goods increases further (panels (d) and (h)). As a result, the home country's trade deficit worsens and the real exchange rate appreciates even more than in the baseline monetary union case (panels (j) and (k)). However, as shown in panel (l), the home country's current account balance (expressed as a percent of initial GDP) registers a modest surplus under this policy. Because the marginal propensity to consume in response to a temporary increase in income is less than unity, the fiscal devaluation leads to an increase in domestic savings. It also leads to an appreciation of the real exchange rate, a deterioration in the trade balance, and an improvement in the home country's external capital position.

Finally, firm balance sheet concerns can provide a new rationale for the foreign country to agree to a unilateral fiscal-devaluation intervention by the home country. As shown, such a fiscal-devaluation policy lessens predatory pricing by foreign firms, eliminating the negative demand externality such behavior imposes on firms in the periphery and on the union-wide demand. The fiscal-devaluation-style policy also helps to stabilize foreign economic activity, though to a lesser extent than in the home country.

The combination of an appreciably less negative output gap in the home country and a smaller positive gap in the foreign country implies a stronger monetary policy response relative to the baseline case. At the same time, lower foreign inflation—reflecting lower markups of both foreign firms and home country exporters—results in a higher real interest rate in the foreign country (about 80 basis points at an annual rate) relative to the baseline case. In turn, this reduces the volatility of consumption and hours worked and points to potential foreign welfare gains as the home country pursues a unilateral fiscal devaluation in order to stabilize its macroeconomy in the wake of a financial shock.

6 Conclusion

This paper introduces financial frictions and customer markets into the conventional two-country open-economy framework: Firms operate in customer markets, both domestically and abroad; and foreign and domestic financial markets are subject to differing degrees of distortions. Because of customer-market considerations, financial shocks affect the firms' pricing decisions, thereby influencing the dynamics of markups and market shares—and therefore patterns of external adjustment—across countries.

When applied to the 2010–12 eurozone crisis, this new framework helps explain several empirical regularities that are difficult to reconcile using conventional international macroeconomic models. First, the pricing mechanism implied by the interaction of financial frictions and customer-market considerations is consistent with the empirical evidence, which shows that the tightening of financial conditions in the euro area periphery between 2008 and 2013 significantly attenuated the downward pressure on prices arising from the emergence of substantial and long-lasting economic slack. And second, this tightening of financial conditions is strongly associated with an increase in price markups in the periphery, which stands in sharp contrast to markup dynamics implied by conventional models, whereby firms absorb the impact of adverse shocks through lower markups.

In the model, the pricing behavior of firms in the core in response to a financial shock in the periphery implies a real exchange rate appreciation in the periphery vis-à-vis the core. In turn, this causes an export-driven boom in the latter and a deepening of the recession in the former. The one-size-fits-all aspect of monetary policy in a common currency regime is especially ill-suited to address such divergent economic outcomes. As an alternative, we analyze macroeconomic stabilization properties of a unilateral fiscal devaluation by the periphery.

In the presence of financial frictions, a fiscal devaluation by the periphery works differently than in a conventional setup, though it is still effective in stabilizing economic conditions in the periphery. The policy works through a consumption channel as well as a novel firm balance sheet channel. Because it mitigates predatory pricing by foreign firms and boosts aggregate demand, the policy is potentially desirable from a political economy angle in both countries. The balance sheet concerns of periphery firms experiencing financial distress also explain why, unlike in a conventional fiscal devaluation, such policy fails to eliminate the real exchange rate appreciation of the periphery vis-à-vis the core.

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Appendix

A Phillips Curves in the Euro Area

Table A-1 contains the parameter estimates of specifications (1)–(3) in the main text. To ensure that the estimates are not unduly influenced by the extraordinary events surrounding the eurozone crisis, we end the estimation in 2007, that is, well before the onset of the crisis in the euro area. In columns (1) and (4), we report the baseline estimates of the coefficients of the standard price and wage Phillips curves, respectively—these specifications allow the regression coefficients to differ between the core an periphery countries. In columns (2) and (5), we repeat the same exercise, except that we allow the coefficients on the unemployment gap $(u_{i,t} - \bar{u}_{i,t})$ to differ across *individual* countries, rather than just between the periphery and core regions; in that case, we report an average of the estimated country-specific coefficients. And lastly, column (3) reports coefficient estimates of the NKPC with region-specific coefficients, using the output gap $(y_{i,t} - \bar{y}_{i,t})$ as a proxy for marginal cost. Specifications in columns (1), (2), (4), and (5) are estimated by OLS. The NKPC in column (3) is estimated by GMM, treating $(y_{i,t} - \bar{y}_{i,t})$ and $E_t\pi_{i,t+1}$ as endogenous and instrumented with lags 1 to 3 of $(y_{i,t} - \bar{y}_{i,t})$ and $\pi_{i,t}$, and lags 0 to 2 of the log-difference of commodity prices.

As shown in columns (1), (2), (4), and (5), the degree of labor market slack is an economically and statistically important determinant of price and wage inflation dynamics in all four standard Phillips curve specifications. The estimated sensitivity of both price and wage inflation to tightness of labor market conditions is, on average, somewhat higher in specifications (2) and (5), which allow for a greater degree of heterogeneity in the price and wage inflation processes across countries. All four specifications, however, explain about the same proportion of the variability in annual price and wage inflation rates across our sample of 11 euro area countries. The estimates of the NKPC in column (3) also indicate an economically significant effect of the output gap—our proxy for marginal cost—on inflation outcomes. This effect, however, is estimated with considerably less precision, compared with the estimated sensitivity of inflation to labor market slack implied by the standard Phillips curve specifications.

Table A-1: Price and Wage Phillips Curves in the Euro Area

Explanatory Variables	Prices[a] (1)	Prices[a] (2)	Prices[a] (3)	Wages[b] (4)	Wages[b] (5)
$(u_{i,t} - \bar{u}_{i,t}) \times \mathbb{1}[i \in \text{C}]$	−0.432	−0.770	.	−0.818	−0.862
	(0.148)	(0.161)		(0.126)	(0.124)
$(u_{i,t} - \bar{u}_{i,t}) \times \mathbb{1}[i \in \text{P}]$	−0.207	−0.312	.	−0.503	−0.555
	(0.113)	(0.153)		(0.127)	(0.194)
$(y_{i,t} - \bar{y}_{i,t}) \times \mathbb{1}[i \in \text{C}]$	.	.	0.173	.	.
			(0.066)	.	.
$(y_{i,t} - \bar{y}_{i,t}) \times \mathbb{1}[i \in \text{P}]$	.	.	0.179	.	.
			(0.096)	.	.
$\pi_{i,t-1} \times \mathbb{1}[i \in \text{C}]$	0.784	0.779	0.466	0.654	0.664
	(0.083)	(0.082)	(0.076)	(0.056)	(0.083)
$\pi_{i,t-1} \times \mathbb{1}[i \in \text{P}]$	0.860	0.839	0.601	0.730	0.591
	(0.045)	(0.044)	(0.099)	(0.084)	(0.167)
$E_t\pi_{i,t+1} \times \mathbb{1}[i \in \text{C}]$	.	.	0.578	.	.
			(0.101)		
$E_t\pi_{i,t+1} \times \mathbb{1}[i \in \text{P}]$	.	.	0.365	.	.
			(0.108)		
$\Delta\tilde{z}_{i,t} \times \mathbb{1}[i \in \text{C}]$	.	.	.	0.906	0.866
				(0.082)	(0.083)
$\Delta\tilde{z}_{i,t} \times \mathbb{1}[i \in \text{P}]$	.	.	.	0.698	0.591
				(0.186)	(0.167)
$\Delta\text{VAT}_{i,t} \times \mathbb{1}[i \in \text{C}]$	0.030	0.015	−0.024	.	.
	(0.033)	(0.033)	(0.017)		
$\Delta\text{VAT}_{i,t} \times \mathbb{1}[i \in \text{P}]$	0.208	0.173	0.125	.	.
	(0.110)	(0.101)	(0.071)		
$\mathbb{1}[i \in €] \times \mathbb{1}[i \in \text{C}]$	−0.637	−0.721	−0.268	−0.369	−0.443
	(0.320)	(0.334)	(0.196)	(0.223)	(0.228)
$\mathbb{1}[i \in €] \times \mathbb{1}[i \in \text{P}]$	−0.724	−0.682	−0.517	−2.886	−2.576
	(0.444)	(0.485)	(0.248)	(0.800)	(0.743)
Adj. R^2	0.843	0.845	.	0.873	0.877
Pr > J[c]	.	.	0.173	.	.
Equal coeff. on $(u_{i,t} - \bar{u}_{i,t})$[d]	.	<.001	.	.	0.003

