The Exchange Rate Insulation Puzzle

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Abstract

Despite widespread skepticism, the notion that flexible exchange rates insulate a country from foreign shocks is central to modern macroeconomics. We confront it with new evidence from Europe. We show that spillovers from euro-area shocks to neighbouring countries are no smaller for floating exchange rates than for pegs—the exchange rate insulation puzzle. We show that a standard business cycle model predicts large spillovers under a float provided that monetary policy chooses to target headline inflation. Yet, the model cannot simultaneously account for our conditional evidence and the fact that business cycles appear no different under pegs and floats.

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A flexible exchange rate is not of course a panacea; it simply provides an extra degree of freedom, by removing the balance-of-payments constraints on policy formation. In so doing, it does not and cannot remove the constraint on policy imposed by the limitation of total available national resources and the consequent necessity of choice among available alternatives; it simply brings this choice, rather than the external consequences of choices made, to the forefront of the policy debate.
Harry Johnson (1969), p.12

1 Introduction

How much insulation can flexible exchange rates afford the open economy? The classics argue: a lot—because the exchange rate operates as an automatic shock absorber which adjusts to soften the impact of external shocks. And, as emphasized by Johnson in the quote above, flexible exchange rates give monetary policy an "extra degree of freedom" to pursue its internal objectives autonomously from the rest of the world (Meade 1951; Friedman 1953; Eichengreen and Sachs 1985).[1] However, skepticism about the virtue of exchange rate flexibility abounds. At a fundamental level, business cycles look very much alike across exchange rate regimes (Baxter and Stockman, 1989). A large body of literature questions the functioning of the exchange rate as a shock absorber, stressing that internationally traded goods and services are priced to market and/or exchange rate pass through is low (Devereux and Engel, 2003). And yet, state-of-the-art models predict that domestic output remains fairly insulated from foreign disturbances, even if, in line with evidence, exports are assumed to be predominantly priced in a dominant (vehicle) currency (Gopinath et al., 2020).[2] Another strand of the literature stresses that a US-dominated global financial cycle may constrain monetary policy even when this is unconstrained by an exchange rate target (Rey, 2013).

In this paper we reconsider the insulation properties of flexible exchange rates on the basis of new empirical evidence and a model-based analysis of the trade-offs that govern monetary policy decisions in the open economy. Our empirical contribution consists of a study of the cross-border spillovers of identified shocks that originate in the euro area to 20 of its geopolitical neighbor countries. These countries maintain different exchange rate regimes vis-à-vis the euro. However, by comparing their dynamic response to common euro-area shocks, we find very little evidence for superior insulation under flexible exchange rates. Crucially, we also find that, conditional on the external shocks, the nominal exchange rate of floaters hardly moves. These are puzzling findings in light of the classic view, which offer a new perspective on the existing literature: our evidence suggests that the apparent "neutrality" of the exchange rate regime not only applies to the broad outline of the business cycle, but also to the effect of certain external shocks. Itskhoki and Mukhin (2020) show that business cycle models can account for the unconditional patterns and, more generally, for the "exchange rate disconnect." However, a coherent account for the lack of insulation of flexible exchange rates needs to confront both the unconditional and the conditional evidence. This insight emerges clearly from the second part of our paper.

[1] Obstfeld (2020) provides an excellent assessment of Johnson's case for flexible exchange rates.

[2] See their Figure 2: a monetary tightening in the dominant-currency country generates basically no output spillovers to countries that have a flexible exchange rate regime. We discuss this result in more detail below.

Our theoretical contribution is centered around Johnson's quote: flexible exchange rates merely offer an extra degree of freedom as central banks trade off conflicting stabilization objectives in the face of domestic and external shocks. In our model-based analysis, this boils down to specifying a target for monetary policy and in this regard headline inflation serves as a natural point of departure given the focus of our study. Two results synthesize our main finding. One the one hand, with headline inflation targeting, monetary policy tolerates very little exchange rate adjustment in the face of external shocks and hence spillovers are large and, in fact, almost as large as under a peg—in line with the evidence. But this reflects a policy choice rather than a failure of flexible exchange rates to provide insulation: if monetary policy targets either producer price inflation or potential output rather than headline inflation, exchange rates respond much more strongly to external shocks and provide more insulation as a result. One the other hand, once we calibrate the model to capture unconditional business cycle moments, the model can no longer account for the extent of spillovers from external shocks. Intuitively, in order to match the level of exchange rate volatility observed in the data, monetary policy would better not respond too aggressively to headline inflation. At a fundamental level the insulation puzzle thus persists: models that account for the unconditional business cycle evidence predict considerable insulation—at odds with the extent of spillovers that we document in the first part of the paper.

Our empirical analysis is based on a sample of European countries and this has several desirable features to study the insulation properties of flexible exchange rates. First, focusing on the euro area as a source of shocks external to other economies allows us to steer clear of a global (US-dominated) financial cycle possibly induced by US monetary policy. Second, there is significant variation in the exchange rate regime that the neighbor countries maintain vis-à-vis the euro, both across time and countries. We exploit this variation as we condition spillovers on the currency regime in each neighbor country at different points in time. The sample includes 20 countries neighboring the euro area and covers the 20-year period since the inception of the euro in 1999 up until the end of 2018—providing us with a total of 4,800 monthly observations for a number of key macro indicators. Over this period, the whole region experiences a strong process of trade and economic integration, led by the institutional development of the European Union and several trade agreements with border countries outside the EU. As a result, these countries trade a lot with the euro area. What is more, and that is the third desirable feature of our data set, their exports to/imports from the euro area are predominantly priced in euros, thus providing a prime example of the type of dominant currency setting emphasized by Gopinath (2015).

In order to classify the time-month observations in our sample as pegs and floats we build on Ilzetzki et al. (2019). In our baseline about one third of the observations qualify as floats and two thirds as pegs. To assess how different economies respond to euro-area shocks and, in particular, if and how the response depends on the exchange rate regime, we pool the data for the neighboring countries, allowing for country fixed effects. We then estimate impulse responses to external shocks which we interact with a (possibly time varying) exchange rate regime dummy. We focus much of our analysis on monetary policy shocks as identified by Jarociński and Karadi (2020), but we also consider their central bank information shocks and a series of spread shocks following earlier work by Gilchrist and Mojon (2018). Our econometric specification does not rule out that an external shock causes a change of the exchange rate regime because we condition impulse responses on the exchange rate regime in the month prior to the shock. In other words, the empirical analysis allows for the exchange rate regime to be endogenous in the face of external shocks. The main result of our empirical analysis is the exchange rate insulation puzzle: the responses of industrial production, the unemployment rate, inflation, trade flows, the short-term interest rate and even the exchange rate are very similar, whether countries pursue a currency peg to the euro, or operate a float.[3]

To explore the extent to which lack of insulation may arise from a policy choice, we rely on a New Keynesian two-country model akin to Gopinath et al. (2020). The model has standard features: there is a large country, representing the euro area to which we refer as "Foreign", and a small country, representing a generic neighbor country; goods markets are not fully integrated because of home bias; firms may employ imported inputs in production; all exports are priced in a Dominant Currency Pricing (DCP), reflecting the role of the euro in intra-European trade.[4] Monetary policy under floating exchange rates is modelled as a targeting rule in the output gap and inflation. We show, both analytically and in a calibrated version of the model, that insulation properties of flexible exchange rates akin to those observed in the data can be driven by policy choices shaping monetary stabilization. The predictions of the model align surprisingly well with the evidence—there is lack of insulation—if floaters engage in consumer price (CPI) inflation targeting. This result provides a new angle on the notion of "fear of floating", originally put forward by Calvo and Reinhart (2002) in the context of disinflation policies pursued by emerging economies. However, countries enjoy some degree of insulation if their inflation target is specified in terms of producer prices (PPI), or even full insulation if, more directly, monetary rules give significant weight to the output gap.

In the model, incomplete exchange rate pass-through under dominant currency pricing means that monetary policy cannot stabilize both the response of inflation and the output gap to external shocks at once: there is no "divine coincidence". Even if currency movements do not contribute to stabilizing the economy, however, flexible exchange rates still put monetary policy in the position to stimulate domestic demand when foreign demand falters. But preserving a high level of economic activity in the face of (inefficient) foreign shocks comes at the cost of tolerating heightened volatility in exchange rates and inflation. Insulation, then, is not an inherent *automatic* feature of flexible exchange rates; rather, it is a policy choice.

While our theoretical analysis is positive rather than normative, we can compare monetary rules in light of current work on optimal monetary policy under DCP (Corsetti et al., 2020; Egorov and Mukhin, 2020). A robust result emerging from these contributions is that mone-

[3]Our evidence is consistent with the results of recent studies that focus on US monetary policy shocks, but the economics differ. Notably, Miranda-Agrippino and Rey (2020) show that contractionary US monetary policy shocks induce sizable spillovers to other countries, including in Europe. These authors emphasize that a monetary contraction in the US tightens global financial conditions, so that international lending falls even though policy rates abroad decline. We present evidence that suggests our euro-area shocks do not load on US monetary shocks. And we find little evidence that a financial transmission channel is key for euro-area spillovers. This does not contradict that the *US driven* global financial cycle is an important driver of international business cycles.

[4]In our DCP environment, border import prices in the (small) domestic economy are sticky in the currency of the foreign producers (euros), as is the case in the more conventional producer currency-pricing framework in Galí and Monacelli (2005). Local currency pricing instead applies to exporters in the small country. They price exports in euros, the export market's currency.

tary authorities in a small open economy should target domestic marginal costs or equivalently producer price inflation—a target that does not necessarily coincide with the goal of stabilizing the output gap, nor with the goal of stabilizing consumer price inflation. As we show using a calibrated version of our model, if central banks followed rules that approximate the optimal targeting rule characterized in these contributions, insulation would not be perfect, but would be much larger than what we find in our data. Likewise, once the model is calibrated to capture the Baxter-Stockman observations, we also find that there is little insulation in the face of external shocks and, hence, at fundamental level the puzzle stands unresolved.

As a comparative exercise and a generalization of our analysis, we show that our theoretical result of (near) equivalence of currency pegs and floats under CPI inflation targeting also holds in our model when we set the exchange rate pass through (ERPT) equal to 100%, the case of Producer Currency Pricing (PCP). Theoretical results deviate slightly from near equivalence when we assume that ERPT is symmetrically incomplete—the case of Local Currency Pricing (LCP)—so that currency movements have no desirable "expenditure switching" effects in either international or domestic markets. In this case, CPI inflation targeting arguably approximates the optimal monetary rule.[5] In the LCP version of our model, CPI targeting marginally improves insulation relative to a peg, but also translates into non-negligible exchange rate volatility.

In addition to the studies mentioned above, our work is related to studies that have looked into the extent of monetary policy independence, and thus the ability of monetary authorities to stabilize the domestic economy, in the context of the Mundellian trilemma (Edwards, 2015; Goldberg, 2013; Klein and Shambaugh, 2015; Obstfeld et al., 2005; Shambaugh, 2004). Levy-Yeyati and Sturzenegger (2003) analyze empirically how the output performance depends on the exchange rate regime. There is also earlier work on how the exchange rate regime alters transmission of external shocks (Bayoumi and Eichengreen, 1994; Broda, 2004; Giovanni and Shambaugh, 2008). More recently Jarociński (2021) and ter Ellen et al. (2020) investigate the spillovers from ECB monetary policy shocks to the US and to Sweden, Denmark, and Norway, respectively. Consistent with our findings, the latter study finds that interest rate spillovers in Norway and Sweden are almost indistinguishable from those to Denmark, even though the Danish krona is pegged to the euro. Lastly, we note that our analysis could also be framed in the classical adjustment model featuring non-traded goods and a homogeneous traded good, recently reconsidered by Schmitt-Grohé and Uribe (2016).[6]

The rest of the paper is structured as follows. In Section 2 we present our empirical framework. Section 3 shows the empirical results regarding spillovers of euro-area shocks. Section 4 outlines the New Keynesian two-country model. Section 5 presents the main arguments of the paper for a linearized version of that model and for a special case, but in closed form. Section 6 shows that the main results carry over to a calibrated version of the model with imported intermediate inputs. A final section concludes.

[5]The normative literature in LCP economies is epitomized by Engel (2011) and Corsetti et al. (2010); for an early New Keynesian model with limited exchange rate pass-through see also Monacelli (2005).

[6]In their model, as in ours, macroeconomic adjustment to negative external shocks can imply deeper recessions under fixed than under flexible exchange rates—full insulation does require extra stimulus of domestic demand. In engineering this stimulus, the monetary authority has to tolerate a large relative price adjustment of domestically-produced goods in terms of imported goods in the domestic market—not corresponding to any gains in price competitiveness in world markets.

2 Empirical framework

In this section we introduce our empirical framework. We rely on this framework in order to establish new evidence on international spillovers to small open economies. In doing so, we focus on a group of countries that look—from a global perspective at least—rather homogeneous and that are, in terms of trade and institutions, firmly integrated, but differ in the exchange-rate regime that they maintain with a large trading partner in which the shocks under study originate. Namely, we focus on the euro area as the "source country" and its geopolitical close neighbors as the "recipient countries".

In our estimation strategy we exploit the variation of the neighbor's exchange rate regime vis-à-vis the euro, not only across, but also within neighbor countries over time. In this section, we describe the empirical strategy and provide details on our sample as well as the data sources. Having established this, in the next section we document our main result: that, in terms of economic activity and inflation, euro-area monetary policy shocks spill over to the neighbors, the currency of which floats, to much the same extent as to the neighbors that peg to the euro. We corroborate this result in several dimensions: the empirical specification, the measurement of the neighbors' exchange-rate regime, and the shocks in question.

2.1 Estimation strategy

We seek to identify the effect that shocks in the large country have on its smaller neighbors, and how the neighbor's choice of exchange rate regime shapes those effects. Toward this end, let there be a panel of N neighbor countries, indexed by $n \in \{1, ..., N\}$. And let $t = 1, ..., T$ denote time. While for most of our results the panel is balanced, it need not be. In terms of the notation that follows, let variables with a subscript n indicate variables specific to each neighboring country. Let variables with a bar pertain to the source country. Define a time-dependent indicator variable $\mathbb{I}_{n,t-1}$ that indicates the exchange-rate regime of neighbor n at time $t-1$. $\mathbb{I}_{n,t-1} = 1$ when neighbor n operates a flexible exchange-rate regime vis-à-vis the large currency union, and zero otherwise.

We estimate local projections for a pooled sample of observations for the neighbors, controlling for the exchange-rate regime (Jordá, 2005).[7] Toward this end, let $h = 0, ..., H$ mark the forecast horizon for the local projection. Let $\bar{\epsilon}_t$ be a time series of identified structural shocks that originate in the source country. Let $x_{n,t+h}$ be the dependent variable of interest for neighbor n in period $t+h$. Let $\mathcal{N}_{h,t}$ be the set of neighbors that are in the sample for a given period t and horizon h. For each horizon $h = 0, 1, ..., H$ we estimate the empirical specification

$$x_{n,t+h} \;=\; \alpha_{n,h} + \mathbf{z}'_{n,t} \cdot \boldsymbol{\beta}_h + \gamma_h^p \left(1 - \mathbb{I}_{n,t-1}\right) \bar{\epsilon}_t + \gamma_h^f \, \mathbb{I}_{n,t-1} \, \bar{\epsilon}_t + u_{n,t+h}, \; n \in \mathcal{N}_{h,t}, t = 1, ..., T. \quad (1)$$

Here $\alpha_{n,h}$ is a neighbor-country fixed effect for horizon h. $\mathbf{z}_{n,t}$ is a row vector of controls for each neighbor country. The time series of the controls are neighbor-specific, but we apply the

[7] Plagborg-Møller and Wolf (Forthcoming) provide a detailed analysis of how local projections relate to more traditional VAR estimators.

same number and type of controls to each neighbor. Accordingly, $\boldsymbol{\beta}_h$ is a conforming vector that is identical across neighbors. Our object of interest are the neighboring countries' impulse responses to the large-country shock, $\bar{\epsilon}_t$, distinguishing neighbors that peg to the euro $\{\gamma_h^p\}_{h=0}^H$ and neighbors that float $\{\gamma_h^f\}_{h=0}^H$. Toward having consistent estimates of these terms, we assume that the relation captures the entire effect of the shock on the dependent variable. That is, we assume that the error term, $u_{n,t+h}$, is uncorrelated with the regressors in $\bar{\epsilon}_t$ and $\mathbb{I}_{n,t-1}\bar{\epsilon}_t$ at all leads and lags. At the same time, the error terms are allowed to be heteroskedastic, and correlated both in the cross section of neighbors and over time. Toward this end, we compute Driscoll and Kraay (1998) robust standard errors. Note that the estimated impulse responses will be economically meaningful as long as the choice of exchange-rate regime is not based on foresight about future shocks to the large source country. We stress, however, that our specification does not rule out that regimes $\mathbb{I}_{n,t-1}$ evolve over time, in response to changes in the state of the economy, and that our estimates capture the average response of floats or pegs, conditional on the pre-shock regime. Likewise, we emphasize that our shock measure $\bar{\epsilon}_t$ is a generated regressor. The standard errors on the generated regressors are asymptotically valid under the null hypothesis that the coefficient is zero (Pagan 1984, Coibion and Gorodnichenko 2015), allowing us to see if spillovers are significant.

We will compare the results to the impulse responses $\{\bar{\gamma}_h\}_{h=0}^H$ that emerge from the corresponding local projections in the source country:

$$\bar{x}_{t+h} \quad = \quad \bar{\alpha}_h + \bar{\mathbf{z}}_t'\bar{\boldsymbol{\beta}} + \bar{\gamma}_h \cdot \bar{\epsilon}_t + \bar{u}_{t+h}, \tag{2}$$

where again we assume that the errors $\bar{u}_{t+h}$ are uncorrelated with $\bar{\epsilon}_t$ at all leads and lags. The error terms themselves can be heteroskedastic and serially correlated. Before proceeding, it will be useful to be clear about the heterogeneity across neighbors that we allow for in estimating model (1). In particular, we allow for neighbor fixed effects (the $\alpha_{n,h}$), and we allow for heterogeneity unrelated to the shock through allowing for potential serial and cross-sectional correlation as well as heteroskedasticity in the error terms. Neighbors can be heterogeneous as to the exchange-rate regime and as to the state of their economy more generally (as captured by the controls). At the same time, we have to impose some homogeneity across member states so as to be able to conduct inference in a small sample. Namely, we assume homogeneity across countries in the coefficients $\boldsymbol{\beta}_h, \gamma_h^f$, and γ_h^p. That is, shocks in the large source country can affect differently neighbors that float and neighbors that peg, but all neighbors that float are affected by the shock the same way. Still, in our robustness analysis below, we consider estimates based on mean group estimator and find our main results unchanged.

2.2 Sample

In our application, we resort to a sample of European countries, plus the euro area. This setting, in our view, provides an ideal test case for how the exchange-rate regime impacts international spillovers. Not only does it comprise a large integrated economy, the euro area (EA), and a large number of smaller open economies. But also is each of the neighbors in our sample linked to the euro-area economy through outright membership of the European Union or by other close association with the EU. In the sample period we consider, indeed, institutional developments of the EU and a number of bilateral agreements have activated a process of increasing economic and trade integration. Because of this process, by global standards, the EA neighbors have many similarities. We make use of the fact that, in spite of the comparably strong ties with the EA and similarities, the neighbors differ in their exchange-rate regimes vis-à-vis the euro. Namely, there is both variation of the exchange rate regime across neighbor countries and over time.

2.2.1 The neighbor countries

Our sample consists of monthly data from the inception of the euro in 1999:M1 through 2018:M12. This gives us at most $T = 240$ observations for each country. Our sample consists of the 11 countries that formed the euro area in 1999 (Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain) and $N = 20$ of its neighbors. The neighbors are Bulgaria, Croatia, Cyprus, Czechia, Denmark, Estonia, Greece, Hungary, Iceland, Latvia, Lithuania, Malta, Norway, Poland, Romania, Slovakia, Slovenia, Sweden, Switzerland, and the United Kingdom. This is the set of countries that at the end of our sample period comprised the European Union (EU, which the UK left in January 2020 only), plus the three larger countries of the European Free Trade Association (EFTA), bar Liechtenstein.[8] We collect time series on several macroeconomic and financial variables of interest. The data are seasonally adjusted and the source is Eurostat unless noted otherwise in data Appendix A.

2.2.2 Classification of Exchange-rate regimes

For each of the N neighbors and each period $t = 1, ..., T$, our methodology asks us to classify the exchange rate regime as a "peg" ($\mathbb{I}_{n,t} = 0$) or a "float" ($\mathbb{I}_{n,t} = 1$). Rather than resorting only to judgment of our own, as much as we can, we rely on the careful work by Ilzetzki, Reinhart, and Rogoff (2019), to whom we refer as IRR for short. We corroborate their evidence, with our application in mind, based on a reading of central bank communication, communication by the European Commission via its bi-annual "Convergence Reports," and the IMF's Annual Report on Exchange Arrangements. For a large sample of countries (including all of the N neighbors analyzed here) IRR finely classify the *de-facto* exchange rate regime using categories 1 (No separate legal tender or currency union) to 15 (Dual market in which parallel market data is missing). We observe no instance of the latter category in our sample. In case of a peg, IRR also provide the reference currency. In case there is an official exchange rate arrangement, they verify if the country's exchange rate against the reference currency actually follows the pre-announced rule. Otherwise, they classify the regime on the basis of its observed exchange rate volatility.

Our theory later makes the case that a flexible exchange rate may not insulate a neighbor

[8]The composition of EFTA has been stable over our sample. The EU, instead, saw several waves of accession. Free access to the European single market typically predates EU membership by several years. An example of this is Croatia, which had preferential access to the single market since the year 2000, formalized with signing its Stabilization and Association Agreement with the EU in 2001 and, thus, before it applied for EU membership (2003) or joined the EU (2013). All other neighbors that joined the EU over the course of our sample already had applied for membership prior to 1991:M1.

country against external shocks if the neighbor pursues inflation targeting. Under this theory, the reason is that the exchange rate may not show much fluctuation under inflation targeting. Since IRR's classification scheme is based precisely on such observed fluctuations, we need to strike a compromise. We do so with the intention to err on the side of caution (rather accidentally labeling a floater as a pegger than *vice versa*). We label as floaters neighbors in IRR's categories 9 through 14. At the one end, this includes neighbors that have broad bands or managed floats against the euro (their category 9). At the other end it includes the 3 percent of our observations (147 out of 4800) that IRR classify as "freely floating" (their category 13) and a few observations of IRR's category 14 "freely falling," namely for Romania in 1999/2000. This definition of floaters is narrow in the sense that it allows the neighbor countries room to use the exchange rate as a shock absorber. For example, IRR require of managed floats, arguably the most restricted category among our floaters, that the exchange rate does not fluctuate by more than two percent *per month* in 80% of months over a five-year window. Clearly, this still allows for exchange-rate movements that are larger than two percent about twice per year, and for notable cumulative changes in the exchange rate. We verify that we observe a great deal of exchange rate flexibility for country-time observations that qualify as a float according to our criterion, see Figure B.1 in the appendix.

Table 1 provides a compact overview how we sort countries according to their exchange rate regime in our baseline specification. Each column refers to one of the 20 neighboring countries in our sample. Each row refers to a month in which the classification for at least one country changes relative to the previous month. In the table, the darker cells indicate a float ($\mathbb{I}_{n,t} = 1$), and the brighter cells indicate a peg ($\mathbb{I}_{n,t} = 0$), including membership in the euro area. In total 1773 or 37 percent of our country-time observations qualify as float under our baseline specification.

Appendix B provides details on the classification for each of the neighboring countries. Here we focus on a few examples only, so as to highlight the nature of our exercise. We are interested in whether the exchange rate of a country is flexible vis-à-vis the euro, or not.[9] Bulgaria is a clear-cut example of a peg. Throughout our sample period it operates a currency board under which its currency is pegged to the euro. The case of Malta, in turn, demonstrates how we deal with a neighbor's transition toward euro membership. In January 2008 Malta joined the euro area. Our assumption throughout is that Malta and other late-adopters of the euro are too small relative to the euro-area economy as a whole to have notable weight in policy decisions or the euro-area's macroeconomy. Rather, we keep Malta and other late-adopters of the euro in our sample as having a hard peg with the euro.[10] At the end of the sample, all the late-adopters combined accounted for less than four percent of euro-area GDP. In robustness analysis, we exclude Greece and Cyprus from the sample because they may have had a non-negligible effect on euro area policies during the sovereign debt crisis. We find that results are basically unchanged relative to the baseline.

As a stepping stone to euro membership, a country has to engineer a stable exchange rate

[9] In our baseline we also assign Lithuania to the peggers. Even though it maintained a soft peg vis-à-vis the US$ up to January 2002. Yet from a theoretical point of view it is crucial that a neighbor country may not adjust its policy stance in the face of an external (ie euro area) shock.

[10] After 1999:M1, the euro became legal tender in eight countries of our sample: in Greece (2001), Slovenia (2007), Cyprus (2008), Slovakia (2009), Estonia (2011), Latvia (2014) and Lithuania (2015).