Note: In columns (1), (2), and (3), the dependent variable is $\pi_{i,t}$, the log-difference of the GDP price deflator of country i; in columns (4) and (5), the dependent variable is $\pi^w_{i,t}$, the log-difference of (nominal) compensation per employee of country i. Explanatory variables: $(u_{i,t} - \bar{u}_{i,t})$ = unemployment gap; $(y_{i,t} - \bar{y}_{i,t})$ = output gap; $\Delta\tilde{z}_{i,t}$ = growth rate of trend labor productivity; $\text{VAT}_{i,t}$ = effective VAT rate; and $\mathbb{1}[i \in €]$ = indicator variable that equals 1 once country i joined the eurozone. All specifications include country fixed effects; those in columns (1), (2), (4), and (5) are estimated by OLS, while the specification in column (3) is estimated by GMM. In columns (2) and (5), the coefficients on the unemployment gap are allowed to differ across the 11 countries, and the entries correspond to the average of the estimated OLS coefficients across the six core countries (i.e., $\mathbb{1}[i \in \text{C}]$) and the five periphery countries (i.e., $\mathbb{1}[i \in \text{P}]$). Asymptotic standard errors reported in parentheses are clustered in the time dimension.

[a] Annual data: from 1970 to 2007 ($\bar{T} = 29.7$); No. of countries = 11; Obs. = 327.

[a] Annual data: 1971 to 2007 ($\bar{T} = 26.1$); No. of countries = 11; Obs. = 287.

[c] p-value for the Hansen (1982) J-test of the over-identifying restrictions.

[d] p-value for the test of equality of country-specific coefficients on $(u_{i,t} - \bar{u}_{i,t})$.

B Technical Model Details

B.1 Firms

This section lays out technical details underlying the firm's optimization problem and the implied pricing dynamics.

The firm's problem: As noted in the main text, the firm's objective is to maximize the present value of its dividend flow, $\mathbb{E}_t\big[\sum_{s=0}^{\infty} m_{t,t+s} d_{i,t+s}\big]$, where $d_{i,t} = D_{i,t}/P_t$ is the real dividend payout when positive and real equity issuance when negative. Firms are owned by households, and they discount future cashflows using the stochastic discount factor of the representative household, denoted by $m_{t,t+s}$, in their respective country.

Before formally stating the firm's optimization problem and the implications for price setting, it is helpful to define relative prices in the open-economy setting, a distinct though rather notational feature relative to the closed-economy setup of GSSZ. Individual product prices relative to the CPIs in home and foreign countries can be written as

$$\frac{P_{i,h,t}}{P_t} = \frac{P_{i,h,t}}{P_{h,t}}\frac{P_{h,t}}{P_t} \equiv p_{i,h,t}p_{h,t} \quad \text{and} \quad \frac{P^*_{i,h,t}}{P^*_t} = \frac{P^*_{i,h,t}}{P^*_{h,t}}\frac{P^*_{h,t}}{P^*_t} \equiv p^*_{i,h,t}p^*_{h,t}.$$

Note that $p_{i,h,t}$ and $p^*_{i,h,t}$ are prices charged by home country firm i relative to the average price level chosen by the home country firms in the home and foreign markets, respectively; $p_{h,t}$ and $p^*_{h,t}$, on the other hand, are the average price levels relative to the CPI in the home and foreign markets, respectively and as such are taken as given by individual firms. From the perspective of firms in the foreign country, the relative prices $p_{i,f,t}$, $p^*_{i,f,t}$, $p_{f,t}$, and $p^*_{f,t}$ are interpreted in the same way.

A home country firm maximizes the present value of real dividends, subject to a flow-of-funds constraint, taking into account both home and foreign demand, as well as (quadratic) price adjustment costs:

$$\begin{aligned} d_{i,t} &= p_{i,h,t}p_{h,t}c_{i,h,t} + q_t p^*_{i,h,t}p^*_{h,t}c^*_{i,h,t} - w_t h_{i,t} + \varphi \min\{0, d_{i,t}\} \\ &\quad - \frac{\gamma_p}{2}\left(\frac{p_{i,h,t}}{p_{i,h,t-1}}\pi_{h,t} - 1\right)^2 c_t - \frac{\gamma_p}{2} q_t \left(\frac{p^*_{i,h,t}}{p^*_{i,h,t-1}}\pi^*_{h,t} - 1\right)^2 c^*_t, \end{aligned}$$

where $w_t = W_t/P_t$ is the real wage, $q_t = Q_t P^*_t/P_t$ is the real exchange rate, and $\pi_{h,t} = P_{h,t}/P_{h,t-1}$ and $\pi^*_{h,t} = P^*_{h,t}/P^*_{h,t-1}$ are the market-specific (gross) inflation rates faced by firms in the home country. An analogous problem applies to foreign firms.

Formally, a home country firm is choosing $\{d_{i,t}, h_{i,t}, c_{i,h,t}, c^*_{i,h,t}, s_{i,h,t}, s^*_{i,h,t}, p_{i,h,t}, p^*_{i,h,t}\}_{t=0}^{\infty}$ to optimize the following Lagrangian:

$$\begin{aligned} \mathcal{L} = \mathbb{E}_0 \sum_{t=0}^{\infty} m_{0,t} \Bigg\{ & d_{i,t} + \kappa_{i,t}\left[\left(\frac{A_t}{a_{i,t}}h_{i,t}\right)^{\alpha} - \phi - (c_{i,h,t} + c^*_{i,h,t})\right] \\ & + \xi_{i,t}\Bigg[p_{i,h,t}p_{h,t}c_{i,h,t} + q_t p^*_{i,h,t}p^*_{h,t}c^*_{i,h,t} - w_t h_{i,t} - d_{i,t} + \varphi\min\{0, d_{i,t}\} \\ & - \frac{\gamma_p}{2}\left(\frac{p_{i,h,t}}{p_{i,h,t-1}}\pi_{h,t} - 1\right)^2 c_t - \frac{\gamma_p}{2} q_t\left(\frac{p^*_{i,h,t}}{p^*_{i,h,t-1}}\pi^*_{h,t} - 1\right)^2 c^*_t\Bigg] \\ & + \nu_{i,h,t}\left[(p_{i,h,t})^{-\eta}\tilde{p}^{\eta}_{h,t}s^{\theta(1-\eta)}_{i,h,t-1}x_{h,t} - c_{i,h,t}\right] + \nu^*_{i,h,t}\left[(p^*_{i,h,t})^{-\eta}\tilde{p}^{*\eta}_{h,t}s^{*\theta(1-\eta)}_{i,h,t-1}x^*_{h,t} - c^*_{i,h,t}\right] \\ & + \lambda_{i,h,t}\left[\rho s_{i,h,t-1} + (1-\rho)c_{i,h,t} - s_{i,h,t}\right] + \lambda^*_{i,h,t}\left[\rho s^*_{i,h,t-1} + (1-\rho)c^*_{i,h,t} - s^*_{i,h,t}\right]\Bigg\}, \end{aligned} \tag{B-1}$$

where $\tilde{p}_{h,t} = \tilde{P}_{h,t}/P_{h,t}$ and $\tilde{p}^*_{h,t} = \tilde{P}^*_{h,t}/P^*_{h,t}$; $\kappa_{i,t}$ and $\xi_{i,t}$ are the Lagrange multipliers associated with the production constraint and the flow-of-funds constraint, respectively; $\nu_{i,h,t}$ and $\nu^*_{i,h,t}$ are the Lagrange multipliers associated with the domestic and foreign demand constraints; and $\lambda_{i,h,t}$ and $\lambda^*_{i,h,t}$ are the multipliers associated with the domestic and foreign habit accumulation processes.[25]

We begin by describing the firm's optimal choice of labor hours and dividends (or equity issuance), two decisions that are made *after* the realization of the idiosyncratic cost shock $a_{i,t}$. In contrast to these two decisions, the optimality conditions for prices $(p_{i,h,t}, p^*_{i,h,t})$, production orders $(c_{i,h,t}, c^*_{i,h,t})$, and habit stocks $(s_{i,h,t}, s^*_{i,h,t})$ in the domestic and foreign markets are determined prior to the realization of the idiosyncratic cost shock. For maximum intuition, we present the case without sticky prices, while in the main text we discuss the implications of the model for inflation and the Phillips curve in an environment where firms face quadratic costs of changing prices.