Table 1: Exchange rate regimes 1999–2018

	Bulgaria	Croatia	Cyprus	Czechia	Denmark	Estonia	Greece	Hungary	Iceland	Latvia	Lithuania	Malta	Norway	Poland	Romania	Slovakia	Slovenia	Sweden	Switzerland	United Kingdom
1999M1	0	0	0	0	0	0	0	1	0	1	0	1	1	1	1	0	0	1	1	1
1999M2	0	0	0	0	0	0	0	1	0	1	0	1	1	1	1	0	0	0	1	1
2000M1	0	0	0	1	0	0	0	1	0	1	0	1	1	1	1	0	0	0	1	1
2000M11	0	0	0	1	0	0	0	1	1	1	0	1	1	1	1	0	0	0	1	1
2001M1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	1	1
2001M4	0	0	0	1	0	0	0	1	1	1	0	0	1	1	0	0	0	0	1	1
2001M9	0	0	0	1	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	1
2004M8	0	0	0	1	0	0	0	1	1	0	0	0	1	1	1	0	0	0	1	1
2005M1	0	0	0	1	0	0	0	1	1	1	0	0	1	1	1	0	0	0	1	1
2006M7	0	0	0	1	0	0	0	1	1	1	0	0	1	1	0	0	0	0	1	1
2008M9	0	0	0	1	0	0	0	1	1	1	0	0	1	1	0	0	0	1	1	1
2009M4	0	0	0	1	0	0	0	0	1	1	0	0	1	1	0	0	0	1	1	1
2009M7	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	1
2011M9	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	0	1
2015M2	0	0	0	1	0	0	0	0	1	0	0	0	1	1	0	0	0	1	1	1

Notes: Rows report exchange rate regime in a specific month whenever there is change of the exchange rate regime in at least one country relative to previous month. Darker cells (1) indicate a floating exchange rate, while lighter cells (0) indicate a peg, including membership in the euro area; floats are categories 9 through 14 in the fine classification of Ilzetzki et al. (2019).

against the euro for some time. Namely, under the Maastricht treaty's convergence criteria (now codified in Article 140 (1) of the Treaty on the Functioning of the European Union), adopting the euro requires "the observance of the normal fluctuation margins provided for by the exchange-rate mechanism of the European Monetary System, for at least two years, without devaluing against the euro," where the latter is typically interpreted as a policy-induced devaluation out of intent. In theory, the exchange-rate mechanism allows for the exchange rate to fluctuate in a band of $\pm$ 15% around an agreed exchange rate between the euro and the country's currency, and this is what Malta announced on May 2, 2005 when entering the Exchange Rate Mechanism. Yet, as Figure B.1 in the appendix shows, Malta did not nearly exhaust that band. Rather, in practice neighbors that aim at eventually adopting the euro operate much tighter bands. Indeed, the exchange rate of the Maltese lira against the euro was basically constant during Malta's membership in the ERM and with the exception of Latvia all neighbors that are members of the ERM are defined as operating a peg. Still, in a robustness exercise below, we use ERM membership as a criterion to classify a neighbor's exchange rate regime. Specifically, we classify as floats all country-months observation for which a country is neither a member of the euro area nor of the ERM. In this case the group of floaters is considerably larger than in the baseline.

Yet our main result is unchanged.

The clearest cases for a floating exchange-rate regime are the UK, Norway, Poland, and for the largest part of the sample period, also Iceland. The clearest cases for a peg outside of the euro zone in addition to Bulgaria are Croatia and Denmark, both of which operated hard pegs throughout. In sum, our empirical strategy is designed to exploit the variation in exchange-rate regimes across time and countries in order to identify the effect of the exchange rate regime on international (monetary) spillovers. The conventional wisdom is that floating exchange rates help insulate the small open economy from foreign shocks. Going with this, we wish to label a neighbor a floater only if the exchange rate truly has room to absorb shocks. Toward this end, we choose a cautious classification of floaters. We provide extensive robustness checks later. IRR's classification ends in 2016M12.[11] Based on the evidence that we have, we have left the exchange-rate classification unchanged for the rest of the sample.

In our theoretical section, we emphasize the role of the inflation targeting regime. Specifically, we will find considerable spillovers of shocks from the euro area to its neighbors, even if the neighbor floats. Later, to explain that finding, we will resort to a theory that makes the case that a strict focus on an inflation target may mask the potential of flexible exchange rates to insulate a country from external shocks. Therefore, it seems important to note that, indeed, throughout most of the sample the neighbors that we classify as having floating exchange rates have operated an inflation targeting regime. The obvious cases are Sweden (since 1993) and the UK (since 1992). Based on the classification by Brito et al. (2018), Norway started being an inflation targeter in March 2001, Switzerland in January 2000. Czechia has been an inflation targeter since 1997, Hungary since June 2001, and Poland started that practice in September 1998. The one country in our sample that we classify as having flexible exchange rates for some time but that Brito et al. (2018) do not classify as an inflation targeter is Latvia.

2.2.3 Exposure to the euro area and the choice of the exchange rate regime

In theory, whether a neighbor operates a fixed exchange rate regime vis-à-via the EA or whether it lets its exchange rate float freely depends on a number of factors, chief amongst them the exposure to the EA in terms of trade and financial flows. The choice of the exchange rate regime, in other words, is endogenous—a notion that is well understood at least since Mundell (1961) put forward criteria for an optimum currency area. At an empirical level the literature has identified a number of factors which appear to govern the choice of the exchange rate regime in the data (e.g. Levy Yeyati et al., 2010). In what follows we briefly assess whether in our sample the exchange rate regime vis-à-vis the euro area varies systematically with determinants which the earlier empirical literature has found to account for the exchange rate regime. Systematic differences between countries might, then, point towards a direction of how to rationalize our main empirical results. Alas, as Table 2 shows, there hardly are systematic differences.[12] We find that none of the key indicators that we consider differs strongly between pegs and floats. An exception is size. To some extent this simply reflects the presence of the UK in the sample,

[11]For Poland the lastest observation is for 2016:M09.

[12]See the notes to the table for details on the data. Our data source is Eurostat. When we compute trade openness we lack data for Cyprus, Estonia, Greece, Latvia, Lithuania, Malta, Slovakia and Slovenia. When we compute the volatility of the terms of trade we lack data for Iceland, Norway, and Switzerland.

Table 2: Determinants of the exchange rate regime

	Peg	Float
Size in percent of euro area GDP	0.9	5.0
Trade openness vis-à-vis euro area	42.2	40.6
Capital account openness (Chinn-Ito index)	1.9	2.1
Terms of trade volatility	3.7	2.5

Notes: exchange rate classification as in Table 1, aggregated to annual frequency (country-years are classified as float if a country floats for a least one months of the year); size is measure in percet of euro-are GDP; trade openness is measured as the sum of exports and imports (to/from the euro area) in percent of GDP; capital account openness is measured by the Chinn-Ito index (Chinn and Ito, 2006). The terms of trade volatility is measured as the standard deviation (in percent) over the entire sample period. For this purpose we classify as floaters those countries which have their currency floating more than 50 percent of the time.

the GDP of which is equivalent to 20 percent of euro-area GDP on average during our sample period.[13] We consider size alone unlikely to be the main element that rationalize our empirical results that we will show below. The reason is simple: In terms of the exposure in trade to the euro area, the openness of the capital account, and the volatility of trade, peggers and floaters look barely distinguishable.

Not only this, but also in terms of conventional business-cycle moments the floaters and peggers look rather similar. One would be hard-pressed to tell pegs and floaters apart based on basic business cycle statistics—except on the basis of the standard deviation of their bilateral exchange rate with the euro and the nominal interest rate (see Table 6 in Section 6.2.3). Unconditionally, our sample, thus, bears out the Baxter-Stockman finding recently revisited and resolved by Itskhoki and Mukhin (2019).[14]

In our analysis below, we go a step further. Namely, the apparent neutrality may be generated by the simultaneous occurrence of different shocks that go in the direction of offsetting any potential benefit from exchange rate flexibility. In what follows, instead, we reconsider—in the spirit of Galí (1999)—the question of neutrality conditional on identified shocks. In this way, we seek to shed light on the mechanism that generates the empirical correlations and to discipline our theoretical exercises.

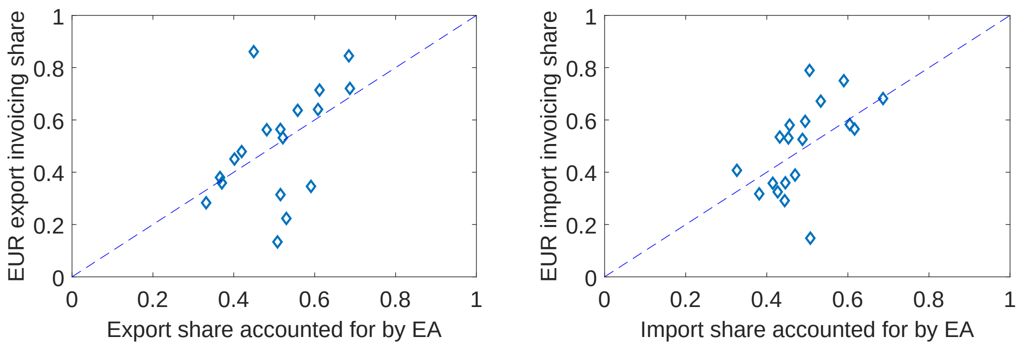
2.3 Dominant currency

We wish to close the description of our sample with information on the invoicing regime in intra-European trade. Namely, as will become important when we rationalize the empirical results later, not only do the neighbors trade a lot with the euro area, but also are their exports to/imports from the EA pre-dominantly priced in euros. The European setting, thus, serves as a prime example of the dominant-currency pricing regime that Gopinath (2015) stresses.

[13] Excluding the UK reduces the relative economic size of the average floating neighbor to 2.5 percent of euro-area GDP. Still, floaters tend to be larger than peggers. This is consistent with earlier findings: larger countries are more likely to operate a float (Levy Yeyati et al., 2010).

[14] In related work, Enders et al. (2013) investigate whether the introduction of the euro changed business cycles in Europe. Comparing the periods 1985–1996 and 1999–2011 for those countries that joined the euro, they also find business cycle moments to be largely unchanged.

Figure 1: Invoicing and trade shares in the euro-area periphery



Note: data for euro-area neighbor countries, see Section 2 for complete list of countries; here we display data on invoicing shares for all countries in our sample except for Croatia, and, in the case of export invoicing shares, Malta. Sources: Gopinath (2015) and IMF Directions of Trade Statistics.

This is illustrated in the two panels of Figure 1. In each panel, the horizontal axis measures the share of, respectively, exports to the EA and imports from the EA for the countries in our sample. Against these shares, we plot the share of trade invoiced in euros along the vertical axis. The figure illustrates the degree of integration of these economies with the euro area and is suggestive of a dominant role of the euro in intra-European trade, in line with the evidence put forward elsewhere (Gopinath, 2015; Amiti et al., 2018).

3 The insulation puzzle: evidence from Europe

We are interested in how an external shock propagates to a neighboring country, and how this propagation depends on the choice of exchange-rate regime. Toward this end, we focus on shocks that originate in the euro area. Throughout we compare the effect of the shocks in the neighbor countries, both pegs and float, to what happens in the euro area itself. Because the composition of the euro area has changed over time and some later members of the euro area are in our sample as pegs, we focus on the adjustment in the original 11 euro area members (EA11) whenever appropriate.[15]

For our empirical strategy we need a measure of structural euro-area shocks. As far as we can, we wish to rely on measures of such shocks that were identified in earlier work, outside of the scope of the current paper. For the baseline specification, we choose as counterpart for $\bar{\epsilon}_t$ in models (1) and (2) above, the monetary policy shocks identified Jarociński and Karadi (2020) for the euro area and updated by Jarociński (2021). These authors combine a high-frequency approach to identification with sign restrictions. Specifically, they capture surprises in 3-months interest-rate forwards around euro-area monetary policy events. And they disentangle monetary policy shocks from central bank information shocks by restricting the sign of the stock market response to the surprise. Intuitively, monetary policy shocks are shocks which generate a positive response to the nominal interest rate, and a negative response of the stock market.

Since we are interested in the spillovers from EA monetary policy shocks on the EA's neigh-

[15]For industrial production, the unemployment rate, HICP inflation and PPI inflation we construct an aggregate time series for EA11, see Appendix A. Results for the EA19 series are very similar (and available on request). This is perhaps to be expected, given the small weight that the late adopters of the euro have in euro-area GDP.

bor countries, we verify that these shocks are not systematically related to other shocks that may impact the global economy. Specifically, we investigate the co-movement of EA monetary policy shocks with US monetary policy shocks as identified by Jarociński and Karadi (2020) and with global risk shocks as identified by (Georgiadis et al., 2021). We find that both series are not correlated with EA monetary policy shocks, see Figure C.2 in the appendix. This is also consistent with results reported by Jarociński (2021). Next, we investigate whether EA monetary policy shocks co-move systematically with either the monthly change in the VIX or the excess bond premium, both widely-used indicators of (global) financial conditions. We find that they do not co-move, see the bottom panels of Figure C.2 in the appendix.

Our baseline estimates focus on the transmission of EA monetary policy shocks to the neighboring countries. In a series of robustness checks, we verify that our main results are neither specific to this measure of monetary policy shocks, nor, in fact, specific to monetary policy shocks in the first place. In our baseline, we include 12 lags of the shock and 12 lags of the dependent variable in the vector of controls. We find that our results are also robust with respect to alternative specifications along this dimension.

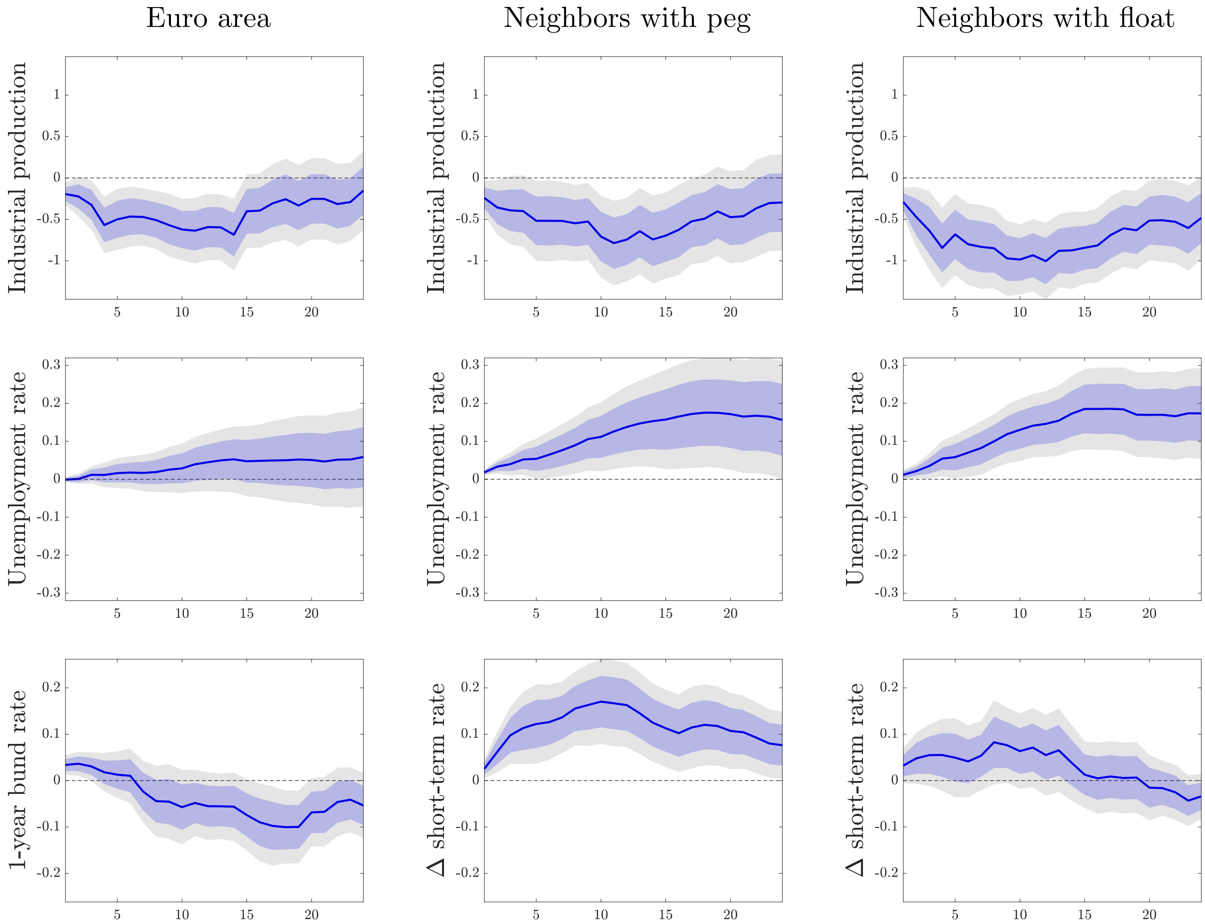
3.1 Euro-area monetary policy shocks and their spillovers

In what follows we present estimates for the adjustment to euro-area monetary policy shocks, both in the euro area itself and the neighboring countries. Figures 2.A and 2.B show our main results. They compare responses in the euro area (left columns) to the responses in the neighboring countries. The middle columns report responses of neighboring countries that peg to the euro. The right columns report responses of neighbors with a floating currency. Each row collects the response of a different macroeconomic or financial time series.

We normalize the shock to a one-standard deviation contractionary monetary policy shock. In each panel of the figures, the horizontal axis measures time in months while the vertical axis measures the deviation of a variable from its no-shock level in percent or in percentage points. The shaded areas represent 68 and 90 percent confidence intervals based on Driscoll and Kraay (1998) robust standard errors and the solid line corresponds to the point estimate. The first two rows of Figure 2.A show the response of two key indicators for real activity that are available at a monthly frequency: industrial production and the unemployment rate. According to the point estimates, a one-standard deviation monetary contraction in the euro area reduces euro-area industrial production by a little over half a percent (first row, first column) and the unemployment rate rises by about 0.1 percentage point (second row, first column). Not surprisingly, perhaps, the shock affects neighbors that peg to the euro in much the same way as the euro area itself (middle column). What is surprising, though, certainly against the received wisdom, is that there also are sizable spillovers to the neighbors that have flexible exchange rates. Indeed, there is no evidence that the flexible exchange rate insulates economic activity in the neighbor countries: the contraction for countries with a flexible exchange rate (right column) is as strong as in those countries where the exchange rate is pegged to the euro (middle column).

The final row of Figure 2.A shows the response of interest rates as measured by the financing costs of governments. Jarociński and Karadi (2020) identify the monetary policy shock based on an event study combined with sign restrictions. It bears noting that their sample, as ours,

Figure 2.A: Adjustment to euro-area monetary policy shock

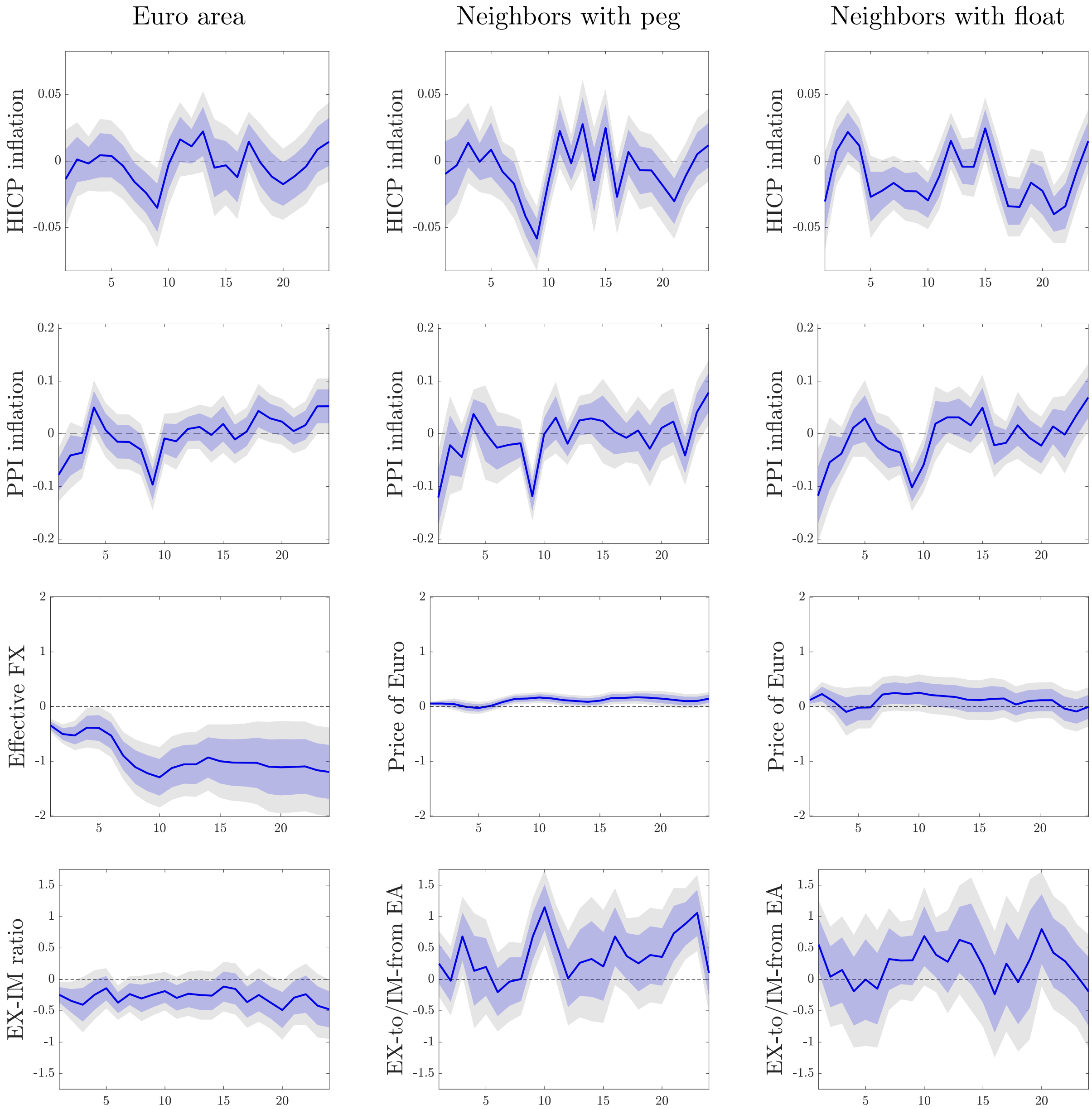


Notes: Shock is one-standard deviation shock identified by Jarociński and Karadi (2020) using high frequency data and sign restrictions. Left column shows response of euro area variables, middle column the response in neighbor countries with an exchange rate peg, right column the response in neighbor countries with a flexible exchange rate; solid line represents point estimate, shaded areas correspond to 68 and 90 percent confidence bounds based on Driscoll and Kraay (1998) robust standard errors. Horizontal axis measures time in months. Vertical axis measures deviation in percent/percentage points.

features a decade of a varied range of unconventional monetary policies in the euro area, including asset purchase programs and forward guidance, in an area where there is no common safe asset (Gertler and Karadi, 2015). Arguably for these reasons, the empirical mapping of the monetary shock to one measure of euro-area interest rates is not as clear cut. In particular, the left panel reports the response of one interest rate in the euro area, the one-year rate on German bunds (in annualized percentage points). This rises on impact, but the response is not persistent.[16] The effect of a change in the euro area's monetary stance is however detectable through its spillovers on the interest rates of neighboring countries that peg to the euro. Indeed, interest rates there rise vis-à-vis the level of measured short term interest rates in the euro area (last row, middle panel). At the short end the interest rates of pegs and floats evolve comparably (rising about 0.1 percentage point annualized above the short term rate in the euro area).

[16] In the analysis of Jarociński and Karadi (2020) the one-year rate also increases on impact only (their Figure

Figure 2.B: Adjustment to euro-area monetary policy shock



Notes: Shock is one-standard deviation shock identified by Jarociński and Karadi (2020) using high frequency data and sign restrictions. Left column shows response of euro area variables, middle column the response in neighbor countries with an exchange rate peg, right column the response in neighbor countries with a flexible exchange rate; solid line represents point estimate, shaded areas correspond to 68 and 90 percent confidence bounds based on Driscoll and Kraay (1998) robust standard errors. Horizontal axis measures time in months. Vertical axis measures deviation in percent/percentage points.

Figure 2.B shows the response of additional variables. It is organized in the same way as Figure 2.A. The top row displays the adjustment of consumer price inflation, as measured by the harmonized consumer price index (HICP), expressed in percent (not annualized). In response to the shock, consumer price inflation declines somewhat in the euro area. But the response is

8.A, panel B).

small, and largely not significant. In the neighbor countries that peg the same pattern occurs. Importantly, for floaters, too, the response of consumer price inflation is small. Besides, the sign of the pattern is inconclusive. The contractionary effect of the monetary policy shock is somewhat more visible, instead, when we consider the response of producer price inflation, as measured by the producer price index (PPI), in the second row of Figure 2.B, also measured in percent. Once more, the response of producer price inflation is of comparable size in the neighbor countries, regardless of whether they peg to the euro (second row, middle panel) or float (right panel).