The efficiency condition for labor hours in problem (B-1) is given by

$$a_{i,t}\xi_{i,t}w_t = \kappa_{i,t}\alpha A_t \left(\frac{A_t}{a_{i,t}}h_{i,t}\right)^{\alpha-1}, \tag{B-2}$$

where given the production function, labor hours satisfy the conditional labor demand:[26]

$$h_{i,t} = \frac{a_{i,t}}{A_t}(\phi + c_{i,h,t} + c^*_{i,h,t})^{\frac{1}{\alpha}}. \tag{B-3}$$

Our timing assumptions imply that $c_{i,h,t}$ and $c^*_{i,h,t}$ are determined prior to the realization of the idiosyncratic cost shock $a_{i,t}$. Combining equations (B-2) and (B-3), applying the expectation operator $\mathbb{E}^a_t[x] \equiv \int x dF(a)$ to both sides of the resulting expression, and dividing through by $\mathbb{E}^a_t[\xi_{i,t}]$ yields the following expression for the expected real marginal cost normalized by the expected shadow value of internal funds:

$$\frac{\mathbb{E}^a_t[\kappa_{i,t}]}{\mathbb{E}^a_t[\xi_{i,t}]} = \frac{\mathbb{E}^a_t[a_{i,t}\xi_{i,t}]}{\mathbb{E}^a_t[\xi_{i,t}]}\frac{w_t}{\alpha A_t}(\phi + c_{i,h,t} + c^*_{i,h,t})^{\frac{1-\alpha}{\alpha}}. \tag{B-4}$$

To understand the economic content behind this expression, consider first the case with no financial frictions. In this case, the shadow value of internal funds $\xi_{i,t} = 1$, for all i and t, implying that $\mathbb{E}^a_t[\xi_{i,t}] = 1$ and $\mathbb{E}^a_t[a_{i,t}\xi_{i,t}] = \mathbb{E}^a_t[a_{i,t}]\mathbb{E}^a_t[\xi_{i,t}] = 1$. With constant returns-to-scale for example, $\mathbb{E}^a_t[\kappa_{i,t}] = w_t/A_t$ and expected marginal cost equals unit labor costs.

In the presence of financial frictions, however, the shadow value of internal funds is not always equal to one and becomes stochastic, according to the realization of the idiosyncratic cost shock $a_{i,t}$, which influences the liquidity position of the firm. The first-order condition for dividend payouts (or equity issuance) implies that

$$\xi_{i,t} = \begin{cases} 1 & \text{if } d_{i,t} \geq 0; \\ 1/(1-\varphi) & \text{if } d_{i,t} < 0. \end{cases} \tag{B-5}$$

In other words, the shadow value of internal funds is equal to one when the firm's revenues are sufficiently high to cover labor and fixed costs, and thus the firm pays dividends. If, however, the

[25] The reader may wonder whether the presence of the "min" operator in the firm's optimization problem renders our use of linear solution methods (noted in the main text) inapplicable. This concern, however, does not apply in our setup because firms decide what prices to charge *before* the realization of the idiosyncratic cost shocks. As a result, the firm's pricing decision is based on $E[\min\{0, d_{i,t}\}]$, which is a smooth object.

[26] This conditional labor demand ensures a symmetric equilibrium, in which all firms produce an identical level of output regardless of their productivity. Relatively inefficient firms, however, have to hire more labor to produce the same level of output than their more efficient counterparts, which exposes them to ex post liquidity risk.

firm incurs an operating loss, it must issue new equity, and the shadow value of internal funds jumps to $1/(1-\varphi)$. Intuitively, given the equity dilution costs, a firm must issue $1/(1-\varphi)$ units of equity to obtain one unit of cashflow. These conditions imply that $\mathbb{E}_t^a[\xi_{i,t}] > 1$.

It is also the case that the realized shadow value of internal funds covaries positively with the idiosyncratic cost shock $a_{i,t}$, as profits and hence dividends are negative when costs are high. Because $\mathbb{E}_t^a[a_{i,t}] = 1$, this implies

$$\frac{\mathbb{E}_t^a[\xi_{i,t}a_{i,t}]}{\mathbb{E}_t^a[\xi_{i,t}]} = 1 + \frac{\text{Cov}[\xi_{i,t}, a_{i,t}]}{\mathbb{E}_t^a[\xi_{i,t}]} > 1.$$

Because of this positive covariance, the firm's ex ante internal valuation of marginal cost, $\mathbb{E}_t^a[\xi_{i,t}a_{i,t}]$, exceeds its ex ante valuation of marginal revenue, $\mathbb{E}_t^a[\xi_{i,t}]$, and financial frictions raise the real marginal cost given by equation (B-4). In effect, the firm must be compensated for the liquidity premium associated with costly external finance, and this required compensation increases its marginal cost, inclusive of financing costs.

Optimal pricing in a symmetric equilibrium: Based on the above optimality conditions, we now derive the implications for price setting in the open-economy setup. In doing so, we focus on an equilibrium that has a number of symmetric features. In particular, because firms are risk-neutral firms and face i.i.d. idiosyncratic costs shocks, the timing of production decisions prior to cost realizations implies that all firms in a given country are identical ex ante. As a result, all home country firms choose identical relative prices ($p_{i,h,t} = 1$ and $p^*_{i,h,t} = 1$), scales of production ($c_{i,h,t} = c_{h,t}$ and $c^*_{i,h,t} = c^*_{h,t}$), and habit stocks ($s_{i,h,t} = s_{h,t}$ and $s^*_{i,h,t} = s^*_{h,t}$). The symmetric equilibrium condition $p_{i,h,t} = p^*_{i,h,t} = 1$ implies that firms in the home country set the same relative prices in domestic and foreign markets vis-à-vis other competitors from the same origin.[27] Similarly, foreign firms make pricing decisions among themselves, both in the domestic and foreign markets, such that $p_{i,f,t} = p^*_{i,f,t} = 1$.

The asymmetric nature of financial conditions imposed below induces differences in the firms' internal liquidity positions and causes home and foreign firms to adopt different pricing policies. As a result, $p_{h,t} = P_{h,t}/P_t \neq 1$, $p^*_{h,t} = P^*_{h,t}/P^*_t \neq 1$, $p_{f,t} = P_{f,t}/P_t \neq 1$, and $p^*_{f,t} = P^*_{f,t}/P^*_t \neq 1$, implying that $p_{h,t} \neq p_{f,t}$ and $p^*_{h,t} \neq p^*_{f,t}$, in general. As we show below, the relatively weaker financial position of home firms forces them to maintain higher prices and markups in the neighborhood of the nonstochastic steady state, such that $p_h > p_f$ and $p^*_h > p^*_f$.

Imposing the relevant symmetric equilibrium conditions, the firm's internal funds are given by revenues less production costs:

$$p_{h,t}c_{h,t} + q_t p^*_{h,t}c^*_{h,t} - w_t \frac{a_{i,t}}{A_t}\left(\phi + c_{h,t} + c^*_{h,t}\right)^{\frac{1}{\alpha}},$$

where we have substituted conditional labor demand for h_t (see equation B-3). In this open-economy setting, both foreign and home market conditions are related to domestic fixed operating costs ϕ and costs $a_{i,t}$. The firm resorts to costly external finance—that is, issues new shares—if and only if

$$a_{i,t} > a_t^E \equiv \frac{A_t}{w_t}\left[\frac{p_{h,t}c_{h,t} + q_t p^*_{h,t}c^*_{h,t}}{\left(\phi + c_{h,t} + c^*_{h,t}\right)^{\frac{1}{\alpha}}}\right]. \tag{B-6}$$

[27] Recall that $p_{i,h,t}$ and $p^*_{i,h,t}$ are relative prices measured against average prices charged by firms in the home country. These are different from the relative prices against local and foreign CPIs, which are averages of prices of both domestic and imported goods.