The third row of Figure 2.B shows the response of the exchange rate, measured in percentage deviations from the pre-shock level. In the left-most column we report the effective exchange rate of the euro against the currencies of its trading partners. This is measured as the price of foreign currency expressed in terms of euro. In response to the contractionary monetary shock in the euro area, the effective exchange rate of the euro appreciates (declines) on impact, the appreciation of the effective exchange rate also being a clear guide to the nature of the shock. In the other two columns, we report the bilateral exchange rate of the national currency of the neighbor countries with the euro. A rise corresponds to a depreciation against the euro. In line with the construction of our sample, there is virtually no response of the exchange rate among neighbors that maintain a hard or soft peg (third row, middle panel): by design, neighbors in the "peg" group have limited exchange rate flexibility. The currency of the neighbors that have a flexible exchange rate depreciate slightly against the euro (the right-most column) but the effect seems moderate and does not exceed 0.2 percent. In sum, even though the exchange rate of neighbors that float depreciates slightly (acting as a "shock absorber"), we find no evidence that economic activity in practice is better insulated from euro area monetary policy shocks under a float than a peg.

The traditional view of the flexible exchange rate as a shock absorber works through international expenditure switching. By this a depreciation of the currency of neighbors with a flexible exchange rate leads domestic and foreign demand to switch towards the goods and services produced in the depreciating country. So as to probe into this channel, the last row of Figure 2.B shows the adjustment of the export-to-import ratio, measured in logs relative to the no-shock level. Expenditure switching would suggest this time series to move in the same direction as the exchange rate. For the euro area, we report total exports over total imports. We do similarly for the neighbors, but here we focus on bilateral trade with the euro area only. A monetary contraction in the euro area reduces this ratio for the euro area moderately, by half a percent. How about trade between the euro area and the neighboring countries, then? In the neighboring countries exports rise relative to imports, suggestive of expenditure switching. This suggests that the spillovers from the euro area to economic activity of its neighbors are not driven by an adverse movement of net exports. We will take this up in our model-based analysis below. And once more, the responses for pegs and floats are quite similar. They do not point toward better insulation of the floaters.

3.2 Robustness analysis

Our main finding is that countries with flexible exchange rates do not seem to be more insulated from external shocks than countries that peg their currencies to the source country of the shock. We have established this finding empirically for a euro-area monetary policy shock documenting its transmission to neighboring countries. This section provides robustness analysis at two levels. First, in Section 3.2.1, we stick to analyzing the transmission of euro-area monetary policy shocks. We study the robustness of the results with respect to the set of controls that we choose and probe into the robustness of our findings by varying the classification of the groups of pegs and floats. Last, we look into alternative measures of euro-area monetary policy shocks. Second, in section D.2, we study the extent to which similar "non-insulation" findings emerge for the transmission of other external shocks.

3.2.1 Robustness for euro-area monetary policy shocks

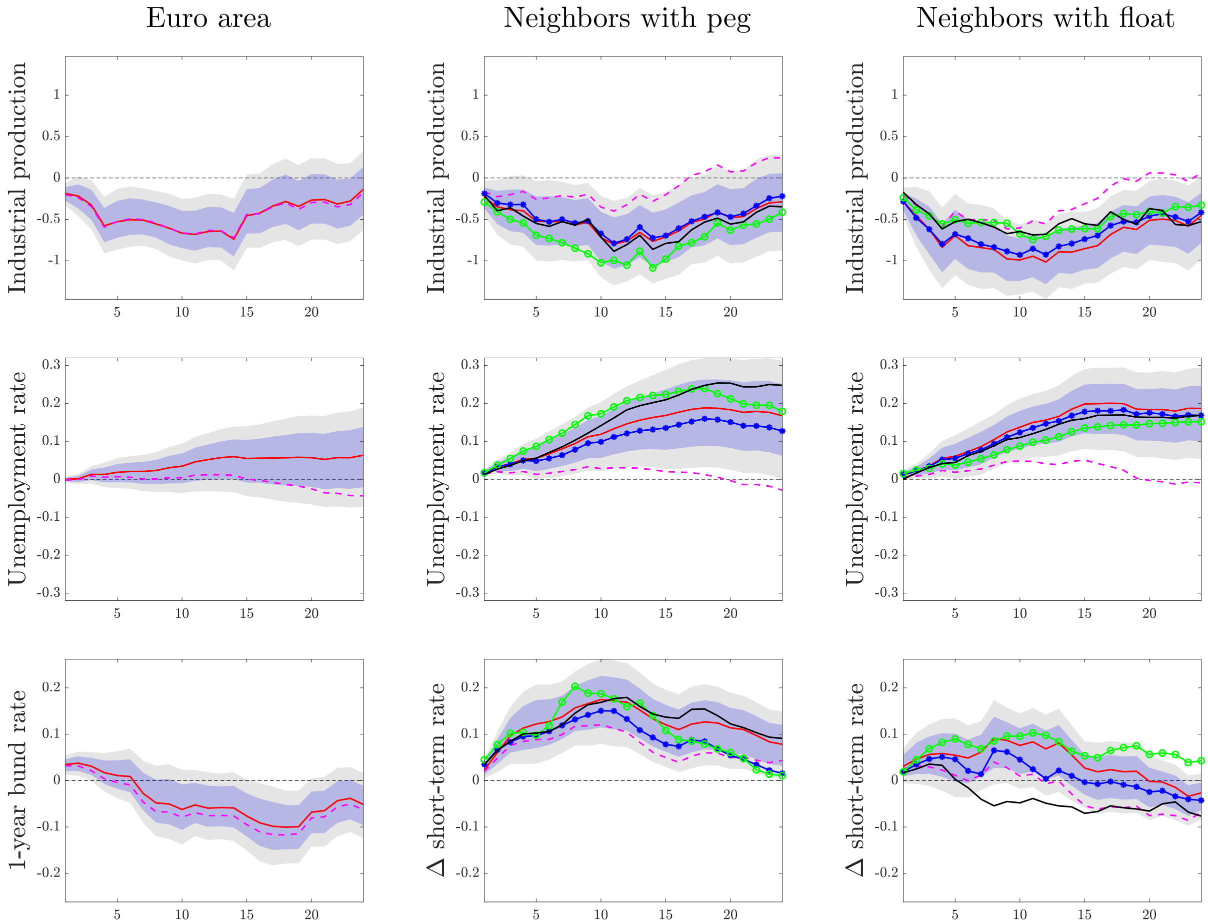
This section reports on the robustness of our findings as to the spillovers of euro-area monetary policy shocks. Figure 3.A and Figure 3.B show the result of a number of changes in the empirical specification, as do Figures D.5 to D.8 in the appendix. The figures are organized in exactly the same way as Figures 2.A and 2.B before. In order to provide a visual benchmark against which to assess the robustness of our baseline, they report the point estimates under alternative specifications against the background of the confidence bounds of the baseline specification (shaded area).

First, we conduct a set of experiments that includes additional controls when we estimate models (1) and (2). In particular, we have to make sure that the conditional comovement of the euro area and its floating and pegging neighbors that we find does not originate from a common shock that is external to both the euro area and its neighbors. One candidate would be a US monetary policy shock which may trigger a global response of economic activity. Toward this end, in a first modification of the baseline specification, we include among the controls US monetary policy shocks as identified by Jarociński and Karadi (2020). The results are shown as red solid lines in the figures, and are virtually unchanged relative to the baseline. In an additional experiment, we seek to purge the EA monetary policy shocks of any possible component caused by US monetary policy shocks. For this purpose we first regress EA monetary policy shocks on US monetary policy shocks in the month and three additional lags. Then, we estimate our baseline model on the residual obtained in the first step. We find that also in this case results are very similar to the baseline, see Figures C.3 and C.4 in the appendix.

Second, we include implied stock market volatility as measured by the VIX and the VSTOXX as additional control variables.[17] In this way we seek to address concerns that there is a global financial cycle that affects the euro area and its neighbors alike, causing us to measure cross-border spillovers (Rey 2013; Miranda-Agrippino and Rey, 2020). The results of this analysis are shown as dashed lines in magenta in the figures. For some variables, notably unemployment and industrial production, the measured spillovers are somewhat weaker than in the baseline. For others, in particular the response of producer and consumer price inflation, they tend to be

[17] We also consider both indicators in isolation and find very similar results.

Figure 3.A: Adjustment to euro-area monetary policy shock: alternative specifications

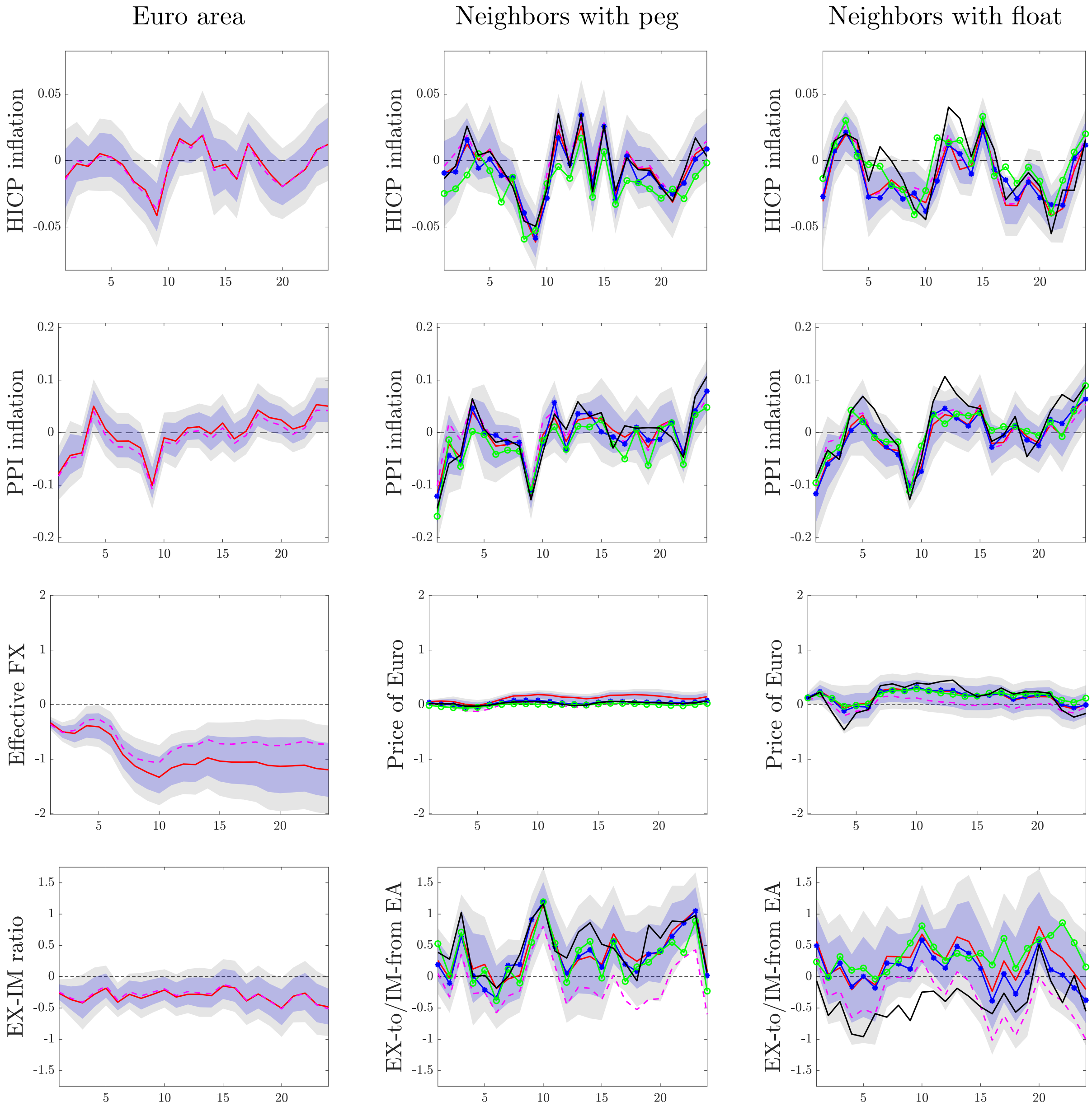


Notes: Shock is one-standard deviation shock. Left column shows responses of euro area variables, middle (right) column the response in neighbor countries with pegged (flexible) exchange rate; shaded areas correspond to 68 and 90 percent confidence bounds of estimate for baseline, see Figures 2.A and 2.B for details. Point estimates for alternative specifications: US monetary policy shocks as additional control variable (red solid line), VIX & VSTOXX as additional control variables (dashed lines in magenta); no intermediate regimes, that is, we drop country-month observations with IRR classification between 5 and 9 (blue line with stars), float defined as all country-month observations where a country is neither in ERM2 nor on euro (green line with circles), mean group estimator for pure pegs and floats (black solid lines).

comparable. Importantly, all of this applies to pegs and floats alike. In all of the charts, the spillovers to floaters are at least as large as the spillovers to neighbors that peg.

In a second set of experiments we assess the robustness of our results with regard to the classification of the exchange rate regime. Naturally, the classification of the neighbors' exchange rate regime does not affect the results for the euro area and hence we do not show any new results in the left column. First, we omit all country-months observations from our sample for which the classification of IRR is between 5 and 9, that is, we consider as pegs only regimes that are operating a de facto peg or a more rigid regime; while as floats we consider exchange rate regimes that operate on a de facto crawling band narrower than or equal to +/-5% (IRR classification: 10), or on a more flexible regime. As a result, we loose some 700 observations (or about 15 percent) of our sample. The results are shown as the blue solid line with stars in

Figure 3.B: Adjustment to euro-area monetary policy shock: alternative specifications



Notes: Shock is one-standard deviation shock. Left column shows responses of euro area variables, middle (right) column the response in neighbor countries with pegged (flexible) exchange rate; shaded areas correspond to 68 and 90 percent confidence bounds of estimate for baseline, see Figures 2.A and 2.B for details. Point estimates for alternative specifications: US monetary policy shocks as additional control variable (red solid line), VIX & VSTOXX as additional control variables (dashed lines in magenta); no intermediate regimes, that is, we drop country-month observations with IRR classification between 5 and 9 (blue line with stars), float defined as all country-month observations where a country is neither in ERM2 nor on euro (green line with circles), mean group estimator for pure pegs and floats (black solid lines).

Figures 3.A and 3.B. Second, we adopt an alternative strategy to define a float. Rather than relying on IRR's classification as in our baseline, we use ERM2 membership as a criterion: we define as floats all country-month observations for which a country is neither a member of the ERM2 nor a member of the euro area. In our sample we have 707 observations with ERM2 membership, and 948 observations with euro area membership. On the basis of this criterion for a peg, we end up with 3145 floaters (or 65% of the total). This is a considerably larger group than in our baseline. Results are shown by the green line with circles in the figure. Last, in order to address concerns that our baseline model imposes too much slope homogeneity, we estimate it on a country-by-country basis for those countries for which the exchange rate regime was stable during our sample period. This allows us to estimate a linear model for each country (rather than modelling interaction effects between the shock and the exchange rate regime). We then compute the average impulse response function across countries, that is, the mean group estimator, separately for pegs and floats (Pesaran and Smith, 1995). For the pegs the neighbors we consider for this exercise are: Bulgaria, Croatia, Cyprus, Denmark, Greece, Lithuania, Slovenia and Slovakia.[18] For the floats we consider Iceland, Norway, Poland, and the United Kingdom. As Figure B.1 in the appendix shows, these countries operated a floating exchange rate almost always during our sample period.[19] The results are shown by the black solid line in the figure. For all three experiments we find that differences relative to the baseline are moderate. Spillovers to economic activity and producer price inflation remain large, notably for floaters.

We further investigate the robustness of our results and verify that the results for our baseline specification are not driven by specific country groups. For this purpose, we first drop Cyprus and Greece from the sample since one may be concerned that the developments in these countries during the sovereign debt crisis may be a source for euro-area monetary policy shocks. Also, we exclude all EMU accession countries from our sample (Bulgaria, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Slovakia) because in this case business-cycle synchronization may be dominated by other factors than the exchange rate regime. Also, we run the model on a subsample of only Eastern European countries (Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia) as well as a sample which exclude precisely these countries. In a further experiment we drop observations for the years 2008–09 from our sample, that is, the period which is arguably dominated by the global financial crisis (GFC). We show results for these specifications in Figures D.5 and D.6 in the appendix. We find that our results are basically unchanged as we drop countries or country groups from our sample. When we drop the GFC period, spillovers are considerably smaller, but the effect of the monetary policy shock in the euro area itself is much smaller, too. This suggests that euro area monetary policy shocks during the GFC have had a rather larger impact, both in the euro area and in the neighbor countries. In any case, we find that spillovers are no smaller for floats than for pegs—exactly as for our baseline specification.

Next, we consider alternative measures of euro-area monetary policy shocks. First, we draw once more on Jarociński and Karadi (2020) and use their shock series which is based on what they call the "poor man's sign restriction." In this case, rather than restricting the impulse responses of an estimated VAR model, the authors classify those monetary surprises as monetary policy shocks for which the stock-market surprise and surprise in the interest-rate forward have the opposite sign. Second, we use a measure of monetary policy shocks compiled by Altavilla

[18] We do not include Estonia because its exchange rate was perfectly constant in sample.

[19] In the first two years of our sample period Iceland is assigned an 8 by IRR, afterwards a 9 or more, as are the other countries in the group of four floaters.

et al. (2019). This measure, too, is based on high-frequency monetary surprises and, thus, conceptually similar to our baseline shock measure. But it does not restrict the sign of the stock market response so as to control for central bank information.

We also consider an alternative specification which features 6 rather than 12 lags of the shock and the dependent variable in the vector of controls. We show results for these specifications in Figures D.7 and D.8 in the appendix. They are generally very similar to those for the baseline.

In sum, we find that our main result is robust across a wide range of alternative specifications: spillovers from the euro area monetary policy shocks on its neighbor countries are no smaller for countries with flexible exchange rates than for countries which peg their currencies to the euro.

3.2.2 Other shocks

So far, we have focused on euro-area monetary policy shocks. Appendix D.2 probes into how general the results are. That is, whether we find that the exchange-rate regime appears to have equally limited effects on the spillovers for other euro-area shocks. For this purpose we once more rely on estimating models (1) and (2), but we choose shocks other than euro-area monetary policy shocks to represent $\bar{\varepsilon}_t$. First, we estimate the effect of central bank information shocks in the euro area, as identified by Jarociński and Karadi (2020) and Jarociński (2021). Intuitively, these shocks account for a positive co-movement of interest-rate forwards and the stock market around monetary events. As a second alternative shock, we consider a euro-area credit "spread shock" that we identify relying on earlier work by Gilchrist and Mojon (2018). Specially, we use their index of credit risk for banks in the euro area which, in turn, aggregates individual security level data for Germany, Italy, Spain and France. We include this time series together with observations for industrial production, HICP inflation (core), and the EONIA in a VAR model and identify the spread shock recursively.

Just like in the case of a monetary policy shock, the contractionary (or expansionary) effect of these other shocks spills over to industrial production and unemployment of the neighbors, and once again – it seems – irrespectively of the exchange rate regime. And just like for the monetary policy shock discussed above, we find a positive response of the measured interest rate differential with respect to the euro area for the neighbor countries—independently of the currency regime.

4 A New Keynesian two-country model

To assess our empirical results in light of theory, we resort to a stylized but tractable open economy model. The structure of the model starts from earlier work of ours, on which we draw in our exposition (Corsetti et al., 2017). Relative to this, we allow for the possibility that prices of domestic exporters are sticky in the currency of a foreign country, the "dominant currency", and that firms employ imported inputs in production. Both of these specifications follow Gopinath et al. (2020).

There are two countries, Home and Foreign. The countries differ only in size, in terms of their monetary policies, and in terms of the shocks that they are exposed to. The world economy is populated by a measure one of households. Households on the segment $[0, n)$ belong to the

Home country and the ones on the segment $[n, 1]$ belong to the Foreign country. Later on, we will assume that the domestic economy is generically small ($n \to 0$). Still, we explicitly model the structure of both Home and Foreign. This is so because the specifics of the developments in Foreign impact Home through both trade and financial markets. The main building blocks of the model are standard. In the following, we thus provide a compact exposition that focuses on Home. When necessary, we refer to Foreign variables by means of an asterisk.

4.1 Households

In each country, there is a representative household. Letting C_t denote a consumption index (defined below) and H_t labor supply, the objective of the household is to maximize expected life-time utility

$$E_t \sum_{k=0}^{\infty} (\xi_{t+k} \beta^k) \left(\ln C_{t+k} - \frac{H_{t+k}^{1+\varphi}}{1+\varphi} \right), \tag{3}$$

$\beta \in (0, 1)$ is the discount factor and ξ_t is a unit-mean shock to the time-discount factor, a "demand shock" for short. $\varphi > 0$ is the inverse of the Frisch elasticity of labor supply, and E_t is the expectations operator. The household trades a complete set of state-contingent securities with the rest of the world. Letting $\mathcal{X}_{t+1}$ denote the payoffs in $t + 1$ of the portfolio that the household has acquired in period t, in units of domestic currency, the household's budget constraint is given by

$$E_t \{\rho_{t,t+1} \mathcal{X}_{t+1}\} - \mathcal{X}_t + P_t C_t = (W_t H_t + \Upsilon_t) - T_t.$$

Here $\rho_{t,t+1}$ is the nominal stochastic discount factor. W_t is the nominal wage. Υ_t are the domestic firms' nominal profits. T_t are lump-sum taxes. P_t is the consumption-based price index. The consumption index C_t is defined as a Dixit-Stiglitz aggregator of Home and Foreign bundles of goods

$$C_t = \left[(1 - (1 - n)\upsilon)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + ((1 - n)\upsilon)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \tag{4}$$

Here $C_{H,t}$ and $C_{F,t}$ are the Home-produced and Foreign-produced bundles consumed in Home. $\eta > 0$ is the elasticity of substitution between the two bundles and $\upsilon \in [0, 1]$ measures the home bias in consumption.[20]

The bundles of Home- and Foreign-produced goods are defined as follows

$$C_{H,t} = \left[\left(\frac{1}{n}\right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \quad C_{F,t} = \left[\left(\frac{1}{1-n}\right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \tag{5}$$

[20] This specification of home bias follows Sutherland (2005) and De Paoli (2009). With $\upsilon = 1$, there is no home bias: if the relative price of foreign and domestic goods is unity, Home's consumption basket contains a share n of Home-produced goods, and a share of $1 - n$ of imported goods. A lower value of υ implies that the fraction of domestically produced goods in final goods exceeds the share of domestic production in the world economy. If $\upsilon = 0$, there is full home bias and no trade across countries. The Foreign consumption basket is defined as

$$C_t^* = \left[(n\upsilon)^{\frac{1}{\eta}} {C_{H,t}^*}^{\frac{\eta-1}{\eta}} + (1 - n\upsilon)^{\frac{1}{\eta}} {C_{F,t}^*}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}.$$

where $C_{H,t}(j)$ and $C_{F,t}(j)$ denote differentiated intermediate goods produced in Home and Foreign, respectively, and $\epsilon > 1$ measures the elasticity of substitution between intermediate goods produced within the same country. All the intermediate goods are traded across borders.

The consumer price index in Home is given by

$$P_t = \left[(1-(1-n)\upsilon)P_{H,t}^{1-\eta} + ((1-n)\upsilon)P_{F,t}^{1-\eta}\right]^{\frac{1}{1-\eta}}, \tag{6}$$

where $P_{H,t}$ and $P_{F,t}$ is the price of the bundle of imported goods.[21]

In maximizing utility, the household takes prices as given. Let $P_{H,t}(j)$ and $P_{F,t}(j)$ denote the domestic currency price of a generic domestically produced and a generic import good, respectively, the price indices for the bundle of domestically produced goods and for imported goods, respectively, are given by

$$P_{H,t} = \left[\frac{1}{n}\int_0^n P_{H,t}(j)^{1-\epsilon}dj\right]^{\frac{1}{1-\epsilon}}, \quad P_{F,t} = \left[\frac{1}{1-n}\int_n^1 P_{F,t}(j)^{1-\epsilon}dj\right]^{\frac{1}{1-\epsilon}}. \tag{7}$$

We let $P^*_{H,t}(j)$ denote the foreign-currency price that the producer in Home charges for its good in Foreign. Let $P^*_{H,t}$ be a price index defined analogously to $P_{H,t}$. Let $\mathcal{E}_t$ be the nominal exchange rate measured as the price of foreign currency in terms of domestic currency. A rise in $\mathcal{E}_t$, thus, represents a nominal depreciation of Home's currency. We assume that Home's export prices are sticky in foreign currency units. The law of one price, thus, does not necessarily hold. Foreign exports, too, are sticky in Foreign's currency, making Foreign's currency "dominant" for international trade in the sense of Gopinath et al. (2020). We define M_t as the resulting law-of-one-price gap for domestic goods such that:

$$M_t P_{H,t} = \mathcal{E}_t P^*_{H,t}. \tag{8}$$

For imported goods in Home, the law of one price holds.

$$P_{F,t} = \mathcal{E}_t P^*_{F,t}. \tag{9}$$

We define the Home terms of trade, S_t, as the price of imports in Home relative to the price of exports, both measured in Foreign currency ("euros"):

$$S_t = \frac{P^*_{F,t}}{P^*_{H,t}} = \frac{\mathcal{E}_t P^*_{F,t}}{M_t P_{H,t}} \tag{10}$$

A rise in S_t marks a depreciation of the Home terms of trade (Home goods becoming relatively cheaper).