Using the above definition of the equity issuance threshold a_t^E, one can express the first-order conditions for dividends as follows:

$$\xi_{i,t} = \begin{cases} 1 & \text{if } a_{i,t} \le a_t^E; \\ 1/(1-\varphi) & \text{if } a_{i,t} > a_t^E, \end{cases}$$

which states that because of costly external financing, the shadow value of internal funds jumps from one to $1/(1-\varphi) > 1$ when the realization of the idiosyncratic cost shock $a_{i,t}$ exceed the threshold value a_t^E.

Taking expectations, the expected shadow value of internal funds is given by

$$\mathbb{E}_t^a[\xi_{i,t}] = \int_0^{a_t^E} dF(a) + \int_{a_t^E}^{\infty} \frac{1}{1-\varphi} dF(a) = 1 + \frac{\varphi}{1-\varphi}\left[1 - \Phi(z_t^E)\right] \ge 1,$$

where $\Phi(\cdot)$ denotes the standard normal CDF, and the expected shadow value of internal funds is strictly greater than one as long as equity issuance is costly ($\varphi > 0$) and future costs are uncertain ($\sigma > 0$).

Imposing symmetric equilibrium conditions, we can express the firm's optimal pricing strategies in the domestic and foreign markets in the absence of nominal pricing frictions as follows:

$$p_{h,t} = \frac{\eta}{\eta-1}\frac{1}{\tilde{\mu}_t} + (1-\rho)\theta\eta\mathbb{E}_t\left[\sum_{s=t+1}^{\infty} \beta_{h,t,s}\frac{\mathbb{E}_s^a[\xi_{i,s}]}{\mathbb{E}_t^a[\xi_{i,t}]}\left(p_{h,s} - \frac{1}{\tilde{\mu}_s}\right)\right]; \tag{B-7}$$

$$q_t p_{h,t}^* = \frac{\eta}{\eta-1}\frac{1}{\tilde{\mu}_t} + (1-\rho)\theta\eta\mathbb{E}_t\left[\sum_{s=t+1}^{\infty} \beta_{h,t,s}^*\frac{\mathbb{E}_s^a[\xi_{i,s}]}{\mathbb{E}_t^a[\xi_{i,t}]}\left(q_s p_{h,s}^* - \frac{1}{\tilde{\mu}_s}\right)\right], \tag{B-8}$$

where the growth-adjusted, compounded discount factors, $\beta_{h,t,s}$ and $\beta_{h,t,s}^*$, are given by

$$\beta_{h,t,s} = \begin{cases} m_{s-1,s}g_{h,s} & \text{if } s = t+1; \\ m_{s-1,s}g_{h,s} \times \prod_{j=1}^{s-(t+1)}(\rho + \chi g_{h,t+j})m_{t+j-1,t+j} & \text{if } s > t+1; \end{cases}$$

$$\beta_{h,t,s}^* = \begin{cases} m_{s-1,s}g_{h,s}^* & \text{if } s = t+1; \\ m_{s-1,s}g_{h,s}^* \times \prod_{j=1}^{s-(t+1)}(\rho + \chi g_{h,t+j}^*)m_{t+j-1,t+j} & \text{if } s > t+1, \end{cases}$$

and where $g_{h,t} = \frac{s_{h,t}/s_{h,t-1}-\rho}{1-\rho}$, $g_{h,t}^* = \frac{s_{h,t}^*/s_{h,t-1}^*-\rho}{1-\rho}$, and $\chi = (1-\rho)\theta(1-\eta) > 0$.

In the absence of customer-market relationships (i.e., $\theta = 0$), the second term on the right-hand sides of equations (B-7) and (B-8) disappears, and we obtain the standard pricing equation for a static monopolist facing isoelastic demand: The price is equal to a constant markup, $\frac{\eta}{\eta-1}$, over current marginal cost, inclusive of financing costs. With customer markets (i.e., $\theta < 0$), prices are, on average, strictly lower than those that would have been set by the static monopolist because firms have an incentive to lower prices in order to expand their market shares.

Financial frictions create a tension between the firm's desire to expand its market share and its desire to maintain adequate internal liquidity. The terms inside the square brackets of equations (B-7) and (B-8) represent the present values of future profits. When expanding market shares becomes more important, which happens through the increase in the growth-adjusted, compounded discount factors $\beta_{h,t,s}$ and $\beta_{h,t,s}^*$, the firm has a greater incentive to reduce prices because $\theta < 0$. However, when the firm faces a liquidity problem in the sense that the shadow value of internal funds today is strictly greater than its future values—that is, $\mathbb{E}_t^a[\xi_{i,t}] > \mathbb{E}_t^a[\xi_{i,s}]$, for $s > t$—the firm discounts future profits more heavily. This in turn leads to a higher price than would otherwise prevail.

Lastly, it is worth noting that in our model, the short-run demand elasticity is less than its long-run counterpart because of customer markets. If the firm discounted the future completely, it would set price as a constant markup, $\frac{\eta}{\eta-1}$, over its current marginal cost $\tilde{\mu}_t$. Such a markup reflects entirely the low short-run demand elasticity. A firm that fully disregards financial considerations, in contrast, would set a substantially lower markup, consistent with the lower long-run demand elasticity that prevails because of the competition for future market share. As the firm encountering a liquidity problem begins to discount the future more heavily, its pricing strategy shifts towards the higher markup associated with the inelastic short-run demand, relative to the optimal long-run markup that fully captures these customer-market considerations.

To see this, define

$$\Theta = \frac{\delta(\rho+\chi)(1-\rho)\theta\eta}{1-\delta(\rho+\chi)},$$

and solve equation (B-7) for the long-run relative price p_h, which yields

$$p_h = \left[1 + \frac{1}{(\eta-1)(1-\Theta)}\right]\frac{1}{\tilde{\mu}}.$$

This equation shows that the long-run relative price p_h is equal to the gross markup over real marginal cost, where the net markup is equal to $\frac{1}{(\eta-1)(1-\Theta)}$. For the net markup to be positive, we need to impose a condition $\frac{1}{(\eta-1)(1-\Theta)} > 0$; because $\eta > 1$, this is equivalent to $\Theta < 1$. In our calibration of the model, this condition is easily satisfied, and the long-run net markup is about seven percent substantially below its short-run value of $\frac{\eta}{\eta-1}$, that is, 100 percent.

B.2 Households

This section lays out the representative household's optimization problem. We first formulate the problem in an environment of flexible exchange rates and independent monetary authorities in the home and foreign countries; we then impose the necessary restrictions that deliver the baseline model of a monetary union and a single central bank.

Flexible exchange rates: The representative household in the home country works h_t hours, earning an hourly wage W_t. It allocates its savings between shares of the home country firms and international bonds that are not state contingent. We denote the home country's holdings of international bonds issued in home and foreign currency units by $B_{h,t+1}$ and $B_{f,t+1}$, respectively, while $B^*_{h,t+1}$ and $B^*_{f,t+1}$ denote their foreign counterparts.[28] The respective (gross) nominal interest rates on these securities are denoted by R_t and R^*_t.

We assume that investors in both countries face identical portfolio rebalancing costs, denoted by $\tau > 0$. Focusing on the home country, these costs are given by

$$\frac{\tau}{2}P_t\left[\left(\frac{B_{h,t+1}}{P_t}\right)^2 + q_t\left(\frac{B_{f,t+1}}{P^*_t}\right)^2\right].$$

Under these assumptions, the marginal cost of borrowing in home currency is given by $R_t/(1+\tau B_{h,t+1}/P_t)$, which is strictly greater than R_t if $B_{h,t+1} < 0$. The marginal return on foreign lending

[28] Our notation implies that $B_{h,t+1} + B^*_{h,t+1} = 0$, where $B_{h,t+1}$ and $B^*_{h,t+1}$ are denominated in home currency—as denoted by the subscript h—and are held by the home and foreign country residents, respectively. If $B_{h,t+1} < 0$ ($B_{f,t+1} < 0$), the home country borrows money in home currency units (in foreign currency units) from the foreign country, whose claim is $B^*_{h,t+1} > 0$ ($B^*_{f,t+1} > 0$).

in home currency is given by $R_t(Q_t/Q_{t+1})/(1+\tau B^*_{h,t+1}/P^*_t)$, which is strictly less than $R_t(Q_t/Q_{t+1})$ if $B^*_{h,t+1} > 0$. Thus, $(1+\tau B_{h,t+1}/P_t)^{-1}$ represents a welfare loss, not only to the borrowers, but also to the lenders. As pointed out by Ghironi and Melitz (2005), the role of such portfolio rebalancing costs is to pin down the steady-state levels of international bond holdings, as varying τ does not modify the model dynamics in any significant way.