The household's problem defines the households' demand function for Foreign-produced and Home-produced goods. Demand from domestic consumers for a generic intermediate good pro-

[21] The consumer price level in Foreign is given by

$$P^*_t = \left[n\upsilon {P^*_{H,t}}^{1-\eta} + (1-n\upsilon){P^*_{F,t}}^{1-\eta}\right]^{\frac{1}{1-\eta}}$$

duced in Home is given by[22]

$$C_t^D(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon}\left[\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(1-(1-n)\upsilon)C_t\right]. \tag{12}$$

4.2 Firms

Intermediate goods producers sell under monopolistic competition and employ labor and intermediate inputs in production:

$$Y_t(j) = Z_t H_t(j)^{1-\alpha} X_t(j)^{\alpha}, \tag{13}$$

where $H_t(j)$ denotes labor services employed by firm $j \in [0, n]$ in period t, $X_t(j)$ is an aggregator of intermediate inputs employed by firm j, and Z_t is a stationary aggregate productivity shock. The intermediate inputs are produced domestically and abroad, and the intermediate input aggregator $X_t(j)$ takes the same functional form as the consumption aggregator in equation (4). Likewise, the bundle of Home (Foreign) intermediate inputs $X_{H,t}(j)$ ($X_{F,t}(j)$) takes the same functional form as the Home-produced (Foreign-produced) bundle of final goods consumed in Home $C_{H,t}$ ($C_{F,t}$).

Total domestic demand for a generic intermediate good produced in Home consists of the demand from domestic consumers and the demand from domestic producers

$$Y_t^D(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon}\left[\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(1-(1-n)\upsilon)\left(C_t + X_t\right)\right], \tag{14}$$

where me made use of the assumption that consumption bundles and intermediate-input bundles are isomorphic. Total foreign demand for a generic intermediate good produced in Home consists of the demand from foreign consumers and the demand from foreign producers

$$Y_t^{D*}(j) = \left(\frac{P_{H,t}^*(j)}{P_{H,t}^*}\right)^{-\epsilon}\left[\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\eta}(1-n)\upsilon\left(C_t^* + X_t^*\right)\right], \tag{15}$$

where X_t^* has the same functional form as C_t^*.

Each period, Home producers choose the cost-minimizing pair of labor and intermediate inputs so as to meet the demand for their intermediate goods

$$\min_{H_t(j), X_t(j)} W_t H_t(j) + P_t X_t(j) - MC_t(j)\left[Z_t H_t(j)^{1-\alpha} X_t(j)^{\alpha} - (Y_t^D(j) + Y_t^{D*}(j))\right]$$

where the Lagrange multiplier $MC_t(j)$ represents nominal marginal costs of firm j in period t. Using the first-order conditions to the cost minimization problem, one can show that firms'

[22] Demand from consumers in the rest of the world is given by

$$C_t^{D*}(j) = \left(\frac{P_{H,t}^*(j)}{P_{H,t}^*}\right)^{-\epsilon}\left[\left(\frac{P_{H,t}^*}{P_t^*}\right)^{-\eta}(1-n)\upsilon C_t^*\right]. \tag{11}$$

marginal costs are not firm-specific, but rather that

$$MC_t(j) = \left(\frac{1}{\alpha}\right)^{\alpha} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \frac{P_t^{\alpha} W_t^{1-\alpha}}{Z_t},$$

for all firms j, and, therefore, $MC_t(j) = MC_t$.

Under a regime of dominant currency pricing, Home producers solve separate price-setting problems for the domestic and the foreign market. For the home market the problem is to

$$\max_{\{P_{H,t+k}(j)\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \rho_{t,t+k} \Bigg\{ \left[(1+\nu)P_{H,t+k}(j) - MC_{t+k}\right] Y_{t+k}^{D}(j) \\ - \frac{\omega}{2}\left[(1-(1-n)\upsilon)\left(\frac{P_{H,t+k}(j)}{P_{H,t+k-1}(j)} - 1\right)^2 P_{H,t+k} Y_{t+k}^{D}\right]\Bigg\}$$

s.t. (14).

The price in the foreign market is determined through

$$\max_{\{P_{H,t+k}^{*}(j)\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \rho_{t,t+k} \Bigg\{ \left[(1+\nu)\mathcal{E}_{t+k} P_{H,t+k}^{*}(j) - MC_{t+k}\right] Y_{t+k}^{D*}(j) \\ - \frac{\omega}{2}\left[(1-n)\upsilon\left(\frac{P_{H,t+k}(j)^{*}}{P_{H,t+k-1}(j)^{*}} - 1\right)^2 P_{H,t+k} Y_{t+k}^{D*}\right]\Bigg\}$$

s.t. (15).

4.3 Monetary policy, market clearing and equilibrium

Monetary policy is conducted by adjusting the short-term nominal interest rate:

$$R_t \equiv 1/E_t \rho_{t,t+1}.$$

The monetary regime in Home and Foreign will be defined further below. We allow for monetary shocks in Foreign to shift Foreign inflation, interest rates, and economic activity. In equilibrium, domestic prices and foreign sales prices, respectively, of all firms will be identical. So that demand from domestic households is

$$Y_t^{D} = (1-(1-n)\upsilon)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(C_t + X_t),$$

and demand from foreign households is

$$Y_t^{D*} = (1-n)\upsilon\left(\frac{P_{H,t}^{*}}{P_t^{*}}\right)^{-\eta}(C_t^{*} + X_t^{*}).$$

Total demand for goods is

$$
\begin{aligned}
Y_t \quad = \quad & \left[\left(\frac{P_{H,t}}{P_t}\right)^{-\eta}(1-(1-n)\upsilon)(C_t+X_t)\right]\left(1+\frac{\omega}{2}\left(\frac{P_{H,t+k}}{P_{H,t+k-1}}-1\right)^2\right) \\
& + \left[\left(\frac{P^*_{H,t}}{P^*_t}\right)^{-\eta}(1-n)\upsilon(C^*_t+X^*_t)\right]\left(1+\frac{\omega}{2}\left(\frac{P^*_{H,t+k}}{P^*_{H,t+k-1}}-1\right)^2\right).
\end{aligned} \tag{16}
$$

The labor markets clear if

$$
H_t = \left(\frac{Y_t}{Z_t X_t^{1-\alpha}}\right)^{\frac{1}{\alpha}}. \tag{17}
$$

Finally, in equilibrium, household behavior and international financial market clearing give rise to the familiar international risk sharing condition.

4.4 Focus on the small open economy

From here onward, we will focus only on the limiting case $n \to 0$. The Foreign consumption basket will almost exclusively contain Foreign-produced goods. The consumer and producer price level in Foreign, therefore, will coincide. Effectively, the Foreign economy operates like a closed economy. From the perspective of the small open Home economy, Foreign can be an important source of shocks, though, transmitted across borders through financial markets and trade.

5 Transmission of foreign monetary shocks: analytical insight

Empirically, we have found that the exchange rate regime appears to make little difference as to the insulation of domestic activity from foreign shocks; recall Section 3. The new-Keynesian model specified above provides a stylized framework for thinking about how the transmission of foreign shocks may vary with the exchange-rate and monetary regime. In this section we will first build analytical intuition—using a tractable version of the model obtained by imposing a few simplifying parametric assumptions. Then, in the next section and the appendix, we will provide extensive numerical simulations using a calibrated version.

The goal of the section is to explore a possible reason for the apparent insulation equivalence across exchange rate regimes. Namely, especially in a dominant-currency regime world, insulating domestic economic activity from adverse foreign shocks requires stimulating *domestic* absorption. This in turn, requires a depreciation of the exchange rate and a—temporary—rise in inflation. By its design, inflation targeting prevents this, inducing the very output spillovers even under flexible exchange rates.

5.1 An analytically tractable version of the model

To obtain sharp and clear results, we focus on a model variant without round-about-production of intermediate goods, that is, we set $\alpha = 0$, and make the following additional assumptions. First, we set the trade elasticity to unity, $\eta = 1$ and assume an infinitely elastic labor supply, $\varphi = 0$. As we show below, these assumptions imply that the terms of trade are exogenous and constant, reducing a model with two endogenous state variables (s_{t-1} and m_{t-1}) to a tractable variant that only has one (m_{t-1}). For tractability, we also focus on the limit $\beta \to 1$, and restrict the process of shocks as specified in subsection 5.5 below. Throughout this section, we consider a linear approximation of the model around a deterministic and symmetric zero-inflation steady state.[23] As regards notation, small letters correspond to the percentage deviation of a variable from the non-stochastic steady state, and variables without a time index mark the variable's steady-state value. By way of example, $y_t^* := \log(Y_t^*) - \log(Y^*)$ marks the percentage deviation of Foreign output from its steady state.

5.2 Equilibrium conditions for Foreign

The equilibrium conditions for the large foreign economy follow the conventional closed-economy New Keynesian model. That is, the intertemporal IS equation in Foreign is given by

$$y_t^* \quad = \quad E_t y_{t+1}^* - \left[r_t^* - E_t \pi_{t+1}^* \right], \tag{18}$$

linking foreign output to its real interest rate. The New Keynesian Phillips curve in Foreign is given by

$$\pi_t^* = E_t \pi_{t+1}^* + \kappa y_t^*, \ \kappa > 0. \tag{19}$$

linking Foreign inflation to economic activity. Last, we need to specify Foreign monetary policy. To be concrete, we assume that foreign monetary policy follows a conventional Taylor rule:

$$r_t^* = \phi \pi_t^* + \gamma y_t^* + \varepsilon_t^*, \tag{20}$$

linking the foreign interest rate, inflation and output. Here $\phi > 1$, $\gamma \geq 0$, so foreign monetary policy obeys the Taylor principle and the equilibrium is determinate. ε_t^* is the foreign monetary policy shock, the transmission of which to the Home economy the current section studies.

5.3 Equilibrium conditions for Home

In the (small) Home economy, the dynamic IS-relation in Home links output with the real interest rate and the law of one-price gap according to

$$y_t \quad = \quad E_t y_{t+1} - \left(r_t - E_t(\pi_{H,t+1} + \upsilon \Delta m_{t+1}) \right). \tag{21}$$

The Phillips curve that governs sales prices of Home goods in Home is given by

$$\pi_{H,t} \quad = \quad E_t \pi_{H,t+1} + \kappa \left[y_t + \upsilon m_t \right]. \tag{22}$$

[23] The market value of initial wealth in Home and Foreign, respectively, is influenced by all shocks that affect the economies, the structural features, as well as by the monetary regime(s). In a linear approximation, however, initial wealth is without material consequences for the dynamics of the model economy. Therefore, we focus on a symmetric steady state so as to keep the exposition tractable. It is well understood that higher-order approximations should not abstract from the market value of initial wealth (see, for instance, Corsetti et al., 2019). Welfare, or the effects of risk are not in the focus of the current paper.

Here, $\kappa > 0$ is the slope of the Phillips curve. Export-price inflation in Foreign currency is given by

$$\pi^*_{H,t} = E_t \pi^*_{H,t+1} + \kappa \left[y_t - (1-\upsilon) m_t \right]. \tag{23}$$

The Home terms of trade evolve according to

$$s_t = s_{t-1} + \pi^*_t - \pi^*_{H,t}. \tag{24}$$

And the law-of-one-price gap, m_t, follows

$$m_t = m_{t-1} + e_t - e_{t-1} + \pi^*_{H,t} - \pi_{H,t}. \tag{25}$$

Last, the international risk sharing condition combined with the demand for Home-produced goods is given by

$$y_t = s_t + y^*_t + (1-\upsilon) m_t. \tag{26}$$

Consumer-price inflation in Home is given by the average of inflation rates in the Home consumer's basket

$$\pi_t = (1-\upsilon)\pi_{H,t} + \upsilon(\pi^*_t + \Delta e_t). \tag{27}$$

Armed with the Foreign variables, equations (21) to (27) combined with a monetary policy rule in Home (to be specified) then form a system of eight variables in eight unknowns for the Home economy.

5.4 The natural-rate benchmark for Home: flexible prices in Home

Before spelling out the effect of the monetary regime on shock transmission, it is useful to derive the natural-rate output in Home. With flexible prices, the level of output in Home is given by

$$y^n_t = 0. \tag{28}$$

That is, with a unitary trade elasticity, Foreign and Home outputs are neither complement nor substitute. If prices were perfectly flexible in Home (but not necessarily in Foreign), output in the Home economy would be completely insulated from Foreign monetary shocks, regardless of the effects of these shocks in the Foreign economy. Furthermore, the natural-rate terms of trade are given by

$$s^n_t = -y^*_t. \tag{29}$$

Under flexible prices, the terms of trade would absorb any demand effect from Foreign output. This is true for any evolution of the foreign monetary shock. For analytical tractability, we next restrict the process that governs the monetary shock next.

5.5 The Foreign response to its own monetary shock

For the remainder of this section we consider a specific shock scenario. Let the two economies be in their non-stochastic steady state prior to period $t = 0$. In period $t = 0$, there is a unitary monetary shock, that is, $\varepsilon_0^* = 1$ (a foreign monetary tightening). In the next period, the shock remains present at that level with probability μ. Else, the shock ceases, being equal to zero forever after. The same applies to each subsequent period. As is well-known, this shock induces a Markov structure for Foreign output, inflation, and the interest rate: while the shock lasts $\pi_t^* = \pi_L^*$, $y_t^* = y_L^*$, $r_t^* = r_L^*$, for fixed values π_L^*, y_L^*, r_L^*. Once the shock ends, foreign variables immediately return to their steady state of zero. Proposition 1 spells out the evolution of the foreign economy.

Proposition 1. *Consider the (large) foreign economy in Section 5.2 amid the shock structure sketched above. Define* $\mathbf{A} := \frac{1}{(1+\gamma-\mu)(1-\mu)+\kappa(\phi-\mu)}$. *While the shock lasts, output in Foreign will be*

$$y_L^* = -(1-\mu) \cdot \mathbf{A}. \tag{30}$$

Inflation in Foreign will be

$$\pi_L^* = -\kappa \cdot \mathbf{A}. \tag{31}$$

The interest rate in Foreign will be

$$r_L^* \;\; = \;\; \left[(1-\mu)^2 - \kappa\mu\right] \cdot \mathbf{A}. \tag{32}$$

Proof. Use equations (18) through (20) along with the Markov assumption for the monetary shock. □

The result of the shock is a contraction in foreign economic activity and inflation, owing to the increase in the real interest rate in Foreign. Observe that the *nominal* interest rate will rise if and only if $(1-\mu)^2 - \kappa\mu > 0$, that is if the shock itself is not overly persistent (μ not too large). All the propositions shown below are valid for any $\mu \in [0, 1)$. When verbally discussing the sign of responses (and the intuition behind those), we will focus on the case in which Foreign interest rates rise when its monetary policy tightens, the conventional response.

5.6 The transmission of Foreign shocks by Home monetary policy regimes

We are interested in understanding the role of the exchange rate as a shock absorber, in relation to the monetary policy regime adopted by a small open economy. Our point of departure is the observation that, with world trade priced in a dominant currency, there is no "divine coincidence." That is, regardless of the monetary regime pursued in Home, the natural allocation in which the output gap is closed and there is zero inflation cannot be attained. In Proposition 2, we formalize this result stressing an important property of our simplified model specification.

Proposition 2. ***Lack of divine coincidence***. *Consider the same assumptions as in Proposition 1, but focus on the Home economy described in Section 5.3 (that is, with DCP). Then,* regardless of the monetary regime in Home*, the terms of trade do not respond to the Foreign shock*

$$s_t = 0 \;\; \textit{for all periods } t.$$

Proof. Solve for $\pi_{H,t}^*$ using (24). Use this to substitute for $\pi_{H,t}^*$ in (23). Similarly, in the same equation, substitute for the y_t from (26). Using the Markov structure of the shock, this leads to a second-order difference equation in s_t, the exogenous driving term of which – while the shock lasts – is $\kappa y_L^* + \pi_L^*(1-\mu)$ (and is zero thereafter). From (30) and (31), this sum is equal to zero. The difference equation is homogeneous, rendering $s_t = 0$ for all t. □

To appreciate the meaning of this proposition, contrast its prediction with what happens under flexible prices. In the natural allocation, in response to the shock, the terms of trade would move to insulate Home economic activity from foreign monetary shocks, recall equation (29). Rigid prices in a dominant-currency pricing regime, instead, rule out this stabilizing movement. Indeed, the terms of trade do not move whatsoever. Any insulation of the Home economy, therefore, will have to come from supporting domestic absorption. Stimulating domestic absorption, however, asks for tolerance of domestic (GDP deflator) inflation. Precisely, the extent to which monetary policy authorities tolerate output spillovers from foreign monetary shocks depends on the extent to which they tolerate inflation.

We articulate this point in the three propositions to follow, characterizing the evolution of the Home economy for three monetary and exchange-rate regimes, targeting, respectively, the natural output, the exchange rate and CPI inflation. We start with a regime that perfectly targets natural output, that is, it ensures that the output gap remains closed. As before, in terms of notation, let y_t^L mark output in period t if the shock still lasts in period t, and correspondingly for all other variables.

Proposition 3. ***Natural-output targeting.*** *Consider the same assumptions as in Proposition 2. Suppose that Home monetary policy aims to completely stabilize domestic output, or equivalently, the output gap (that is, it targets $y_t = y_t^n = 0$). Let $\mathbf{A} > 0$ be as defined in Proposition 1. Then, while the foreign monetary shock lasts, the following is true:*

1. *by the policy regime, output is not affected by the shock in Foreign, $y_t^L = 0$.*
2. *Home producer price inflation is given by*
$$\pi_{H,t}^L = \frac{\upsilon}{1-\upsilon}\kappa \cdot \mathbf{A} = -\frac{\upsilon}{1-\upsilon}\pi_L^*.$$
3. *Home consumer price inflation is given by*
$$\pi_0^L = \frac{\upsilon}{1-\upsilon}[1-\mu+\kappa] \cdot \mathbf{A}, \ \ \text{and } \pi_t^L = \frac{\upsilon}{1-\upsilon}\kappa \cdot \mathbf{A}, \ \ t > 0.$$
4. *The nominal exchange rate is given by*
$$e_t^L = \frac{1}{1-\upsilon}\left[(1-\mu) + \kappa(t+1)\right] \cdot \mathbf{A}.$$
5. *The interest differential to Foreign is given by*
$$r_t^L - r_t^{*,L} = -\frac{1}{1-\upsilon}\left[(1-\mu)^2 - \kappa\mu\right] \cdot \mathbf{A}. \tag{33}$$

Proof. Natural output does not move (Section 5.4), so output gap targeting yields (1.). Solving for m_t from (26) with $y_t = 0$ and $s_t = 0$ (Proposition 2), using Proposition 1 and the Markov structure of shocks, (22) gives (2.). (24) with $s_t = 0$ gives $\pi_{H.t}^*$. Using this with the law of motion for m_t and $\pi_{H,t}$ in (25) gives (4.). Uncovered interest parity (UIP) follows from taking the difference between (21) and (18), and using (24) and (25). UIP gives (5.). Using the aforementioned results in (27) gives (3.). □

Proposition 3 highlights that Home monetary policy can in theory completely stabilize economic activity in the face of the foreign shock. The proposition also highlights what is required to bring this about. Namely, since with a dominant currency, there is no divine coincidence, stabilizing output comes at the expense of higher producer-price *and* consumer-price inflation. Since the terms of trade do not contribute toward expenditure switching by *Foreign* households, all stabilization of output has to come from *domestic absorption.* That is, the central bank in Home needs to induce domestic demand and engineer enough expenditure switching by *Home* households. This is achieved by a sharp monetary expansion, that translates into a deep depreciation of the exchange rate on impact. As this in turn passes through to Home-currency consumer prices of imports, the depreciation amid rigid prices is central to expenditure switching by Home households toward Home-produced goods. Note that this switching occurs in spite of the fact that the price level of Home-produced goods expressed in Home currency also rises on impact. Corollary 1 further highlights the response of the Home nominal and real rate of interest in Home.

Corollary 1. *Consider the same conditions as in Proposition 3. Then the following is true:*

1. *The Home nominal rate of interest* r_t^L *falls if the Foreign interest rate,* $r_t^{*,L}$*, rises.*
2. *The Home real rate of interest,* $r_t - E_t\pi_{t+1}$*, is constant.*

Proof. The first item follows from (32) and (33). The second item follows from $y_t = 0$ in all periods, the Home IS equation (21), (24) (with $s_t = 0$), (25), and the definition of consumer price inflation (27). □

In sum, insulating Home output from a fall in foreign economic activity means stimulating domestic demand and tolerating producer-price and consumer-price inflation. This marks one end of the policy spectrum in which Home monetary policy can position itself. The next proposition shows the other end: a regime of fixed exchange rates.

Proposition 4. *Fixed exchange rate*. *Consider the same assumptions as in Proposition 3. The one difference is that Home monetary policy targets* $e_t = 0$ *(operates a peg). Then, while the shock lasts the following is true:*

1. *Home output evolves according to*
$$y_t^L = -(1-\mu)\cdot \mathbf{A} = y_L^*.$$
2. *Home producer price inflation is given by*
$$\pi_{H,t}^L = -\kappa \cdot \mathbf{A} = \pi_L^*.$$
3. *Home consumer price inflation is given by*
$$\pi_t^L = -\kappa \cdot \mathbf{A} = \pi_L^*.$$
4. *By design, the nominal exchange rate is constant* $e_t^L = 0$.
5. *The Home interest rate is given by* $r_t^L - r_L^* = 0$.

Proof. Uncovered interest parity and fixed exchange rates give (5.). For the remainder, guess $y_t = y_t^*$. With this, from (26) and Proposition 2, $m_t = 0$. Using (22), the Markov structure of the shock, $y_t = y_t^*$ and Proposition 1 gives (2.). Using (27) and the law of motion for pi_t^*, (3.) follows. With these results, the guess for y_t is easily verified. □

The fixed exchange rate means that Home monetary policy gives up the ability of stabilizing its business cycle and insulating the Home economy from Foreign shocks. On the contrary, the Home monetary policy follows the Foreign policy one-to-one, so as to keep the peg. Thus, Home imports Foreign's monetary stance and with it both the foreign recession (one-to-one) and the drift in the foreign price level (one-to-one again). The home economy moves in lockstep with the Foreign economy.

Between the two extreme regimes above, there are many others. We now turn to a monetary regime that, even if exchange rates are flexible, may not afford much insulation. The following proposition focuses on CPI inflation targeting.

Proposition 5. ***Targeting consumer price inflation****. Consider the same conditions as in Proposition 2. Let Home monetary policy target stable consumer prices ($\pi_t = 0$). Then, while the foreign monetary shock lasts, the following is true:*

1. *Home output evolves according to*

$$y_t^L = y_L^* + (1-\upsilon)\frac{1-\alpha^{t+1}}{1-\alpha}\frac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa}\cdot \mathbf{A},$$

   where $\alpha = 1 + \kappa/(2\upsilon) - \sqrt{[1+\kappa/(2\upsilon)]^2 - 1}$, so that $\alpha \in (0,1)$.

2. *Home producer price inflation is given by*

$$\pi_{H,t}^L = -\upsilon\alpha^t \frac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\cdot \mathbf{A}.$$

3. *Home consumer price inflation, by construction is zero, $\pi_t^L = 0$.*

4. *The nominal exchange rate is given by*

$$e_t^L = \left[(1-\upsilon)\frac{1-\alpha^{t+1}}{1-\alpha}\frac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa} + (t+1)\kappa\right]\cdot \mathbf{A}.$$

5. *The Home interest rate is given*

$$r_t^L - r_t^{*,L} = \left[-(1-\upsilon)(1-\alpha^{t+1})\frac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa} + \mu\left(\frac{(1-\nu)\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa}+\kappa\right)\right]\cdot \mathbf{A}.$$

Proof. See Appendix E. □

Targeting consumer price inflation insulates consumer prices from the Foreign shock, but at the expense of a pronounced fall in output in Home. Indeed output in Home falls along with Foreign output. The more so, the more open the economy is (the lower the home bias, that is, the closer υ to unity) or the more rigid prices are. Second, in the extreme, if prices were perfectly rigid, $\kappa = 0$, CPI inflation targeting would have *exactly* the same consequences as pegging the exchange rate. That is, under the special parameterization we use in this subsection, an economy that operates a float but targets consumer price inflation would—in terms of its responses to a foreign monetary shock—be *indistinguishable* from an economy that pegs outright. In this sense, inflation targeting may mask the potential of flexible exchange rates to insulate domestic activity from foreign shocks. Under a dominant currency regime, insulation of output requires a depreciation of the currency, which raises consumer prices, a rise that CPI targeting prevents.

The appendix provides further results that help put the findings above into context. First, we show that in a dominant currency pricing regime, inflation targeting invites output spillovers, even if the target is not consumer-price inflation. Namely, Appendix F provides the producer-price inflation targeting counterpart to Proposition 5. It shows that also if Home monetary policy were to target producer prices (instead of consumer prices), policy would fail to insulate domestic output. Output in Home falls along with Foreign output if somewhat less so than under CPI inflation targeting. Second, we highlight how important the dominant-currency regime is for the spillovers. Toward this end, Appendix G provides the same scenarios as above, but assumes that there is producer-currency pricing. As is well-known, under producer-currency pricing there is divine coincidence: targeting producer prices induces the flexible-price allocation in Home (Galí and Monacelli, 2005). This insulation is *automatically* provided by the flexible exchange rate, in the following sense: that the nominal interest rate in Home does not need to move *at all* to bring about the insulation. Still, the appendix shows, if the central bank were to target consumer price inflation instead of producer price inflation, it would invite some output spillovers. Throughout this section, we have focused on the transmission of a Foreign *monetary policy* shock only, and we have restricted ourselves to the case of perfectly elastic labor supply. Appendix H presents analytical solutions relaxing both assumptions. Namely, the appendix presents derivations for any $\varphi \geq 0$ and for all the possible foreign shocks that we spelled out in the model section, Section 4. The main insight survives: also for other shocks, targeting inflation in a dominant-currency regime may mask the insulation properties of flexible exchange rates. We illustrate this, next, in a calibrated version of the model.