The number of outstanding shares of home country firm i is denoted by $S_{i,t}$, while $P^s_{i,t-1,t}$ is the period-t per-share value of the shares outstanding as of period $t-1$ and $P^s_{i,t}$ is the (ex-dividend) per-share value of shares in period t. Using the fact that $\int_{N_k} P_{i,k,t}c_{i,k,t}di = \tilde{P}_{k,t}x_{k,t}$, for $k = h, f$, we can express the household's budget constraint as

$$\begin{aligned} 0 &= W_t h_t + R_{t-1}B_{h,t} + Q_t R^*_{t-1}B_{f,t} \\ &+ \int_{N_h} \left[\max\{D_{i,t}, 0\} + P^s_{i,t-1,t}\right] S^s_{i,t}di - \tilde{P}_t x_t - B_{h,t+1} - Q_t B_{f,t+1} \\ &- \frac{\tau}{2}P_t\left[\left(\frac{B_{h,t+1}}{P_t}\right)^2 + q_t\left(\frac{B_{f,t+1}}{P^*_t}\right)^2\right] - \int_{N_h} P^s_{i,t}S^s_{i,t+1}di. \end{aligned} \tag{B-9}$$

The consumption expenditure problem is expressed as purchasing the habit-adjusted consumption bundle x_t using the price index $\tilde{P}_t$, which is possible because $\tilde{P}_t$ is a welfare-based price index.

The representative household maximizes the life-time utility subject to the budget constraint (B-9). Letting Λ_t denote the Lagrange multiplier associated with the budget constraint, the first-order condition for x_t is then given by $\Lambda_t = U_{x,t}/\tilde{P}_t = U_{x,t}/(\tilde{P}_t/P_t)P_t = (U_{x,t}/\tilde{p}_t)/P_t$. We can then express the first-order condition for hours as $U_{x,t}w_t/\tilde{p}_t = -U_{h,t}$.

The two equity valuation terms that appear in the budget constraint are related to each other through an accounting identity $P^s_{i,t} = P^s_{i,t-1,t} + E^s_{i,t}$, where $E^s_{i,t}$ is the per-share value of new equity issued by a firm i in period t. Because of equity dilution costs, $E^s_{i,t} = -(1-\varphi)\min\{D_{i,t}, 0\}$. Substituting $P^s_{i,t-1,t} = P^s_{i,t} - E^s_{i,t} = P^s_{i,t} + (1-\varphi)\min\{D_{i,t}, 0\}$ into the budget constraint (B-9), we obtain the optimality conditions governing the household's holdings of international bonds and shares of firms:

$$1 = \delta\mathbb{E}_t\left[\frac{U_{x,t+1}/\tilde{p}_{t+1}}{U_{x,t}/\tilde{p}_t}\left(\frac{R_t}{\pi_{t+1}}\frac{1}{1+\tau b_{h,t+1}}\right)\right]; \tag{B-10}$$

$$1 = \delta\mathbb{E}_t\left[\frac{U_{x,t+1}/\tilde{p}_{t+1}}{U_{x,t}/\tilde{p}_t}\left(\frac{q_{t+1}}{q_t}\frac{R^*_t}{\pi^*_{t+1}}\frac{1}{1+\tau b_{f,t+1}}\right)\right]; \tag{B-11}$$

$$1 = \delta\mathbb{E}_t\left[\frac{U_{x,t+1}/\tilde{p}_{t+1}}{U_{x,t}/\tilde{p}_t}\frac{1}{\pi_{t+1}}\left(\frac{\mathbb{E}^a_{t+1}[\tilde{D}_{i,t+1}] + P^s_{t+1}}{P^s_t}\right)\right], \tag{B-12}$$

where $\tilde{D}_{i,t} = \max\{D_{i,t}, 0\} + (1-\varphi)\min\{D_{i,t}, 0\}$, $b_{h,t+1} = B_{h,t+1}/P_t$, and $b_{f,t+1} = B_{f,t+1}/P^*_t$.[29] In deriving the first-order condition (B-12), we exploited the fact that the ex ante value of the firm—the value prior to the realization of the idiosyncratic cost shock—is the same for all firms; that is, $\mathbb{E}^a_{t+1}[P^s_{i,t+1}] = P^s_{t+1}$ in the symmetric equilibrium.

The bond market clearing conditions are given by

$$0 = b_{h,t+1} + b^*_{h,t+1} \quad \text{and} \quad 0 = b_{f,t+1} + b^*_{f,t+1}, \tag{B-13}$$

[29] Equity dilution costs do not affect the resource constraint because the existing shareholders' loss is exactly offset by the corresponding gain of new shareholders; both types of shareholders are, of course, the representative household and thus are the same.

where foreign holdings of international bonds denominated in home and foreign currencies—$b^*_{h,t+1}$ and $b^*_{f,t+1}$, respectively—satisfy the foreign counterparts of equations (B-10) and (B-11).[30]

$$
\begin{aligned}
1 &= \delta \mathbb{E}_t \left[\frac{U^*_{x,t+1}/\tilde{p}^*_{t+1}}{U^*_{x,t}/\tilde{p}^*_t} \frac{q_t}{q_{t+1}} \frac{R_t}{\pi_{t+1}} \frac{1}{1+\tau b^*_{h,t+1}} \right]; \\
1 &= \delta \mathbb{E}_t \left[\frac{U^*_{x,t+1}/\tilde{p}^*_{t+1}}{U^*_{x,t}/\tilde{p}^*_t} \frac{R^*_t}{\pi^*_{t+1}} \frac{1}{1+\tau b^*_{f,t+1}} \right].
\end{aligned}
$$

Assuming that the portfolio rebalancing costs are transferred back to the household in a lump-sum fashion, imposing the stock market equilibrium condition $S_{i,t} = S_{i,t+1} = 1$, $i \in N_h$, and dividing the budget constraint through by P_t, equation (B-9) then implies the following law of motion for the bond holdings in the home country:

$$
b_{h,t+1} + q_t b_{f,t+1} = \frac{R_{t-1}}{\pi_t} b_{h,t} + \frac{R^*_{t-1}}{\pi^*_t} q_t b_{f,t} + w_t h_t + \tilde{d}_t - \tilde{p}_t x_t, \tag{B-14}
$$

where $\tilde{d}_t = \tilde{D}_t / P_t$; the corresponding law of motion for the bond holdings in the foreign country is given by

$$
\frac{1}{q_t} b^*_{h,t+1} + b^*_{f,t+1} = \frac{R_{t-1}}{q_t \pi_t} b^*_{h,t} + \frac{R^*_{t-1}}{\pi^*_t} b^*_{f,t} + w^*_t h^*_t + \tilde{d}^*_t - \tilde{p}^*_t x^*_t, \tag{B-15}
$$

where $\tilde{d}^*_t = \tilde{D}^*_t / P^*_t$. Multiplying equation (B-15) by q_t, subtracting the resulting expression from equation (B-14), and imposing the bond market clearing conditions given in equation (B-13) yields

$$
\begin{aligned}
b_{h,t+1} + q_t b_{f,t+1} = {} & \frac{R_{t-1}}{\pi_t} b_{h,t} + \frac{R^*_{t-1}}{\pi^*_t} q_t b_{f,t} + \frac{1}{2}(w_t h_t - q_t w^*_t h^*_t) \\
& + \frac{1}{2}(\tilde{d}_t - q_t \tilde{d}^*_t) - \frac{1}{2}(\tilde{p}_t x_t - q_t \tilde{p}^*_t x^*_t).
\end{aligned} \tag{B-16}
$$

This condition, together with bond market clearing conditions (B-13), should hold for the balance-of-payments between the two countries.