6 Numerical simulations

This section resorts to a calibrated version of the model, so as to quantitatively discuss how the policy regime shapes international spillovers. The calibration deviates from the case of a unitary trade elasticity and infinitely elastic labor supply of Section 5, and accounts for a non-zero share of intermediate inputs in production.[24] In addition, we move from complete to incomplete markets. This is virtually without consequence for the international transmission of monetary shocks. It allows us to introduce frictions to international arbitrage, however, with relative portfolio demand shocks driving exchange-rate fluctuations. Itskhoki and Mukhin (2020) show that relative portfolio demand shocks together with home bias in the product market can help standard open economy models replicate the Baxter-Stockman result of the apparent neutrality of the exchange rate regime. We parsimoniously augment the calibration by further shocks in Home and Foreign. That way, we can compare the theory against both conditional and unconditional evidence. Compared to the previous analytical section, these assumptions imply that, in response to a Foreign monetary shock, natural output in Home is no longer decoupled from Foreign economic activity, and that the model can no longer be solved by pencil and paper.

[24]The use of imported inputs in the production of export goods is well documented. Gopinath et al. (2020) show that imported input use is an important factor for open-economy models to match the empirical evidence on exchange rate pass-through into import and export prices.

6.1 Extensions of baseline model for a numerical assessment

The model that we will use is the same as laid out in Section 4, bar for a few extensions that we list in the following, using the linearized version of the model.

6.1.1 Incomplete markets

We follow Itskhoki and Mukhin (2020) in the way in which we introduce incomplete financial markets; see also earlier work by Devereux and Engel (2002) and Kollmann (2005). Foreign and Home households can hold domestic and Foreign safe nominal bonds. The international relative demand for the two regions' bonds itself is subject to shocks. Therefore, we replace the risk sharing condition, which had implied uncovered interest parity by a modified version of UIP. Namely, in linearized terms.

$$r_t - r_t^* = E_t\left\{\Delta e_{t+1}\right\} + \psi_t^* - \gamma b_t,\ \gamma \geq 0.$$

Here ψ_t^* is a shock to the international substitutability of bonds issued in different currencies. b_t is the net foreign asset position of the Home economy as a share of steady state Home output. Once linearized, the net foreign asset position evolves according to

$$\beta b_t - b_{t-1} = \upsilon\left((\eta(2-\upsilon)-1)s_t + \eta(1-\upsilon)m_t + (1-\alpha)(c_t^* - c_t) + \alpha(x_t^* - x_t)\right).$$

6.1.2 Monetary policy in Foreign

Foreign monetary policy is governed by a Taylor-type feedback rule

$$r_t^* = \rho_{r^*} r_{t-1}^* + (1-\rho_{r^*})\left(\alpha_{\pi^*}\pi_t^* + \alpha_{y^*} y_t^*\right) + \boldsymbol{\varepsilon}_t^*, \tag{34}$$

where $\boldsymbol{\varepsilon}_t^*$ is the Foreign monetary policy shock.

6.1.3 Law of motion of external shocks

Next to the Foreign monetary shock and the shock to the international substitutability of bonds, there are time-preference and productivity shocks in Foreign. Let ζ_t^* mark the shocks, with $\zeta_t^* \in \{\boldsymbol{\varepsilon}_t^*, \psi_t^*, Z_t^*, \xi_t^*\}$. All the external shocks, in principle, are serially correlated. In (log) deviation from steady state, they each follow

$$\zeta_t^* = \rho_{\zeta^*}\, \zeta_{t-1}^* + \sigma_{\zeta^*} \cdot u_{\zeta^*,t},\ \text{ with } \rho_{\zeta^*} \in [0,1),\ \sigma_{\zeta^*} > 0,\ \text{and } u_{\zeta^*,t} \overset{\text{iid}}{\sim} N(0,1), \quad \zeta^* \in \{\boldsymbol{\varepsilon}^*, \psi^*, Z^*, \xi^*\}.$$

6.1.4 Law of motion of domestic shocks

The same types of shocks that affect Foreign directly also affect the Home economy. We allow for potential spillovers such that

$$\zeta_t = \boldsymbol{\zeta}_t + \chi_\zeta \cdot \zeta_t^*,\ \text{ with all } \chi_\zeta \in [0,1]; \zeta \in \{\boldsymbol{\varepsilon}, Z, \xi\}.$$

Here ζ_t is the disturbance affecting the Home economy. This disturbance has two components: the spillover from the Foreign shock, the extent of which is measured by χ_ζ (separately for each shock), and shocks that are specific to the small open economy (and uncorrelated with Foreign shocks). The Home-specific shock component follows

$$\boldsymbol{\zeta}_t = \rho_{\boldsymbol{\zeta}}\, \boldsymbol{\zeta}_{t-1} + \sigma_{\boldsymbol{\zeta}}\, u_{\boldsymbol{\zeta},t}, \quad \text{with } \rho_{\boldsymbol{\zeta}} \in [0,1), \sigma_{\boldsymbol{\zeta}} > 0 \text{ and } u_{\boldsymbol{\zeta},t} \overset{\text{iid}}{\sim} N(0,1), \text{ where } \boldsymbol{\zeta} \in \{\boldsymbol{\varepsilon}, Z, \xi\}.$$

6.2 Calibration

We calibrate the model to the euro-area economy (Foreign country) and to a prototypical neighboring small open economy (Home). The calibration proceeds in two steps. First, we calibrate those parameters that we need to set to assess the extent to which the model can replicate the conditional evidence on monetary transmission that we have documented above. Then, second, we calibrate the remaining parameters (pertaining to the other shock processes, in particular) that are required to compare the theory with the unconditional moments in the data.

6.2.1 Calibration part I: parameters governing monetary transmission

Table 3 documents the first part of the baseline parameterization. We calibrate the model such that one period is a quarter, which allows us to compare the model's unconditional moments against national accounts data. Most parameters are standard. Our choice of β implies an

Table 3: Baseline parameterization, Part I

Parameters	Description	Values
A. Preferences		
β	Discount factor	0.995
φ	Inverse of labor supply elasticity	0.5
ϵ	Elasticity of substitution between intermediate goods	10
η	Trade elasticity	2
υ	Share of imported goods	0.3
B. Production and price setting		
α	Share of intermediate inputs in production	2/3
ω	Price adjustment costs	400
C. Foreign monetary policy rule		
ρ_{r^*}	Interest rate smoothing	0.85
α_{π^*}	Response to inflation	1.25
α_{y^*}	Response to output	0.025
D. Foreign shocks (monetary)		
$\rho_{\boldsymbol{\varepsilon}^*}$	AR(1) parameter monetary policy shock	0
$\sigma_{\boldsymbol{\varepsilon}^*}$	Standard deviation monetary policy shock	0.25/400
E. International financial markets		
γ	Response of spread to net foreign assets	0.001

annual real rate of interest of 2 percent. We set $\varphi = 0.5$, implying a Frisch elasticity of 2, as is customary in the business-cycle literature. We set the elasticity of substitution to $\epsilon = 10$, another customary value. Following Gopinath et al. (2020), we set the elasticity of external demand to $\eta = 2$. We set $\upsilon = 0.3$ so that the home bias is $1 - \upsilon = 0.7$. This is consistent with the average import and export shares of EU countries vis-à-vis the euro area. Turning next to production, the share of intermediate inputs in production is set to $\alpha = 2/3$, again following Gopinath et al. (2020). We set the price adjustment costs to $\omega = 800$, implying that the Phillips curve is reasonably flat.[25] The Foreign monetary policy rule is parameterized roughly in line with the estimates in Adolfson et al. (2007). We set $\rho_{r^*} = 0.85$, $\alpha_{\pi^*} = 1.25$, and $\alpha_{y^*} = 0.025$. Next, the Foreign monetary policy shock is assumed to be iid, with the innovation having a standard deviation of 25bps, annualized. Both of these choices are customary. Last, turning to international financial markets, in line with Schmitt-Grohé and Uribe (2003) and Itskhoki and Mukhin (2020), we set $\gamma = 0.001$, a small value that is sufficient to render the real value of net foreign assets stationary. Once complemented by an assumption on monetary policy in Home, the parameters in Table 3 alone are sufficient to compare the model with the transmission of Foreign monetary shocks presented in Figures 2.A and 2.B above.

6.2.2 Calibration part II: external shocks

A comparison with the unconditional business cycle moments, however, requires us to calibrate also the remaining parts of the model; the shock processes in particular. This is what we do next. We start with Foreign (the euro area). The left panel of Table 4 presents business cycle statistics for the euro area, using the same data set as in our analysis above, except that we opt for a quarterly frequency here, as is the standard in the international business-cycle literature. This allows us to directly compare model and data. Data moments are computed after applying a quadratic trend. The right panel shows the corresponding moments in the

Table 4: Business cycle moments for the euro area/Foreign

	data			model		
x_{EA}	$\sigma_{x_{EA}}$	$\rho_{x_{EA},y_{EA}}$	$\rho_{x_{EA},x_{EA}(-1)}$	$\sigma_{x_{EA}}$	$\rho_{x_{EA},y_{EA}}$	$\rho_{x_{EA},x_{EA}(-1)}$
GDP	2.11	1.00	0.96	2.11	1.00	0.83
i rate	0.94	0.76	0.92	1.55	0.22	0.98
HICP infl.	0.30	0.39	0.32	0.33	0.58	0.94
PPI infl.	1.01	0.42	0.62	0.33	0.58	0.94

Notes: Moments for the euro area in the data and the calibrated model. Left block: quarterly aggregates of monthly data for the euro area. All data are detrended using a quadratic trend. Right block: unconditional moments in the model. GDP is from the quarterly national accounts. The interest rate is quarterly average value and annualized. HICP and PPI inflation are reported as quarter-on-quarter inflation rates (not annualized). For each block, the table shows the standard deviation of the variable, the correlation with output, and the first-order autocorrelation.

calibrated model. In calibrating the two non-monetary shocks to Foreign, we proceed as follows. Both the autocorrelation and standard deviation of the productivity shock follow the estimates for the euro area given in Table 2 of Adolfson et al. (2007). The autocorrelation of the preference

[25] Our calibration of the adjustment cost parameter matches the slope of the euro-area Phillips curve in Alvarez et al. (2006). The slope is tantamount to firms reoptimizing their prices, on average, once every 6.5 quarters in a setup with staggered price setting a la Calvo and no further real rigidities.

(demand) shock follows the estimate in Table 1 in Andrade et al. (2021). We adjust the standard deviation of the innovation to the demand shock such that economic activity of the Foreign country in the model aligns with the volatility of euro-area GDP that we measure in the data. Section D of Table 5 summarizes these parameter choices. The parsimonious structure of the model notwithstanding, the simple calibration exercise leads to business-cycle moments that line up rather well with the data; see the right panel of Table 4 in comparison with the same table's left panel.

6.2.3 Calibration part III: Home monetary policy and remaining shocks

We calibrate the remaining parameters for the Home economy as follows. We target moments for the floaters. We assume that Home monetary policy follows the same Taylor rule as Foreign (see panel G. of Table 5). As regards the shocks for the small open economy, we proceed as follows.

Table 5: Calibration c'td

Parameters	Description	Values
D. Foreign shocks c'td		
ρ_{Z^*}	AR(1) parameter productivity shock	0.935
σ_{Z^*}	Standard deviation productivity shock	0.004
ρ_{ξ^*}	AR(1) parameter preference shock	0.98
σ_{ξ^*}	Standard deviation preference shock	0.0131
E. Home shocks		
χ_Z	productivity spillover	0.9
ρ_Z	SOE-specific productivity shock, AR(1)	ρ_{Z^*}
σ_Z	Standard deviation productivity shock	$(1-\chi_Z)\sigma_{Z^*}$
χ_ξ	demand preference shock spillover	0
ρ_ξ	SOE-specific preference shock, AR(1)	ρ_{ξ^*}
σ_ξ	Standard deviation preference shock	$(1-\chi_\xi)\sigma_{\xi^*}$
χ_ε	monetary shock spillover	0
ρ_ε	AR(1) parameter monetary policy shock	ρ_{ε^*}
σ_ε	Standard deviation monetary policy shock	$(1-\chi_\varepsilon)\sigma_{\varepsilon^*}$
F. International financial markets		
ρ_{ζ^*}	AR(1) parameter international financial shock	0.5
σ_{ζ^*}	Standard deviation international financial shock	0.017
G. Home monetary policy under Taylor rule		
ρ_r	Interest rate smoothing	ρ_{r^*}
α_π	Response to consumer price inflation	α_{π^*}
α_y	Response to output	α_{y^*}

The monetary-policy and demand-preference shocks in Home are parameterized as in Foreign, and are independent from Foreign, so that $\chi_\varepsilon = \chi_\xi = 0$. For the productivity shock, instead, we do allow for direct spillovers from Foreign to Home. As in Itskhoki and Mukhin (2020), we do so with a view toward better accounting for the comovement of business cycles. In our baseline calibration, 90 percent of the Foreign TFP shock is assumed to be reflected in Home

TFP ($\chi_Z = 0.9$). This value is larger than used in Backus et al. (1992) or Heathcote and Perri (2002) but seems reasonable given the close integration of production networks between the euro area and its neighbors (ECB Working Group on Global Value Chains, 2019). The idiosyncratic component of Home TFP, then, is scaled accordingly such that the total size of productivity shocks hitting Home and Foreign is identical. The resulting parameter values are documented in panel E. of Table 5. Finally, we assume that shocks to the international substitutability of bonds are rather short-lived, $\rho^*_\zeta = 0.5$. We choose the standard deviation of the innovation of the shock such that, under the float, the model roughly replicates the volatility of the nominal exchange rate that we observe in the data.

Panel A in Table 6 shows the business cycle moments for neighbors that have floating exchange rates. The left block are the moments in the data, the right block the moments in the model. The simple calibration of a rather bare-bones international business-cycle model captures

Table 6: Business cycle moments for neighbors

	data					model				
x_i	σ_{x_i}	ρ_{x_i,y_i}	$\rho_{x_i,x_i(-1)}$	$\rho_{x_i,x_{EA}}$	$\rho_{x_i,y_{EA}}$	σ_{x_i}	ρ_{x_i,y_i}	$\rho_{x_i,x_i(-1)}$	$\rho_{x_i,x_{EA}}$	$\rho_{x_i,y_{EA}}$
A. Float										
Δ FX	3.65	0.12	0.17	–	0.03	3.65	0.32	-0.24	–	-0.04
GDP	3.36	1.00	0.76	0.68	0.68	3.23	1.00	0.70	0.41	0.41
i rate	2.90	0.42	0.88	0.51	0.23	1.52	0.48	0.81	0.55	0.05
HICP infl.	0.93	0.29	0.51	0.32	0.19	1.15	0.41	-0.18	0.17	0.04
PPI infl.	1.56	0.27	0.46	0.44	0.21	0.29	0.42	0.91	0.68	0.19
B. Peg										
Δ FX	1.17	0.05	0.04	–	0.01	0.00	0.00	0.00	–	0.00
GDP	4.07	1.00	0.85	0.56	0.66	3.39	1.00	0.94	0.51	0.51
i rate	1.53	0.22	0.90	0.24	0.07	1.59	0.26	0.95	0.97	0.21
HICP infl.	0.60	0.20	0.37	0.49	0.31	0.32	0.45	0.95	0.96	0.49
PPI infl.	1.45	0.22	0.35	0.60	0.29	0.33	0.47	0.95	0.93	0.44

Notes: Δ FX rate is the quarter-on-quarter change of the nominal exchange rate, applying a quadratic trend. For each block, the table shows the standard deviation of the variable, the correlation with the same country's GDP, the first-order autocorrelation, the contemporaneous correlation with the same variable at the euro-area level, and the contemporaneous correlation of the variable with euro-area GDP. For the model counterpart, we look at a CPI-focused Taylor rule.

the main dimensions of the data remarkably well: strong volatility of nominal exchange rates for floaters, but little correlation of exchange rates with economic activity in either the euro area or the neighboring country. The model also produces the positive comovement of inflation and interest rates with the neighbor's GDP, as observed in the data, and international comovement of economic activity.

Panel B in Table 6, in turn, presents the resulting business-cycle moments for peggers. Policy apart, the parameterization is identical to that for floaters. The one exception is that we assume that pegs are credible and that—therefore—deviations from UIP due to shocks to the international substitutability of bonds are smaller, consistent with the theoretical framework in Itskhoki and Mukhin (2020) and our earlier assumptions. Therefore, under the peg, for the numbers shown here, the standard deviation of the international financial shock is only five percent the size as under the float.[26] Also for the peggers, the model captures the broad outline of the business cycle in neighboring countries. Both economic activity and inflation are positively correlated with economic activity in the euro area. In words: the model matches the apparent disconnect between the choice of exchange rate regime and the overall shape of the business cycle that Baxter and Stockman (1989) and Itskhoki and Mukhin (2020) point out.

6.3 The role of the Home monetary regime for monetary spillovers

The evidence that we have presented above goes further, however. Namely, what we have documented is that floats and pegs empirically are also barely distinguishable when one conditions on a specific set of external shocks; monetary policy shocks in particular. This section shows under assumptions on the conduct of monetary policy the calibrated model can account for such *conditional* spillovers to neighbors that let their currency float. The figures that follow show the effect that a monetary shock in Foreign has on the Foreign economy and the small open Home economy, and how that effect is shaped by the exchange-rate regime and, in case of a float, by *how* the Home central bank chooses to resolve the trade-off between stabilizing real activity and inflation.

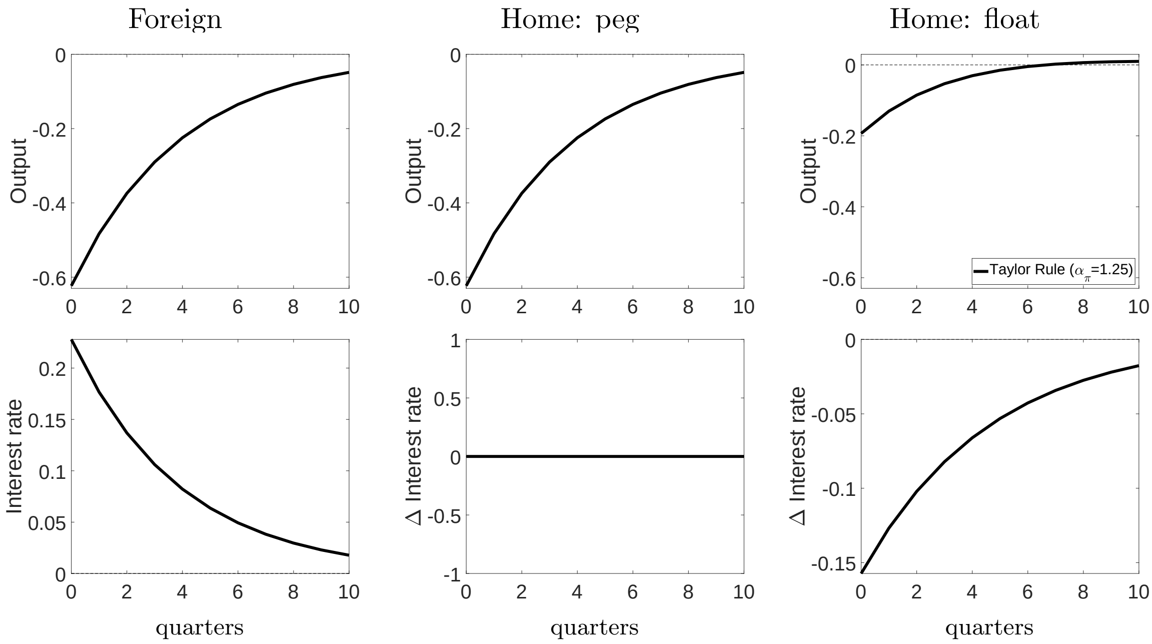
The left column of Figure 6 shows the response in Foreign. The middle column shows the response in the Home economy under a peg. The right column shows the response in Home if, under a float, the central bank follows the Taylor rule that underlies the baseline calibration discussed above. Foreign shows the conventional New Keynesian response: the interest rate rises and output falls (left columnn). And, of course, if Home pegs its currency to Foreign, it has to import Foreign's monetary stance, leading to a complete spillover of the Foreign-induced recession (middle panel). What is more noteworthy, instead, are the policy response and spillovers if the Home economy operates a conventional Taylor rule (right column). Indeed, under the Taylor rule, the monetary authority in Home—when faced with a Foreign tightening—engineers a monetary stance that is more accommodative than in Foreign. As a result, output in Home falls, but only about 1/3 as much as it does under a peg. Insulation, thus, is possible, in line with the conventional wisdom. The problem with this is that such a response contrasts rather sharply with our own empirical findings earlier in the paper (compare Figure 2.A); that is, it fails to replicate the very insulation puzzle.

An important take-away from our paper is that in understanding the extent to which flexible exchange rates *can* provide insulation, it is not sufficient to ascertain whether they *do* provide insulation in practice. The reason is that insulation is not automatic. Rather, it requires the Home monetary authority to *use* the extra degree of freedom stressed by Harry Johnson in the introductory quote.

Toward showing the extent to which the choice of monetary policy strategy may shape the observed degree of insulation that flexible exchange rates provide consider Figure 7. The setup is as before. But now, in its right column the Figure revisits the response of the Home economy

[26] We choose five percent such that the interest rate under the peg has a variability that is commensurate with the data.

Figure 6: Adjustment to Foreign monetary policy shock



Note: Under the float, Home monetary policy follows the Taylor rule. Interest rates are expressed in annualized percentage deviations from steady state. Δ Interest rate denotes the difference between the response of the Home and Foreign interest rate.

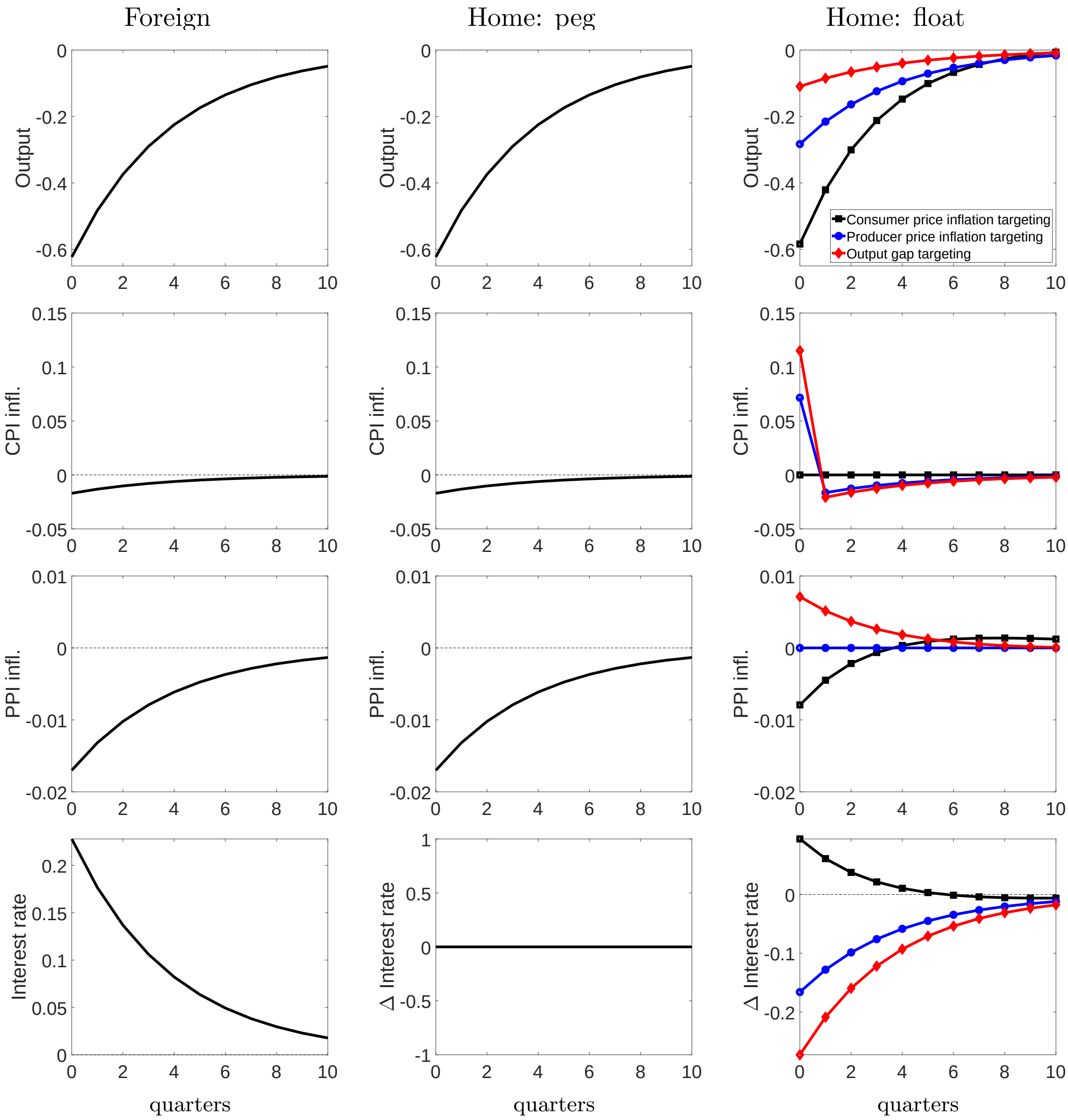
under the different targeting rules considered in Section 5.

Focusing on the response of floaters, the first observation is that one *can* replicate the empirical insulation puzzle. Namely, under consumer price inflation targeting (black line with squares), the response of Home output is very similar to the one under the peg (first row). Consumer-price inflation targeting requires the Home monetary authority to tighten its monetary stance in line with (indeed, even somewhat more so than in) Foreign. The policy trade-off is apparent: the increase in the Home real interest rate required to stabilize CPI inflation, induces large adverse output spillovers. Producer price inflation (third row) declines, just like in Figure 2.B above.

The second observation is that – viewed through the lense of the model – the lack of output insulation is a *policy choice*. Even under DCP, flexible exchange rates render it possible for domestic policy to shield the level of Home economic activity from the external shock, though at the cost of heightened variability of inflation. This is exemplified by the output gap targeting regime. Focus once more on the right column of Figure 7, but look at the red line with diamonds. Stabilizing Home output at its natural level—which declines slightly in response to the foreign shock due to the drop in demand in Foreign for intermediate inputs—requires a cut in the Home interest rate, to stimulate aggregate demand in Home (bottom panel). Clearly, insulating domestic output from the foreign shock is not a free lunch. It requires the willingness of the Home monetary authority to tolerate an increase in both consumer price and producer price inflation.

This trade-off is also apparent under producer price inflation targeting, an intermediate case between consumer price inflation and output gap targeting (blue lines with circles). Under

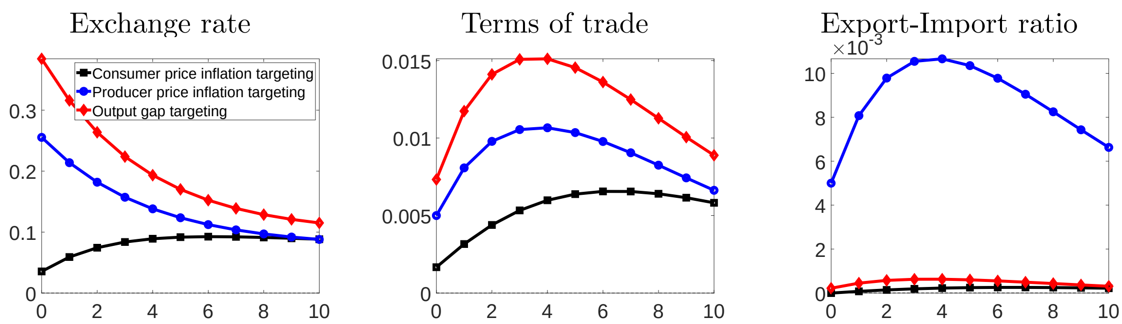
Figure 7: Adjustment to Foreign monetary policy shock



Note: CPI inflation is consumer-price inflation (not annualized), PPI inflation is producer-price inflation (not annualized). Interest rates are expressed in annualized percentage deviations from steady state. Δ Interest rate denotes the difference between the response of the Home and Foreign interest rate.

producer price inflation targeting, Home output falls less than under consumer price inflation targeting but more than under output gap targeting. On the one hand, in response to the tightening of Foreign monetary policy, the decline in external demand for Home export goods puts downward pressure on marginal costs of firms in Home and, thereby, on Home producer prices. On the other hand, the depreciation of the Home exchange rate raises the price of firms' imported inputs and puts upward pressure on Home marginal costs. For our baseline calibration, the second channel dominates and the Home monetary authority has to raise the interest rate slightly in order to stabilize producer prices in Home (the bottom panel shows the interest differential with respect to Foreign). Consequently, the real interest rate increases, resulting in

Figure 8: Home float: Adjustment of external variables to Foreign monetary policy shock



a fall in Home output below its natural level.

Figure 8 shows the corresponding response of the external variables, including (in the left panel) the nominal exchange rate. Under consumer price inflation targeting (black solid line marked by squares), the exchange rate hardly moves in equilibrium. Remarkably, this response, too, is rather consistent with the empirical evidence put forward in Section 3 for euro area neighbor countries that pursue a floating exchange rate regime.

The case of output gap targeting (red line with diamonds) once more shows the opposite end of the spectrum. Given the size of the monetary expansion in Home, relative to Foreign, the Home exchange rate depreciates substantially (see left panel of Figure 8). Under DCP, the role of the exchange rate as a shock absorber is limited. Specifically, since exports are priced in the foreign currency and those export prices are rigid, the depreciation does not induce immediate expenditure switching by Foreign households or firms toward Home-produced goods. Indeed, the terms of trade barely move on impact under either policy (center panel of Figure 8). Expenditure-switching effects of the exchange rate are only felt in Home: imported inflation reflecting the strong exchange rate response induces a change in the composition of consumption by Home households and the composition of intermediate inputs used by Home firms (right panel) over and above the effect that accommodative policy has on intertemporal substitution.

The conclusion from this is that the choice of *how* to float may have a substantial bearing on the *observed* insulation properties of flexible exchange rates. The apparent lack of insulation that we observe in the data may lie to some extent with the incidence of imported inflation in the objectives of central banks in relatively open economies. A primary instance is consumer price inflation targeting. Under DCP, such targets make monetary policy implicitly lean against exchange rate movements, bringing the economy to operate closer in line with the case of an exchange rate peg. Note that, while our analysis is purely positive, we have looked at well-founded monetary policy choices. On the one hand, because the majority of floaters in our sample assert that they follow a regime of CPI inflation targeting. On the other hand because theory suggests that these regimes resemble good policy. In particular, Egorov and Mukhin (2020) show that inflation targeting is the optimal non-cooperative policy under DCP for neighboring countries of the dominant currency issuer, and that the commensurate policy target is close to the consumer price index.[27]

[27]Our conclusion of, at least, sizable spillovers under inflation targeting is not predicated on the lack of divine

6.4 So where is the puzzle? Conditional and unconditional evidence

The previous section has shown that a regime of inflation targeting could help reconcile the evidence on the transmission of euro-area monetary policy shocks (the observed insulation puzzle) with the model dynamics under DCP. Suppose that the neighboring countries that have flexible exchange rates choose to target inflation. This, perhaps inadvertently, would restrict exchange-rate flexibility and hamper insulation. But would this approach be consistent with the Baxter-Stockman observation? Put differently, can the model still account for the *unconditional* moments once we assume that Home monetary policy pursues a CPI target?

Table 7 shows that this cannot be taken for granted. The reason is that an unconditional focus on inflation attenuates exchange rate volatility in the model in response not only to monetary shocks, but also to shocks to international portfolio demand. Under strict inflation targeting,

Table 7: Model-based moments for neighbors under float with strict CPI inflation targeting

x_i	σ_{x_i}	ρ_{x_i,y_i}	$\rho_{x_i,x_i(-1)}$	$\rho_{x_i,x_{EA}}$	$\rho_{x_i,y_{EA}}$
Δ FX	0.37	-0.27	0.86	–	-0.58
GDP	3.31	1.00	0.64	0.48	0.48
i rate	7.91	-0.75	0.49	0.05	-0.06
HICP infl.	0.00	–	–	–	–
PPI infl.	0.06	0.66	0.55	0.17	0.20

Notes: Same as the right panel for floaters in Table 6, with the one difference that now the floater engages in strict CPI inflation targeting.

as a result, the nominal interest rate would be too volatile relative to the data and the nominal exchange rate would show fluctuations that are an order of magnitude too small. Importantly, this discrepancy between the exchange rate volatility in our model and the data arises in spite of the fact that the model features incomplete international financial markets, imperfect pass-through, and portfolio demand shocks.[28] The conditional exchange rate insulation puzzle that we document provides further constraints on the mechanisms that may explain international business-cycle comovement.

coincidence in the first place. Appendix I shows that even in economies where pass through is symmetrically *high* (complete) in all countries—the case of Producer Currency Pricing—it will still be true that the distance between a peg and inflation targeting shrinks when the central bank targets consumer prices (arguably suboptimally so). Conversely, the same applies to economies where pass-through is symmetrically *low*—the case of Local Currency Pricing (LCP). In this case, currency movements are larger even under inflation targeting, but they do not have expenditure switching effects, either at Home or abroad.

[28] Fluctuations in the nominal exchange rate affect consumer prices in the small open economy via their effect on import prices for consumption and intermediate goods, both of which, under DCP, are sticky in the Foreign currency. Thus, a volatile exchange rate impedes stable consumer price inflation in an open economy with a sufficiently high import share. This is consistent with the finding in Itskhoki and Mukhin (2020) that it requires both incomplete international financial markets with portfolio demand shocks and a high degree of home bias in the product market for their model to match the unconditional evidence on exchange rate volatility. We calibrate the degree of openness of the Home economy in our model consistent with the average import and export share of EU countries against the euro area. Given this parameterization dictated by the data, our model appears unable to match the conditional evidence on spillovers without—at the same time—giving up on the unconditional evidence on exchange rate volatility.

7 Conclusions

In this paper we reassess the traditional notion that a flexible exchange rate provides open economies with some insulation from the adverse effects of external shocks. We first provide new empirical evidence for Europe that is at odds with this very notion. We then delve into theory in light of considerations which may give rise to "flexibility pessimism".

At an empirical level we produce novel evidence for Europe studying spillovers from the euro area to a large set of neighboring countries, which adopt different exchange rate regimes over different periods. We show that spillovers are sizeable. What is more, they appear barely distinguishable across flexible and fixed exchange rate regimes. The evidence, thus, suggests that the apparent "neutrality" of the exchange rate regime not only applies to the broad outline of the business cycle (Baxter and Stockman, 1989), but also to the effect of certain external shocks.

At the theoretical level, we study cross-border spillovers in a New Keynesian two-country model, where shocks originate in the (large) country issuing the dominant currency. The model generally predicts a high degree of insulation under a flexible exchange rate—unless monetary policy pursues inflation targeting focusing on headline CPI inflation. In the latter case, insulation is low since preventing an increase in consumer price inflation requires a contraction in domestic demand. The interest-rate increase that brings about the decline in domestic demand also mutes the reaction of the exchange rate, which is in line with our evidence.

A coherent account for the lack of insulation of flexible exchange rates needs to confront both the unconditional and the conditional evidence, however. Our analysis suggests that such an account may be hard to come by. Unconditionally, nominal exchange rates are notoriously volatile. Any explanation that accounts for the conditional stability of the exchange rate would need to make sure not to dampen exchange rate volatility more generally.

The exchange rate insulation puzzle may thus be even worse than the literature has so far recognized. It applies unconditionally, and conditional on specific shocks (monetary shocks in particular). And it asks for theories that reconcile both dimensions.

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A Time-series data

Unless noted otherwise our data source is Eurostat and the sample runs from 1999:M01–2018:M12. In what follows we list details and exceptions.

Industrial production: manufacturing (series: sts_inpr_m), Index (2015=100), seasonally adjusted. First observation: 2000:M01, except for euro area, Croatia, Lithuania, Slovenia, United Kingdom, and Norway (all 1999:M01), Switzerland (2010:M10). For Iceland no data from Eurostat, use OECD (series: PRMNTO01) instead (only available up to 2018:M02). To construct an aggregate series for EA11 we use the 2015 weights reported by Eurostat for the construction of the EA19 series and reweigh series accordingly. In some instances we use OECD data for 1999 as Eurostat data not available for that year, as well as for Ireland after 2010.

Unemployment rate: harmonized unemployment rate according to ILO definition (series: ei_lmhr_m), seasonally adjusted. First observation: 1999:M01, except for Bulgaria (2000:M01), Estonia (2000:M02), Croatia (2000:M01), Cyprus (2000:M01), Malta (2000:M01), Iceland (2003:M01), Switzerland (2010:M01). To construct an aggregate times series for EA11 we compute time series for labor force using Eurostat data for the number of unemployed as well as the unemployment rate. We sum the over all EA11 countries to compute the total number of unemployed and divide by the total labor force.

Interest rates: short-term interest rates for the euro area, for Croatia (since 2002:, with some observations missing afterwards), Romania (since 1999:M01), Bulgaria (since 1999:M09) from Eurostat (series: `irt_st_m`). For other countries we use OECD data (series: STINT), available since 1999:M01, except for Malta and Cyprus where we use long-term interest rates (source: ECB) to proxy for short-term rates. In our analysis we also use the interest rate on German government bonds with one year maturity from the Bundesbank (Term structure of interest rates on listed Federal securities (method by Svensson) / residual maturity of 1.0 year / monthly data. We remove a linear trend from the series prior to the estimation.

Harmonized index of consumer prices (HICP): All-items HICP, 2015=100 (series: prc_hicp_midx). First observation: 1999:M01, except for Switzerland (2004:M12). We construct the series for EA11 using the annual HCIP country weights reported by Eurostat for the computation of the EA19 series.

Producer price index (PPI): Domestic output price index - industry (series: sts_inppd_m). First observation: 2000:M01, except for euro area, Denmark, Lithuania, Sweden, United Kingdom (1999:M01), Estonia (2002:M01), Latvia (2001:M01), and Switzerland (2003:M05). For Iceland no data from Eurostat, use FRED Economic data instead (series: ISLPPDMMINMEI, available since 2006:M06). To construct a series for EA11 we use the country weights for industrial production reported by Eurostat. In case Eurostat does not provide data for individual EA11 countries we use OECD data (except for Austria for which no data available for 1999).

Euro-exchange rates: for neighbor countries national currency per euro (monthly average). For countries that adopt euro in sample we use historical series (`ert_h_eur_m`) available up to 2015:M12, afterwards euro exchange rate is irrevocably fixed. For other countries we use the series `ert_bil_eur_m`. For the euro area we use the effective exchange rate of the euro from FRED Economic Data (series: NBXMBIS).

Export-Import ratio of neighbor countries with euro area: trade statistics of Eurostat available at: https://ec.europa.eu/eurostat/web/international-trade-in-goods/data/database. For neighbor countries reporting country is EA19: imports from neighbor country n are exports of neighor country to EA, likewise exports of EA to neighbor n are neighbor's imports. First observation is generally 2002:M01. We compute the log ratio of exports-to-imports. For EA we compute total exports-to-import ratio (source: Haver).

Real gross domestic product at market prices from Eurostat. Chain-linked volumes (2010), million euro. Quarterly. Seasonally adjusted and calendar adjusted. For Iceland: only seasonally adjusted. **Currently, the euro- area data are EA12**.

B Exchange rate polices in neighbor countries

Here we provide a brief overview of the exchange rate policies of the EA neighbor countries from 1999 to 2018. Figure B.1 displays for each country in our sample the time series of the fine exchange-rate regime classification of IRR, measured against the left axis (1-14, since there are no instances of 15 in our sample), and the month-on-month change of the bilateral euro exchange rate, measured against the right axis (in percent). The shaded area indicates country-month observations that qualify as a float in our baseline (IRR category 9 or higher). Table 1 in the main text summarizes this information in a compact way. In what follows we look at each country in more detail and provide details on the classification of IRR. When appropriate, we also provide information from the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER), the convergence reports by the European Commission, or the websites of the central banks.

Bulgaria: Currency board in place since 1997 under which the Bulgarian Lev (BGN) is pegged to Deutsche Mark and to the Euro afterwards. IRR classification: 2 ("Pre announced peg or currency board arrangement").

Croatia: According to the central bank the "monetary policy framework is based on maintaining the stability of the nominal exchange rate of the kuna against the euro." IRR classification: 4 ("De facto peg").

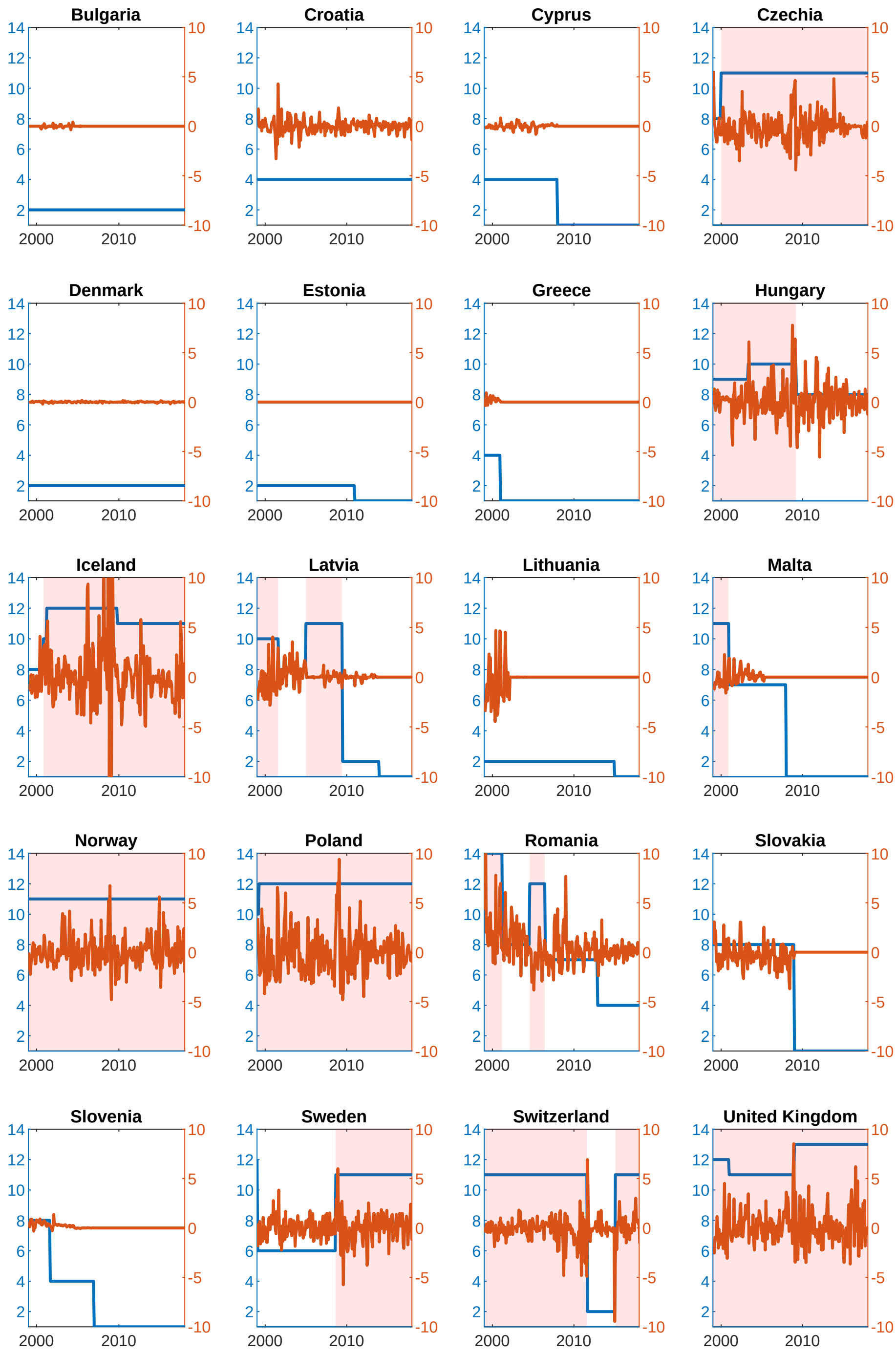
Cyprus: Adoption of the euro on January 1, 2008. IRR classification: 1 ("No separate legal tender or currency union") since then. On May 2, 2005 Cyprus joined the ERM2, but the exchange rate fluctuations were much narrower than the +/- 15% margin permitted under ERM2. IRR classification from 1999-2008: 4 ("De facto peg"); see also Central Bank of Cyprus website.

Czechia: CPI-Inflation targeting since 1998. From November 2013 to April 2017, exchange rate target as an additional monetary policy instrument, to avoid koruna to strengthen below 27 CZK/EUR (see Convergence programme of the Czech Republic, April 2017). IRR classification: 4 ("De facto peg"). IRR classification throughout 1999: 8 ("De facto crawling band that is narrower than or equal to +/-2%"), since 2000:M01: 11 ("Moving band that is narrower than or equal to +/-2%").

Denmark: Denmark is a member of the ERM2 for the whole sample priod, but it pegs the Danish krone (DKK) against the euro allowing for a fluctuation band of only +/- 2.25% (see website of the Danish central bank). IRR classification: 2 ("Pre announced peg or currency board arrangement").

Estonia: In the early part of our sample the Eesti kroon is pegged to euro via a currency board arrangement. In 2004, Estonia joined the ERM2, in January 2011 the euro. IRR classification: 2 ("Pre announced peg or currency board arrangement") and 1 ("No separate legal tender or currency union"), before and after, respectively.

Figure B.1: Exchange rate regimes and fluctuations



Notes: each panel displays the fine exchange-rate regime classification of IRR against the left axis (1-14, since there are no instances of 15) in our sample), and the month-on-month change of the bilateral euro exchange rate against the right axis (in percent). The shaded area indicates country-month observations that qualify as a float in our baseline (IRR category 9 or higher).

Greece: Adoption of the euro following a currency peg on January 1, 2002. Greece was member of the ERM2 until the end of 2001. IRR classification: 4 ("De facto peg") and 1 ("No separate legal tender or currency union"), before and after, respectively.

Hungary: Since 2001 inflation target (see website of the Hungarian central bank) and freely floating exchange rate since February 2008 (see website of the Hungarian central bank). Prior to October 2001, the currency followed a crawling peg to a currency basket of composed of the euro (70%) and the USD (30%), allowing for horizontal bands of ± 2.25%. In May 2001, the size of the bands was increased to ± 15%. Furthermore, the reference currency was changed to the euro in 2001. This regime was upheld until 2008. IRR classification: 9 ("Pre announced crawling band that is wider than or equal to ±2%") up to 2003:M04, 10 ("De facto crawling band that is narrower than or equal to ±5%") up to 2009:M03 and 8 ("De facto crawling band that is narrower than or equal to ±2%") since then.

Iceland: In 1999 and 2000 the Icelandic króna (ISK) was pegged to a basket of nine currencies (the Canadian dollar, the Danish krone, the euro, the Japanese yen, the Norwegian krone, the pound sterling, the Swedish krona, the Swiss franc, and the U.S. dollar) allowing for horizontal bands of +/- 9%. IRR classification: 8 ("Pre announced crawling band that is wider than or equal to ±2%"). In March 2001 this peg was dropped in favor of an inflation target. However, a subordinate goal of exchange rate stabilisation was formulated, which gives the central bank a mandate to intervene on the foreign exchange markets (see website of the central bank of Iceland). According to the AREAER, disruptions on the international financial markets from 2008 onward led the central bank to intervene on the foreign exchange markets to stabilise the currency. IRR classification 1999–2008: 8 ("De facto crawling band that is narrower than or equal to ±2%"), up 2011:M09: 12 ("De facto moving band ±5% , Managed floating), 11 ("Moving band that is narrower than or equal to ±2%") since then.

Latvia: Up to 2004:M12 peg to IMF special drawing rights. Switch from peg to euro peg on January 1, 2005 with ±1% bands. Joined ERM2 in May 2005 (see website of the central bank of Latvia). Since June 2009 de facto peg to euro, joined euro in January 2014. IRR classification from 1999:M01–2001:M07: 10 ("De facto crawling band that is narrower than or equal to ±5%"), up to 2004:M12: 8 ("De facto crawling band that is narrower than or equal to ±2%"), up to 2009:M06: 11 ("Moving band that is narrower than or equal to +/-2%"), up to 2013:M12: 2 ("Pre announced peg or currency board arrangement"), and 1 ("No separate legal tender or currency union") since then.

Lithuania: Up to 2002 the Lithuanian litas (LTL) was pegged to the US dollar by means of a currency board arrangement. On February 2, 2002 this peg was transformed into a euro-peg. In 2004 Lithuania joined the ERM2 without changing its effective exchange rate regime (AREAER). Adoption of the euro on January 1, 2015. IRR classification up to 2014:M12: 2 ("Pre announced peg or currency board arrangement") and 1 ("No separate legal tender or currency union") since then.

Malta: In the early part of the sample the Maltese lira was pegged to a currency basket, with weight of euro increased in August 2002. Peg to euro only started in January 2005, and adoption of the euro on January 1, 2008 (AREAER). IRR classifiction: 11 ("Moving band that is narrower than or equal to $\pm 2\%$") up to 2000:M12, 7 ("De facto crawling peg") up to 2007:M12; 1 ("No separate legal tender or currency union") afterwards.

Norway: Floating exchange rate rate. Since March 2001 CPI inflation target. IRR classification: 11 ("Moving band that is narrower than or equal to $\pm 2\%$").

Poland: Up to March 2001 Polish zloty (PLN) was pegged to a currency basket consisting of the euro (55%) and the US dollar (45%). The peg followed a crawling and pre-announced central exchange rate to its reference basket. On March 24, 1999 the fluctuation band of the exchange rate around this central rate was increased from +/- 12.5% to +/- 15%. Floating exchange rate since April 2000 (AREAER). IRR classification up to 1999:M03: 10 ("De facto crawling band that is narrower than or equal to $\pm 5\%$") and 12 ("De facto moving band $\pm 5\%$, Managed floating") afterwards.