As in GSSZ, we allow for nominal wage rigidities by assuming market power for households supplying labor to firms and a quadratic cost of adjusting nominal wages. Assuming a separable, constant elasticity of labor supply, $U_{h,t} = -h_t^{1/\zeta}$, the efficiency condition for labor hours is given by

$$
\begin{aligned}
\eta_w \frac{h_t^{1/\zeta}/U_{x,t}}{w_t/\tilde{p}_t} = {} & \eta_w - 1 + \gamma_w(\pi_{w,t} - \pi_w)\pi_{w,t} \\
& - \delta \mathbb{E}_t \left[\frac{U_{x,t+1}/\tilde{p}_{t+1}}{U_{x,t}/\tilde{p}_t} \gamma_w (\pi_{w,t+1} - \pi_w) \pi_{w,t+1} \frac{\pi_{w,t+1}}{\pi_{t+1}} \frac{h_{t+1}}{h_t} \right],
\end{aligned}
$$

where $\pi_{w,t} = W_t / W_{t-1}$, γ_w is the coefficient of nominal wage adjustment costs, and ζ is the labor supply elasticity.

Closing the model requires us to specify a monetary policy rule. In the case of flexible exchange rates, we assume that monetary authorities in the home and foreign countries set prices of government bonds in their respective countries using interest-rate rules of the form:

$$
R_t = R \left(\frac{y_t}{y} \right)^{\psi_y} \left(\frac{\pi_t}{\pi} \right)^{\psi_\pi} \quad \text{and} \quad R^*_t = R^* \left(\frac{y^*_t}{y^*} \right)^{\psi_y} \left(\frac{\pi^*_t}{\pi^*} \right)^{\psi_\pi},
$$

[30]Note that in equation (B-13), $b_{h,t+1}$ and $b^*_{h,t+1}$ are normalized by the home country's price level. This implies that $b^*_{h,t+1}$ enters the foreign country's budget constraint as $b^*_{h,t+1}/q_t$. In contrast, $b_{f,t+1}$ and $b^*_{f,t+1}$ are normalized by the foreign country's price level, and $b_{f,t+1}$ enters the home country's budget constraint as $q_t b_{f,t+1}$.

where the reaction coefficients ψ_y and ψ_π are assumed to be the same across the two countries. We do not assume any policy inertia because such an inertial term is frequently a source of inefficiency in the conduct of monetary policy.[31]

Monetary union: In a monetary union, all products and financial assets are denominated in units of common currency. As a result, the nominal exchange rate Q_t is not defined. In addition, a single monetary authority sets the interest rate, denoted by R_t^U, and all investors, regardless of their country of origin and current location, earn the same nominal return on their bond holdings.[32] We assume that monetary policy in the union is conducted in a manner that reflects the economic fundamentals of both countries:

$$R_t^U = R^U \left(\frac{y_t^U}{y^U}\right)^{\psi_y} \left(\frac{\pi_t^U}{\pi^U}\right)^{\psi_\pi},$$

where the union-wide variables are constructed as weighted averages of country-specific aggregates, with the weights given by the steady-state share of output:

$$y_t^U = y_t\left(\frac{y}{y+qy^*}\right) + q_t y_t^*\left(\frac{qy^*}{y+qy^*}\right);$$

and

$$\pi_t^U = \pi_t\left(\frac{y}{y+qy^*}\right) + \pi_t^*\left(\frac{qy^*}{y+qy^*}\right).$$

Because there is no longer any distinction between bonds issued in home or foreign currency, we replace the bond market clearing conditions (see equation B-13) by

$$b_{t+1} + b_{t+1}^* = 0, \tag{B-17}$$

where b_{t+1} and b_{t+1}^* denote holdings of international bonds in the single currency units by home and foreign countries, respectively. Now there are two, instead of four, Euler equations characterizing the equilibrium in the international bond market:

$$1 = \delta\mathbb{E}_t\left[\frac{U_{x,t+1}/\tilde{p}_{t+1}}{U_{x,t}/\tilde{p}_t}\frac{R_t^U}{\pi_{t+1}}\frac{1}{1+\tau b_{t+1}}\right]; \tag{B-18}$$

$$1 = \delta\mathbb{E}_t\left[\frac{U_{x,t+1}^*/\tilde{p}_{t+1}^*}{U_{x,t}^*/\tilde{p}_t^*}\frac{q_t}{q_{t+1}}\frac{R_t^U}{\pi_{t+1}^*}\frac{1}{1+\tau b_{t+1}^*}\right]. \tag{B-19}$$

[31] The output gap in the monetary policy rule does not correspond to the deviation of actual output from the efficient level of output—that is, the level of output that would prevail in the absence of nominal rigidities and inefficient sources of output fluctuations. However, when inefficient sources of output fluctuations are the primary driver of business cycles, which is the case in our calibration, our definition of the output gap works in the same way as the output gap implied by flexible prices.

[32] However, the *real* returns on international bond holdings will differ in equilibrium, depending on the reference location of investors. This divergence in real returns reflects two factors. First, the two countries have different consumption baskets in the long run, owing to the presence of home bias in consumption. Second, at any point in time, the law of one price does not hold in the monetary union because two consumers residing in different countries have accumulated different stocks of habit for an identical product. Because firms price their products to markets—the so-called pricing to habits as in Ravn et al. (2007)—inflation rates are not equalized across countries, despite the adoption of a single currency and common monetary policy.

Note that $q_t/q_{t+1} = (Q_t/Q_{t+1})(\pi_{t+1}/\pi^*_{t+1}) = \pi_{t+1}/\pi^*_{t+1}$ in a monetary union. Finally, a monetary union implies that the combined law of motion for the international bond holdings given in equation (B-16) can be expressed as

$$b_{t+1} = \frac{R^U_{t-1}}{\pi_t} b_t + \frac{1}{2}(w_t h_t - q_t w^*_t h^*_t) + \frac{1}{2}(\tilde{d}_t - q_t \tilde{d}^*_t) - \frac{1}{2}(\tilde{p}_t x_t - q_t \tilde{p}^*_t x^*_t). \tag{B-20}$$

C Calibration Summary

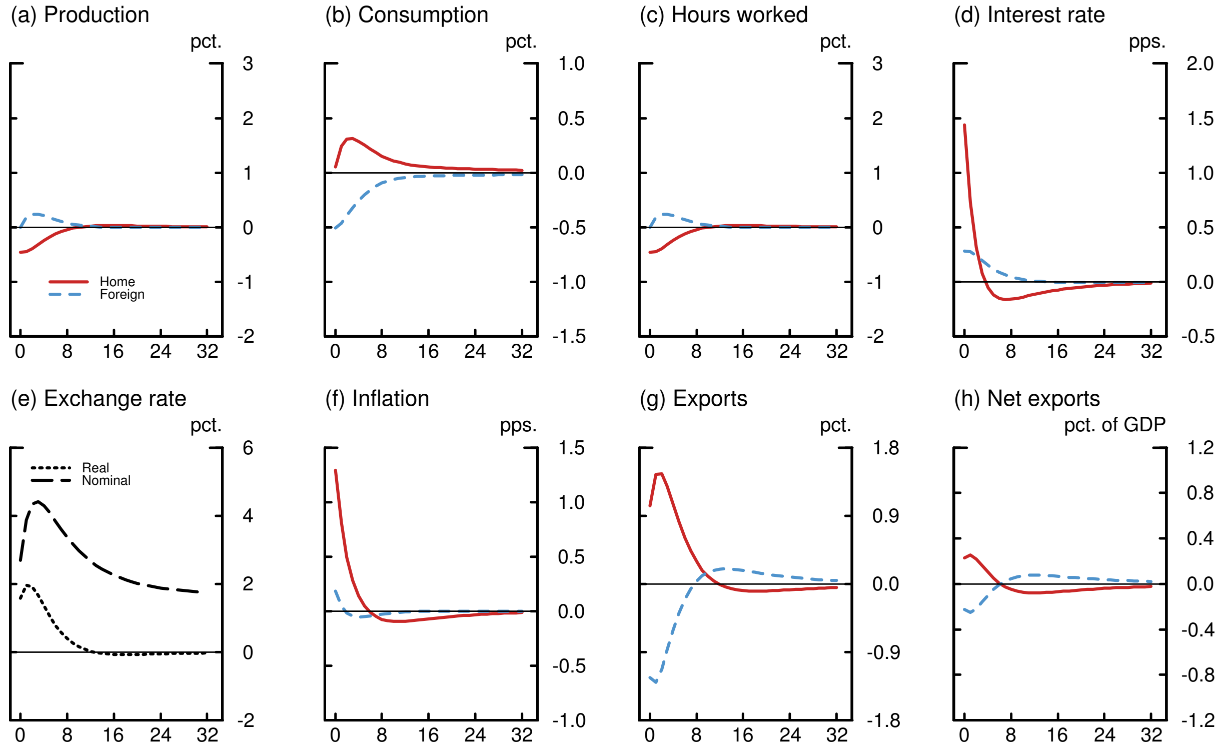
The entries in the table denote the values of the model parameters used in the calibration of the model.