Romania: Central bank maintains "managed float, in line with using inflation targets as a nominal anchor for monetary policy and allowing for a flexible policy response to unpredicted shocks likely to affect the economy" (see central bank website). With the exception of the period from 2002 to 2004, the IMF has also classified the exchange rate regime of Romania as a managed float (AREAER). In August 2005, the central bank adopted an inflation target (see central bank website). Romania has set 2024 as its target year to adopt the euro, but has not joined the ERM2 yet (see European Commission website). IRR classification up to 2001:M01: 14 ("Freely falling"), up to 2004:M07: 8 ("De facto crawling band that is narrower than or equal to $\pm 2\%$"), up to 2006:M06: 12 ("De facto moving band $\pm 5\%$, Managed floating"), up to 2011:M11: 7 ("De facto crawling peg"), and 4 ("De facto peg") since then.

Slovakia: Adoption of the euro following a managed float on January 1, 2009 (AREAER). Joined ERM2 in 2005. IRR classification up to 2008:M12: 8 ("De facto crawling band that is narrower than or equal to $\pm 2\%$"), and 1 afterwards ("No separate legal tender or currency union") .

Slovenia: Adoption of the euro following a managed float on January 1, 2007. Joined ERM II in June 2004. IRR classification up to 2001:M08: 8 ("De facto crawling band that is narrower than or equal to $\pm 2\%$"), up to 2006:M12: 4 ("de facto peg") and 1 afterwards ("No separate legal tender or currency union") .

Sweden: Inflation targeting since 1993; floating exchange rate. IRR classification up to 1999:M01: 12 (De facto moving band $\pm 5\%$, Managed floating), up to 2008:M08: 6 ("De facto crawling peg") and 11 ("Moving band that is narrower than or equal to $\pm 2\%$") since then.

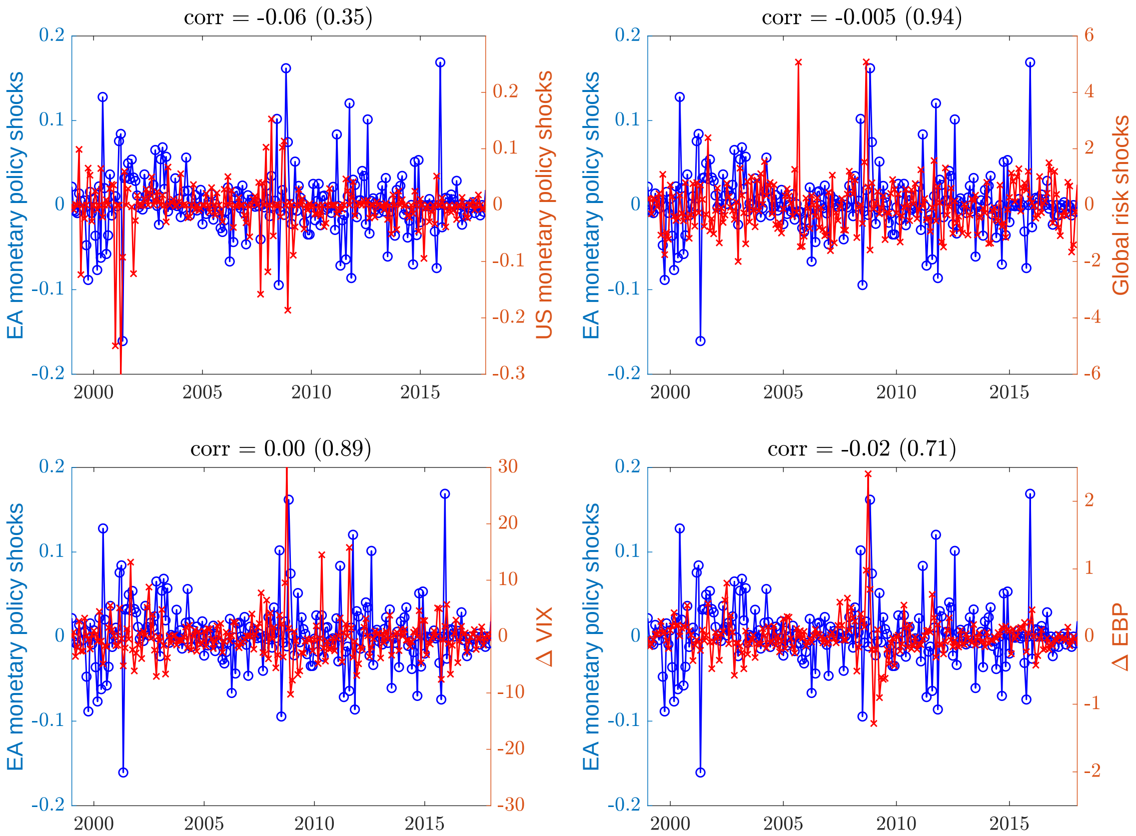
Switzerland: Free float before September 6, 2011 and after January 15, 2015. Exchange rate floor equivalent to a de facto peg in the period in between. IRR classification up 2011:M8: 11 ("Moving band that is narrower than or equal to $\pm 2\%$") , up to 2014:M12: 2 ("Pre announced peg or currency board arrangement"), and 11 since then.

United Kingdom: CPI inflation target since 1992. Flexible exchange rate. IRR: classification up to 2000:M12: 12, up to 2008:M12: 11, and 13 since then.

C How well-identified are the euro area monetary policy shocks?

A concern that one may have is that the euro-area monetary policy shocks may not truly be euro-area shocks, but that they may reflect a common global factor. Toward this end, Figure C.2 plots the euro-area monetary policy shock series that we make use of in the baseline (left axis) against (right axis), respectively, a series of US monetary policy shocks, a series of global risk shocks, and against changes in the VIX and the excess bond premium. The title of the respective panels reports the correlation with the euro area shocks and reports the correlation (p-values in parentheses). The upshot seems to be that there is little correlation for all the series.

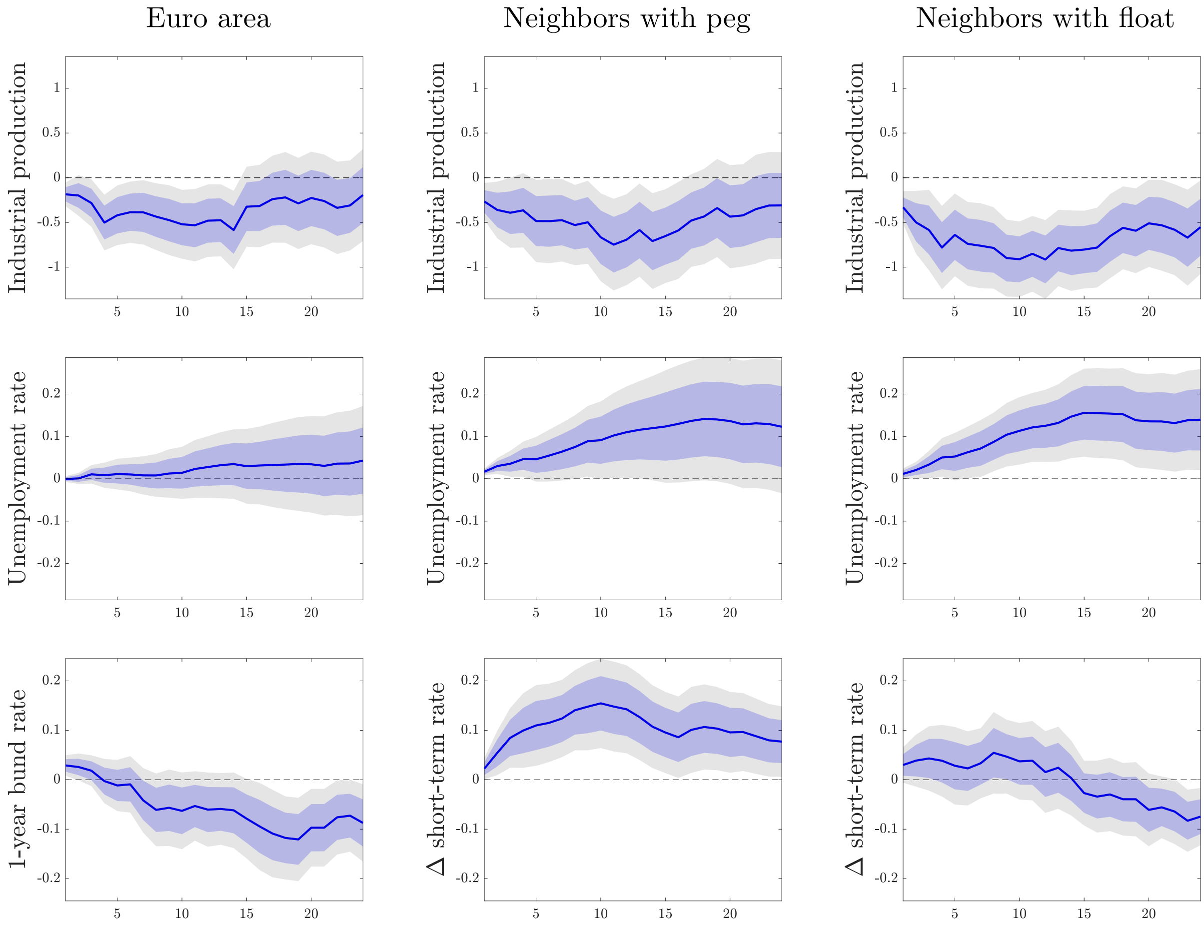
Figure C.2: Euro area monetary policy shocks and other global innovations



Notes: Each panel plots EA monetary policy shock (blue line) jointly with a series of US monetary policy shocks (Jarociński and Karadi, 2020), shown in the upper-left panel, jointly with a measure of global risk shocks (Georgiadis et al., 2021), shown in the upper-right panel, jointly with the monthly change in the VIX, and jointly with the monthly change in the external bond premium (Favara et al., 2016). We report the correlation of the two series on top of each panel (p-value in parenthesis).

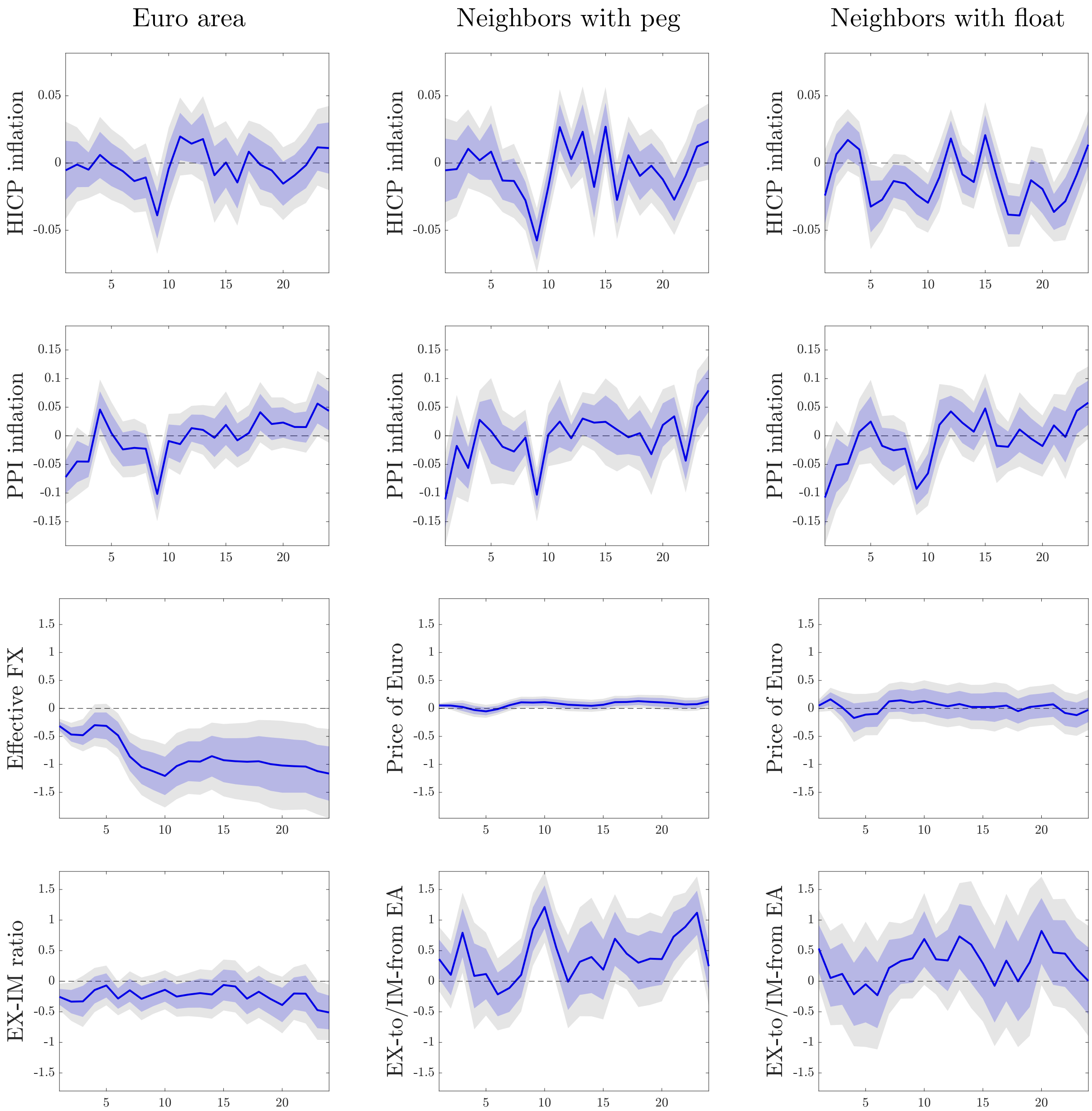
Next, we go a step further and explicitly purge the information in US monetary policy shocks from the euro-area shocks. More in detail, we regress the euro-area monetary policy shock series from (Jarociński and Karadi, 2020) on contemporaneous (same-month) US monetary policy shocks and three lags of the latter. We then use as our measure of the euro-area monetary shock the residual of the above regression. This residual, by design, is orthogonal to the measure of US monetary policy shocks. Figures C.3 and C.4 show the resulting impulse responses. Perhaps not surprisingly in light of the evidence in Figure C.2, the spillovers to inflation and real activity are virtually identical to those shown in the main text (compare Figures 2.A and 2.B).

Figure C.3: Adjustment to orthogonal component of euro-area monetary policy shock



Notes: Shock is one-standard deviation shock identified by Jarociński and Karadi (2020) using high frequency data and sign restrictions, see Figure 2.A for details. The EA monetary policy shock is the residual of a regression of the Jarociński and Karadi (2020) series on the contemporaneous US monetary policy shock (and three of the latter shock's lags).

Figure C.4: Adjustment to orthogonal component of euro-area monetary policy shock c'td



Notes: Shock is one-standard deviation shock identified by Jarociński and Karadi (2020) using high frequency data and sign restrictions, see Figure 2.B for details. The EA monetary policy shock is the residual of a regression of the Jarociński and Karadi (2020) series on the contemporaneous US monetary policy shock (and three of the latter shock's lags).

D Alternative specifications of empirical model and other shocks

Here we report robustness with respect to the sample split and with respect to the specific choice of euro-area monetary policy shock series. We also report impulse responses for euro-area shocks other than policy shocks.

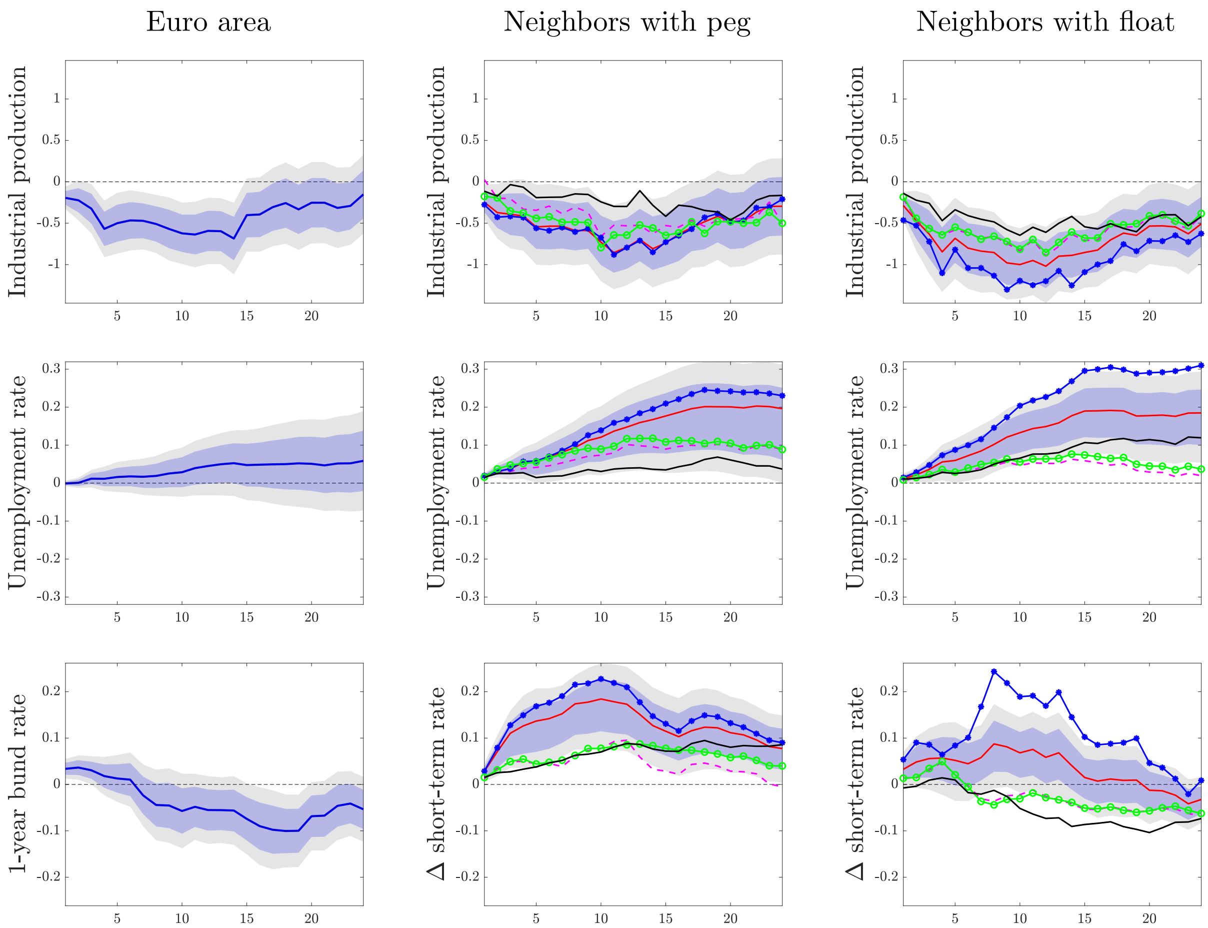
D.1 Monetary policy shocks: alternative specifications

This section documents the spillover effects for other specifications of the baseline regression.

D.1.1 Different sample split

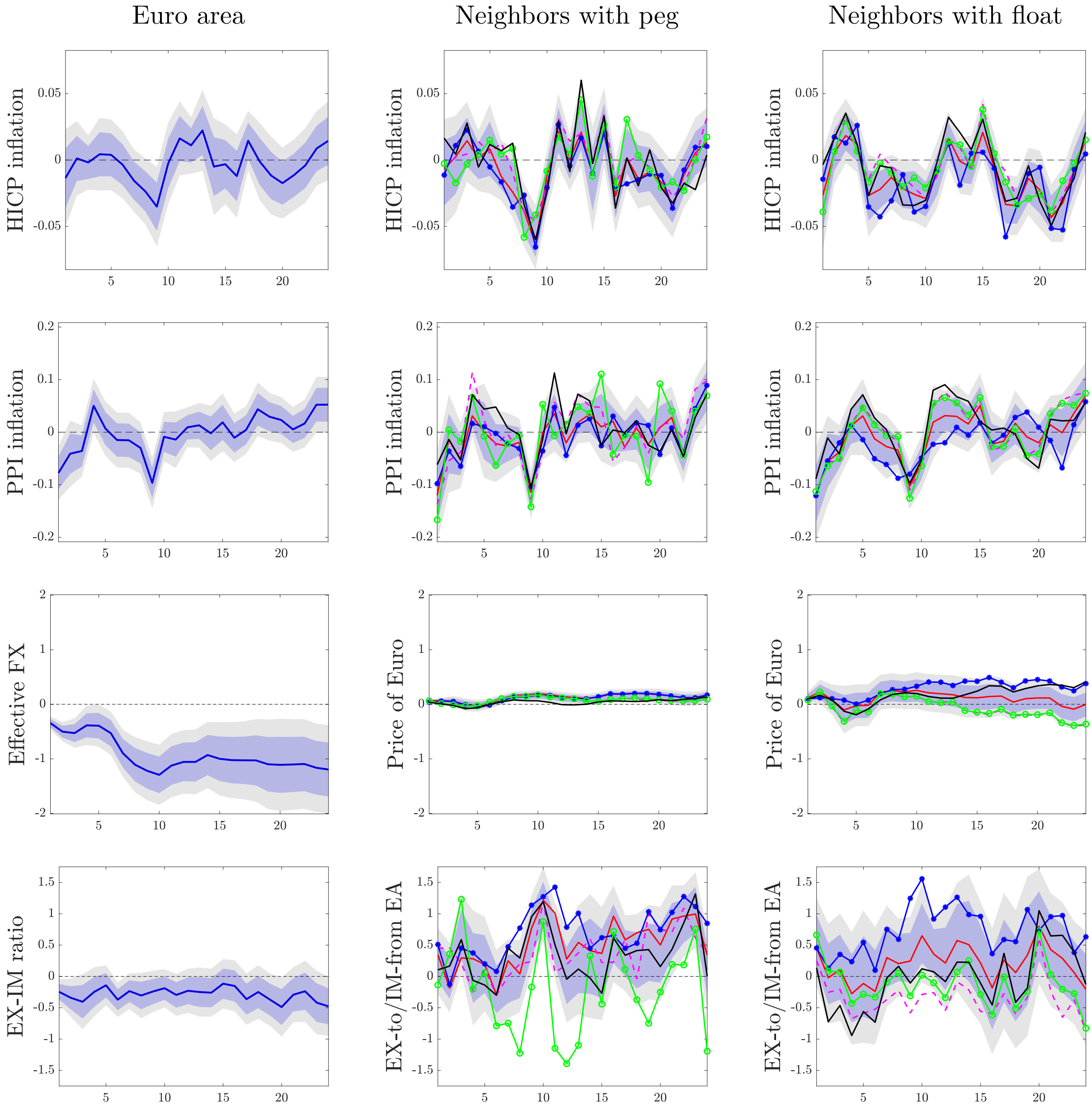
First, we do further robustness with respect to splitting the sample into pegs and floats. In the alternatives, respectively, we drop Cyprus and Greece from the sample (among the neighbors that peg, these were the countries worst-hit by the fiscal crisis), we drop EMU accession countries, and we perform sensitivity with respect to including former communist countries or not. Figures D.5 and D.6 as well as the notes to the figures provide details.

Figure D.5: Adjustment to euro-area monetary policy shock: alternative specifications



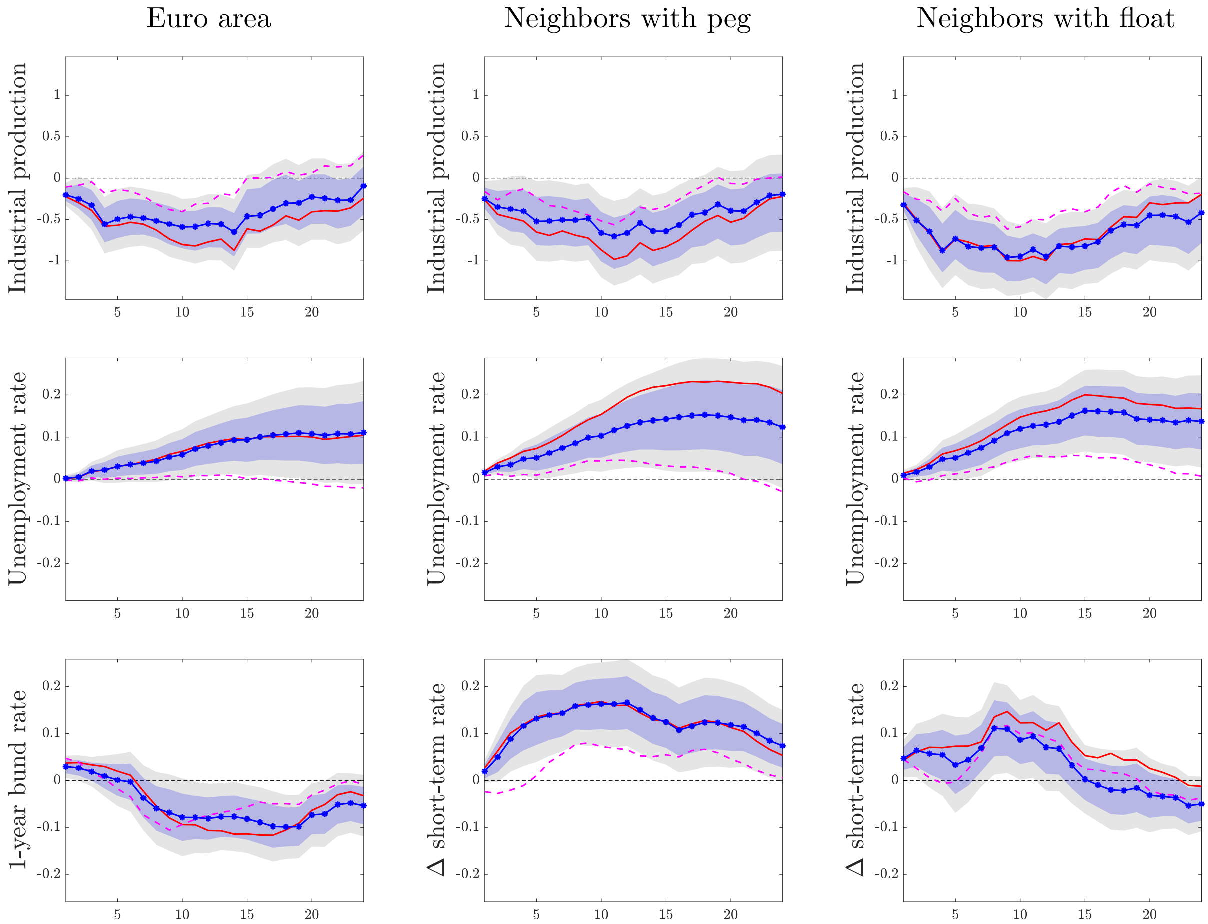
Notes: Shock is one-standard deviation shock. Left column shows responses of euro area variables, middle (right) column the response in neighbor countries with pegged (flexible) exchange rate; shaded areas correspond to 68 and 90 percent confidence bounds of estimate for baseline, see Figures 2.A and 2.B for details. Point estimates for alternative specifications: Cyprus and Greece not in sample (red solid line), No EMU accession countries in sample, that is, we drop Bulgaria, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Slovakia (dashed line in magenta), only Eastern European countries in sample, that is, only Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia (blue line with stars), no eastern European countries in sample, that is the complement of the previous selection (green with circles), drop observations for financial crisis 2008–09 (black solid line).