Table C-1: Baseline Calibration

Model Parameters	Value
Preferences & technology	
time discount factor (δ)	0.99
constant relative risk aversion (γ_x)	2.00
elasticity of labor supply (ζ)	3.00
elasticity of substitution between differentiated labor (η_w)	2.00
strength of deep habits (θ)	-0.86
persistence of deep habits (ρ)	0.850
elasticity of substitution between differentiated goods (η)	2.000
Armington elasticity (ε)	1.500
home bias ($\Xi_h^{\varepsilon}, \Xi_f^{*\varepsilon}$)	$(0.60, 0.60)$
returns-to-scale (α)	1.00
fixed operating costs (ϕ, ϕ^*)	$(0.10, 0.10)$
Nominal rigidities & monetary policy	
price adjustment costs (γ_p)	10.00
wage adjustment costs (γ_w)	30.00
Taylor rule inflation gap coefficient (ψ_π)	1.50
Taylor rule output gap coefficient (ψ_y)	1.00
Financial frictions & shocks	
equity dilution costs (φ, φ^*)	$(0.20, 0.02)$
std. deviation of idiosyncratic cost shocks (σ)	0.20
portfolio rebalancing costs (τ)	0.15
persistence of financial shocks (ρ_f)	0.90
std. deviation of financial shocks (σ_f)	0.20
persistence of technology shocks (ρ_A)	0.90
std. deviation of technology shocks (σ_A)	0.01

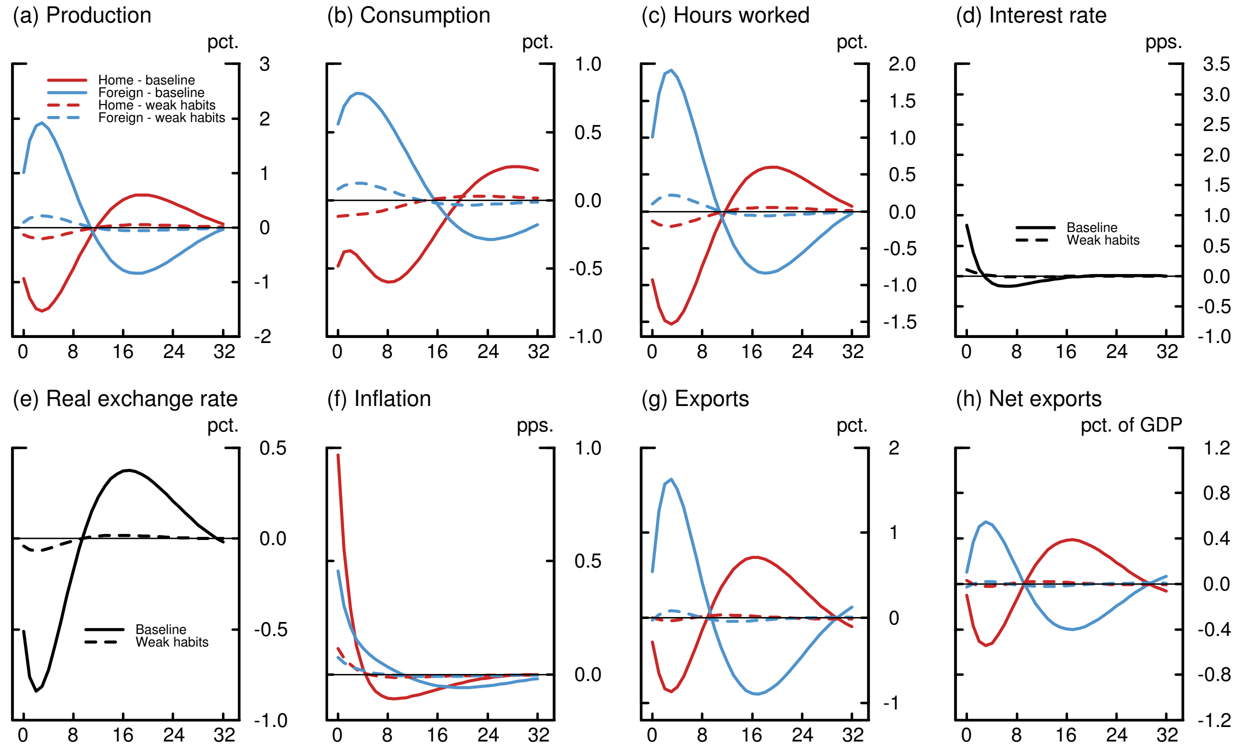
D Supplementary Results

Figure D-1: Asymmetric Financial Shock with Flexible Exchange Rates



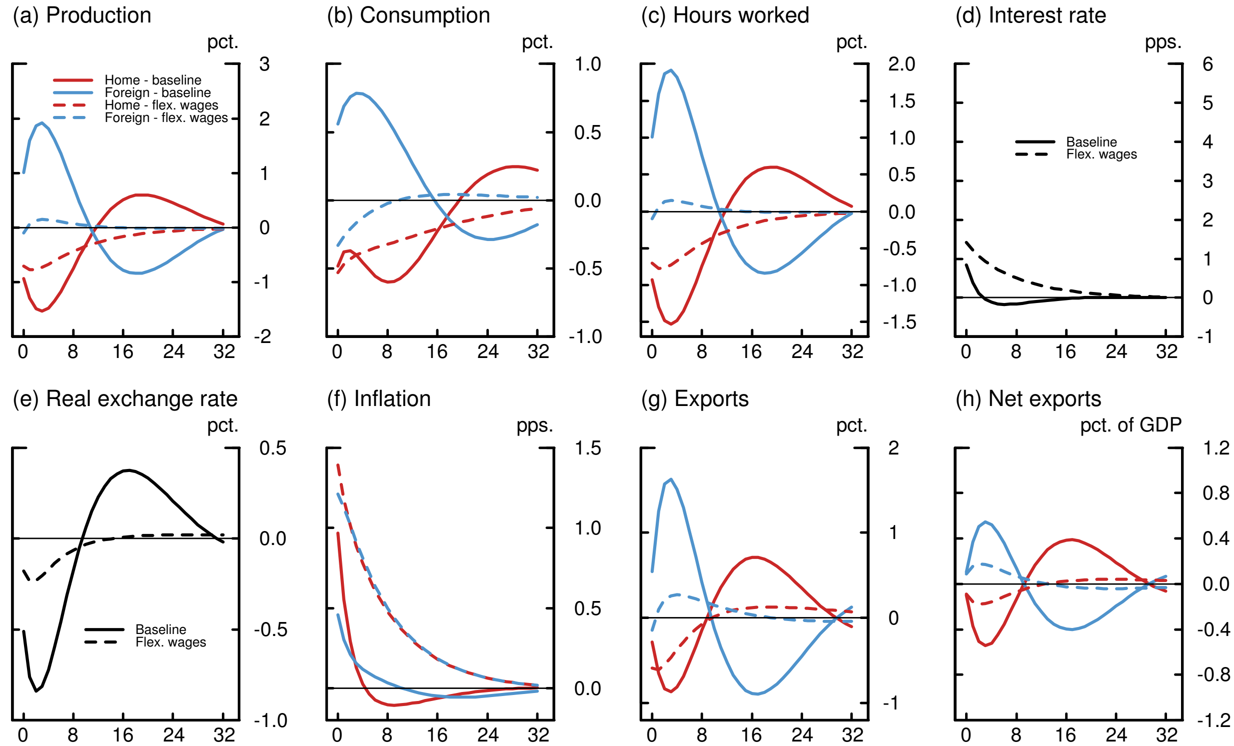
Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0. Unless noted otherwise, the solid lines show responses of variables in the home country, while the dashed lines show those of the foreign country. Exchange rates are expressed as home currency relative to foreign currency.

Figure D-2: Asymmetric Financial Shock with Weak Habits



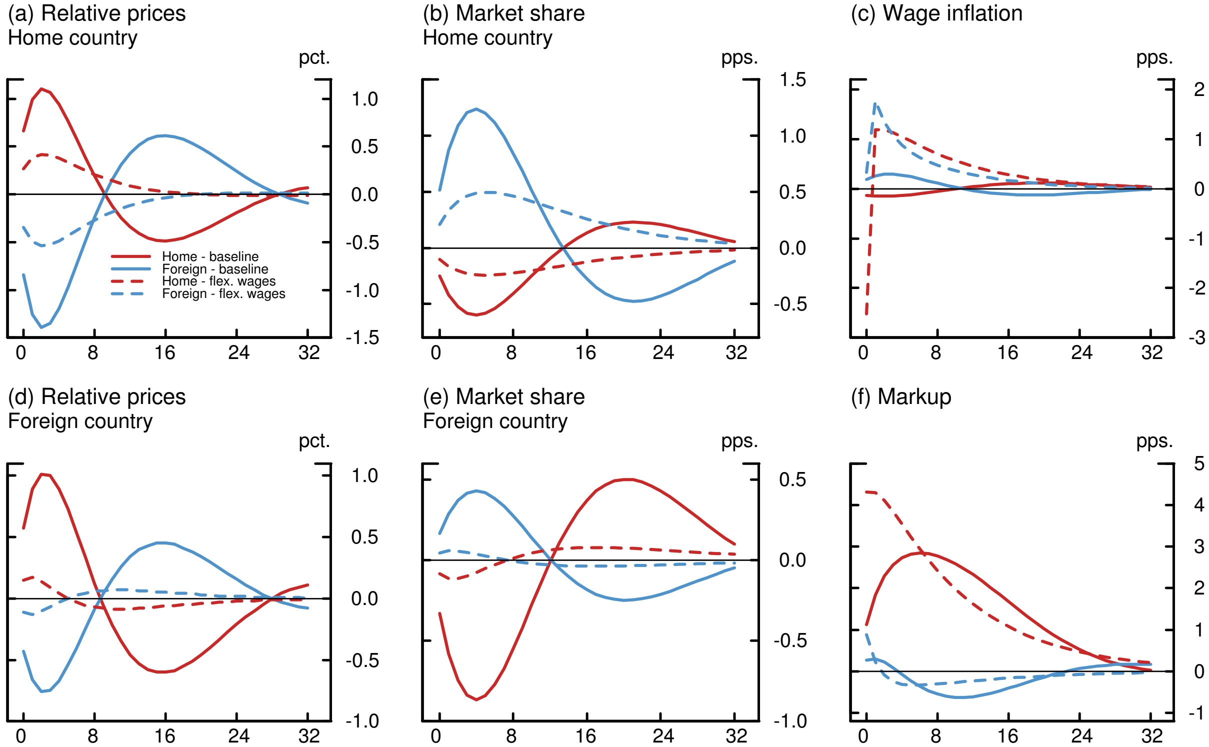
Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0, when the two countries are in a monetary union. The solid lines show the responses from the baseline monetary union case, while the dashed lines show the corresponding responses under the weak-habit calibration of the model (i.e., $\theta = -0.3$ and $\rho = 0.3$). The real exchange rate is expressed as home currency relative to foreign currency.

Figure D-3: Asymmetric Financial Shock with Flexible Wages



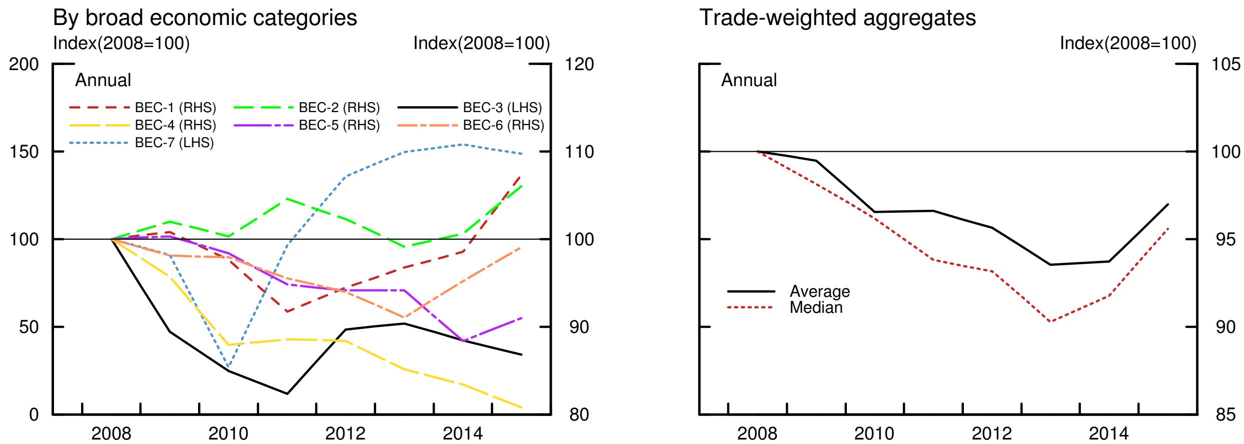
Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0, when the two countries are in a monetary union. The solid lines show the responses from the baseline monetary union case, while the dashed lines show the corresponding responses when wages in both countries are completely flexible. The real exchange rate is expressed as home currency relative to foreign currency.

Figure D-4: Asymmetric Financial Shock – Relative Prices, Flexible Wages, and Markups



Note: The panels of the figure depict the model-implied responses of selected variables to an adverse financial shock in the home country in period 0, when the two countries are in a monetary union. The solid lines show the responses from the baseline monetary union case, while the dashed lines show the corresponding responses when wages in both countries are completely flexible.

Figure D-5: Relative Importer Shares in the Euro Area (2008–2015)



Note: The left panel depicts the behavior of relative importer shares between the eurozone periphery and core in seven broad economic categories (BECs): BEC-1 = Food & Beverages; BEC-2 = Industrial Supplies; BEC-3 = Fuels & Lubricants; BEC-4 = Capital Goods (excluding transport equipment); BEC-5 = Transport Equipment; BEC-6 = Consumer Goods; and BEC-7 = Goods, not elsewhere specified. The right panel depicts the cumulative trade-weighted average and the trade-weighted median of the relative growth in importer market shares across the seven BECs, using total trade flows between the two regions as weights.

The left panel of Figure D-5 shows the cumulative relative growth in importer market shares between the periphery and core for the seven broad economic categories. With the exception of BEC-2 (Industrial Supplies)—a category of goods for which the relative importer market share between the eurozone periphery and core was about unchanged—the relative importer market shares for all other categories declined markedly during the crisis. Although in BEC-7 (Goods, not elsewhere classified), the sharp drop in the relative importer market share was fairly transient, the relative importer market shares in the remaining categories registered appreciably more persistent declines. We also verified that these movements are not driven by increases in the difference of the total volume of imports, but rather mainly by the declines in the size of relative flows.

To gauge the aggregate implications of these trade patterns, the right panel shows the cumulative trade-weighted average and the trade-weighted median of the relative growth in importer market shares across the seven BECs, using total trade flows between the two regions as weights. Both measures paint the same picture: As the crisis in the euro area unfolded, imports by the periphery countries from the core countries—normalized by the periphery's total imports—declined by considerably more than the imports by the core countries from the periphery, normalized by the total imports of the core countries. The aggregate patterns are qualitatively the same if instead of total imports by each region, imports from the periphery and core and vice versa are normalized by the relevant region's nominal GDP. Such dynamics in relative importer market shares are consistent with our model, which predicts that in periods of financial distress, firms in the home country will lose importer market share, while their financially stronger foreign competitors will gain importer market share.

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