Figure D.6: Adjustment to euro-area monetary policy shock: alternative specifications



Notes: Shock is one-standard deviation shock. Left column shows responses of euro area variables, middle (right) column the response in neighbor countries with pegged (flexible) exchange rate; shaded areas correspond to 68 and 90 percent confidence bounds of estimate for baseline, see Figures 2.A and 2.B for details. Point estimates for alternative specifications: Cyprus and Greece not in sample (red solid line), No EMU accession countries in sample, that is, we drop Bulgaria, Cyprus, Czechia, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovenia, Slovakia (dashed line in magenta), only Eastern European countries in sample, that is, only Bulgaria, Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia (blue line with stars), no eastern European countries in sample, that is the complement of the previous selection (green with circles), drop observations for financial crisis 2008–09 (black solid line).

Figure D.7: Adjustment to euro-area monetary policy shock: alternative specifications

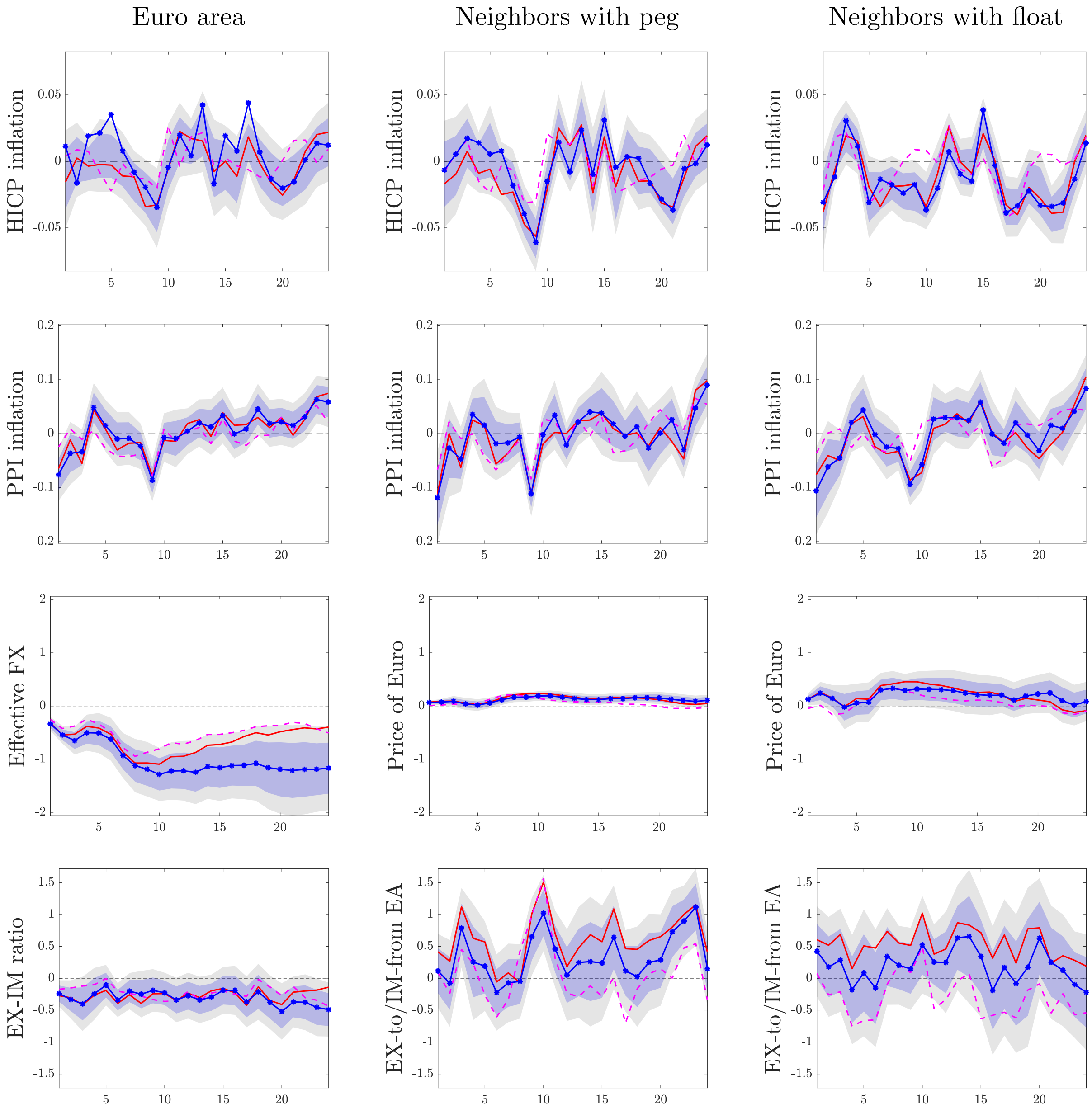


Notes: Shock is one-standard deviation shock. Left column shows responses of euro area variables, middle (right) column the response in neighbor countries with pegged (flexible) exchange rate; shaded areas correspond to 68 and 90 percent confidence bounds of estimate for baseline, see Figures 2.A and 2.B for details. Point estimates for alternative specifications: monetary policy shocks identified using poorman's condition (red solid line), monetary policy shocks measured as monetary surprises in EA-MPD (dashed line in magenta), 6 (rather than 12) lags of shock and dependent variable as controls.

D.1.2 Different series for monetary shocks, and controls

This section reports on the impulse responses when using other measures of monetary policy shocks, and when changing the controls. The notes to Figures D.7 and D.8 provide the details.

Figure D.8: Adjustment to euro-area monetary policy shock: alternative specifications



Notes: Shock is one-standard deviation shock. Left column shows responses of euro area variables, middle (right) column the response in neighbor countries with pegged (flexible) exchange rate; shaded areas correspond to 68 and 90 percent confidence bounds of estimate for baseline, see Figures 2.A and 2.B for details. Point estimates for alternative specifications: monetary policy shocks identified using poorman's condition (red solid line), monetary policy shocks measured as monetary surprises in EA-MPD (dashed line in magenta), 6 (rather than 12) lags of shock and dependent variable as controls.

D.2 Spillovers from other shocks

So far, we have focused on euro-area monetary policy shocks. The current section probes into the spillovers from other euro-area shocks. For these as well, we find the exchange-rate regime appears to have similarly limited effects. For this purpose we once more rely on estimating models (1) and (2), but we choose shocks other than euro-area monetary policy shocks to represent $\bar{\varepsilon}_t$.

First, we estimate the effect of central bank information shocks in the euro area, as identified by Jarociński and Karadi (2020) and Jarociński (2021). Intuitively, these shocks account for a positive co-movement of interest-rate forwards and the stock market around monetary events. The idea is that a monetary surprise may provide information to market participants, to the extent that the central bank has more information about non-monetary fundamentals and is responding to these (see also Nakamura and Steinsson, 2018; Romer and Romer, 2000). The identification does not reveal the precise type of information advantage of the central bank. It seems natural to assume, however, that the euro-area monetary authorities have an information advantage, relative to the market and relative to information revealed by other central banks, primarily with respect to forces that are specific to the euro-area economy.

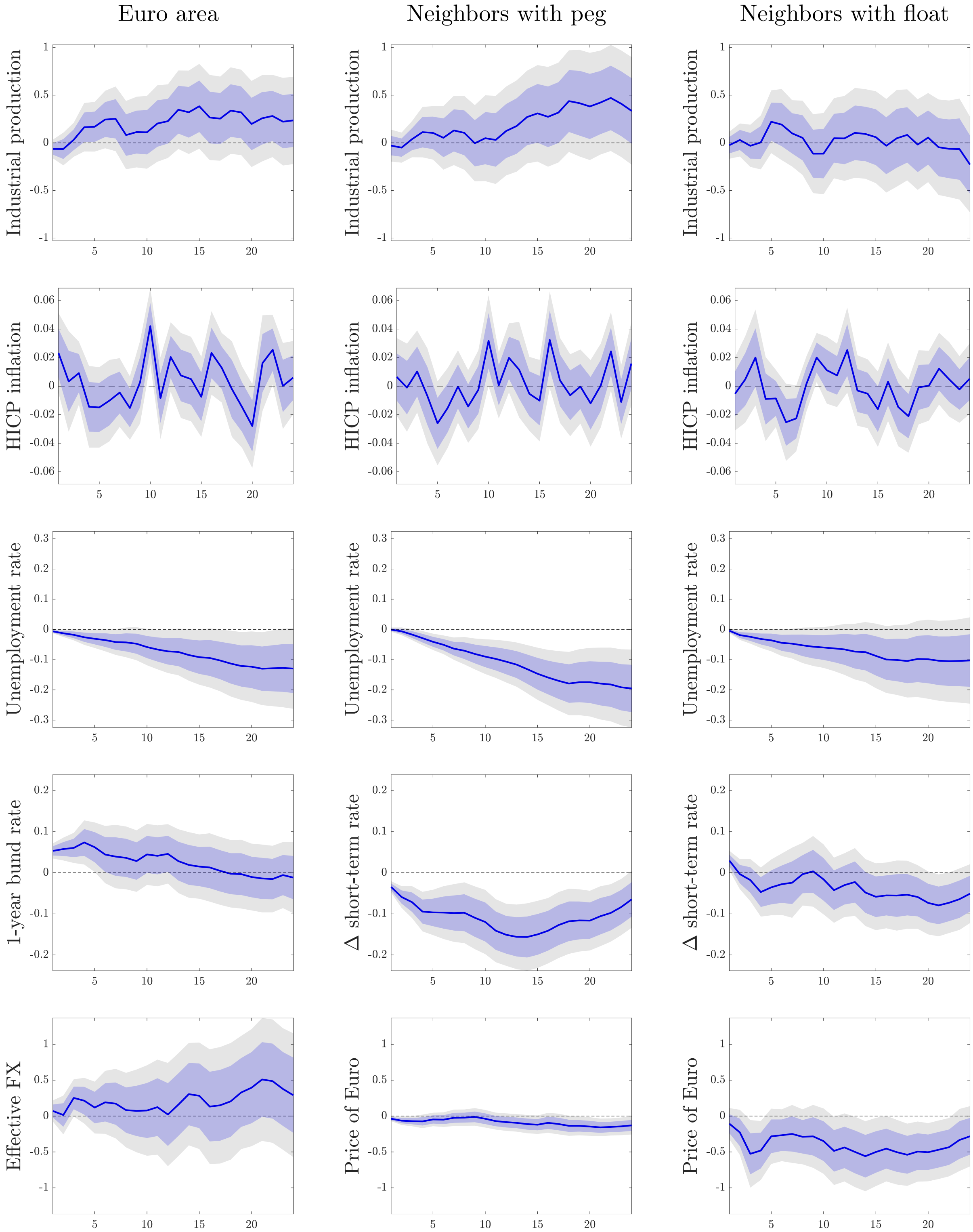
Figure D.9 shows the adjustment to euro-area central bank information shocks, both in the euro area and in the neighbor countries. It is organized in the same way as previous figures. In particular, the left column shows results for the euro area, the middle column for neighbors with a peg, the right column for neighbors with a float. In the figure, to keep the exposition compact, we focus on the response of four variables only: industrial production, unemployment, interest rates, and the exchange rate. In line with the notion that underlies a central bank information shock, we find this shock to be expansionary in the euro area. And, it is expansionary in the neighbor countries as well. Indeed, we find a very similar picture as with monetary policy shocks—except that all signs are reversed. The spillovers are positive and sizeable and they similar for floats and for pegs.

As a second alternative shock, we consider a euro-area credit "spread shock" that we identify relying on earlier work by Gilchrist and Mojon (2018). Specially, we use their index of credit risk for banks in the euro area which, in turn, aggregates individual security level data for Germany, Italy, Spain and France. We include this time series together with observations for industrial production, HICP inflation (core), and the EONIA in a VAR model and identify the spread shock recursively.[29]

Figure D.10 shows the estimated responses to the identified euro area spread shocks. As before, we show the adjustment in the euro area itself in the left column. Focus first on the third row of that column. This shows that the spread shock raises the credit spread in the euro area persistently. The euro-area spread shock induces euro-area economic activity to contract (first

[29] We obtain the series for the spread from the website at the Banque de France: https://publications.banque-france.fr/en/economic-and-financial-publications-working-papers/credit-risk-euro-area. We identify the spread shock recursively, assuming that the variables in the VAR are pre-determined relative to the credit spread. In doing so, we rely on a key result by Gilchrist and Mojon (2018). Namely, while they also consider alternative approaches, namely a FAVAR and identification by means of an external instrument, these authors emphasize that results from these alternatives are fairly similar to those obtained under a recursive VAR. We estimate the VAR on monthly time series for the period 1999M1–2018M12. Since it features 6 lags, our time series of spread shocks covers the period 1999M7–2018M12.

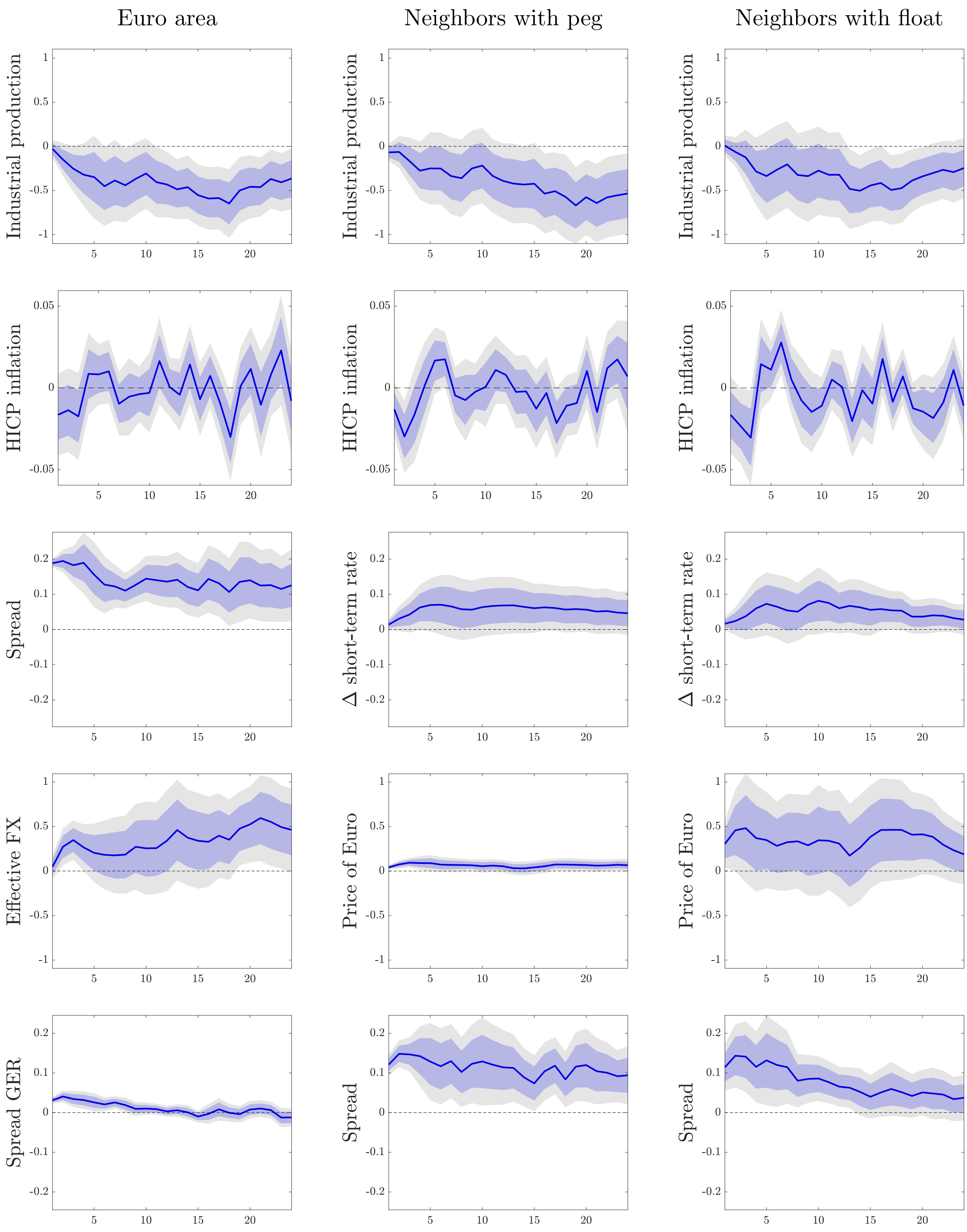
Figure D.9: Adjustment to euro-area central bank information shock



Notes: Central bank information shock identified by Jarociński and Karadi (2020) using high frequency data and VAR model with sign restrictions. Left column shows response of euro area variables, middle (right) column response in neighbor countries with exchange rate peg. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.

two rows), and the euro to depreciate in effective terms (an increase in the bottom left panel). As before, there are sizable spillovers to the neighboring countries. The response in economic activity may be somewhat more muted for floaters, but overall it hardly differs between pegs (middle panels) and floats (right panels). Just like in the case of a monetary policy shock, the contractionary effect of a spread shock spills over to industrial production and unemployment of its neighbors (first and second row). And just like for the monetary policy shock discussed above, we find a positive response of the measured interest rate differential with respect to the euro area for the neighbor countries—independently of the currency regime (third row, middle and right panels). As regards the response of the exchange rate, shown in the bottom row, we find that the currency of neighbor countries with a flexible exchange rate depreciates against the euro—an effect that we, naturally, do not observe in the neighbor countries with limited exchange rate flexibility. But even accounting for this, one may be tempted to conclude that flexible exchange rates do not seem to offer much insulation against a spread shock that originates in the euro area.

Figure D.10: Adjustment to euro-area spread shock



Notes: spread shock identified in recursive VAR estimated using time series of bank credit spread of Gilchrist and Mojon (2018). Left column shows response of euro area variables, middle (right) column response in neighbor countries with exchange rate peg. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.

E Proof of Proposition 5 (CPI inflation targeting with DCP)

This section derives the formulae in Proposition 5 of the main text. The proposition shows the evolution of the economy in the regime with dominant currency pricing under strict consumer-price inflation targeting.

Proof of Proposition 5: From Proposition 2, we know that $s_t = 0$, so that by (24), $\pi^*_{H,t} = \pi^*_t$. (25) then implies

$$m_t = m_{t-1} + \pi^*_t + \Delta e_t - \pi_{H,t} \tag{35}$$

By assumption, there is strict consumer-price inflation targeting, $\pi_t = 0$, which by the definition of consumer price inflation, (27), means $\pi_t = (1-\upsilon)\pi_{H,t} + \upsilon(\pi^*_t + \Delta e_t) = 0$. Solving this for $\pi^*_t + \Delta e_t$, and substituting in (35) gives

$$m_t = m_{t-1} - \frac{1}{\upsilon}\pi_{H,t}, \tag{36}$$

or $\pi_{H,t} = -\upsilon \Delta m_t$. In turn, substituting this into Phillips curve (22) gives

$$-\upsilon\Delta m_t = -\upsilon E_t\left\{\Delta m_{t+1}\right\} + \kappa\left[y_t + \upsilon m_t\right].$$

Using risk sharing condition (26) to substitute for y_t (with $s_t = 0$ again) gives

$$-\upsilon(m_t - m_{t-1}) = -\upsilon E_t\left\{m_{t+1} - m_t\right\} + \kappa\left[y^*_t + m_t\right]. \tag{37}$$

We solve (37) using the method of undetermined coefficients. We do so first for the case that shocks have already ceased in period t, then for the case that the shocks still prevail in period t.

Suppose that the shocks have already ceased in period t. Guess that for any such period t, $m_t = \alpha \cdot m_{t-1}$, with $|\alpha| < 1$. Using this guess in (37), with $y^*_t = 0$ (since shocks have already ceased by assumption), and solving for the stable root gives $\alpha = 1 + \frac{\kappa}{2\upsilon} - \sqrt{[1+\kappa/(2\upsilon)]^2 - 1}$. Next, suppose that the shocks still prevail in period t. Guess that while shocks last, $m^L_t = \alpha \cdot m^L_{t-1} + \vartheta$. Then

$$\begin{aligned} E_t\left\{m_{t+1} - m_t\right\} &= \mu(m^L_{t+1} - m^L_t) + (1-\mu)(\alpha m^L_t - m^L_t) \\ &= \mu[(\alpha-1)m^L_t + \vartheta] + (1-\mu)(\alpha-1)m^L_t \\ &= (\alpha-1)m^L_t + \mu\vartheta, \end{aligned}$$

where μ is the probability that the shock continues to last next period.

Using this in (37) along with the solution for y^*_t gives, after matching coefficients,

$$\vartheta = \frac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A}.$$

Using $m^L_t = \alpha \cdot m^L_{t-1} + \vartheta$, one, then, arrives at

$$m^L_t = \frac{1-\alpha^{t+1}}{1-\alpha}\frac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A}. \tag{38}$$

Use this in (36) to solve for the formula for $\pi^L_{H,t}$ that is given in item (2.) of the proposition.

For the evolution of output in item (1.) of the proposition set $s_t = 0$ in risk sharing condition (26), use the law of motion for foreign output from Proposition 1, and use (38).
So as to obtain item (4.) of the proposition, observe that consumer price inflation targeting ($\pi_t = 0$, as in item (3.)) implies, using the definition in (27), that

$$\Delta e_t = -\frac{1-\upsilon}{\upsilon}\pi_{H,t} - \pi_t^*, \tag{39}$$

so that while the shocks persist (using the law of motion $\pi_{H,t}^L$)

$$\Delta e_t^L = (1-\upsilon)\alpha^t \frac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A} - \pi_L^*. \tag{40}$$

Substituting for π_L^* from Proposition 1, one obtains the law of motion for e_t^L in item (4.) of the proposition.
So as to derive the interest-rate spread, item (5.) of the proposition, we use the uncovered interest parity (UIP). UIP itself follows from taking the difference between the IS equations in Home and Foreign, (21) and (18), and using (24) and (25) to simplify. UIP is given by

$$r_t - r_t^* = E_t\{\Delta e_{t+1}\}. \tag{41}$$

Use this to derive the formula for the interest spread. Suppose that shocks are still active in period t. Then using the Markov structure, and equations (36), (39), and (40),

$$\begin{aligned}
E_t\left\{\Delta e_{t+1}\right\} &= -(1-\mu)(1-\alpha)(1-\upsilon)m_t^L \\
&\quad +\mu(1-\upsilon)\alpha^{t+1}\tfrac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A} + \mu\kappa\mathbf{A}. \\
&= -(1-\mu)(1-\upsilon)(1-\alpha^{t+1})\tfrac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A} \\
&\quad +\mu(1-\upsilon)\alpha^{t+1}\tfrac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A} + \mu\kappa\mathbf{A} \\
&= (1-\upsilon)(\alpha^{t+1}-1)\tfrac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\mathbf{A} + \mu\left[\kappa + (1-\upsilon)\tfrac{\kappa(1-\mu)}{\upsilon(2-\alpha-\mu)+\kappa}\right]\mathbf{A},
\end{aligned}$$

whence item (5.) in the proposition follows. This completes the proof of Proposition 5. □

F Dominant currency, stabilizing producer price inflation

Under otherwise the same assumptions as in Section 5.6, the current appendix derives the response of the Home economy to Foreign monetary shocks if the Home central bank targets producer-price inflation.

Proposition 6. ***Targeting producer price inflation***. *Consider the same conditions as in Proposition 2. Let Home monetary policy target stable producer prices ($\pi_{H,t} = 0$). Then, while the foreign monetary shock lasts, the following is true:*

1. *Home output evolves according to*

$$y_t^L = -\upsilon(1-\mu) \cdot \mathbf{A} = \upsilon y_L^*.$$

2. *Home producer price inflation, by design, is zero $\pi_{H,t}^L = 0$.*
3. *Home consumer price inflation is given by*

$$\pi_0^L = \nu(1-\mu) \cdot \mathbf{A}, \text{ and } \pi_t^L = 0 \text{ for } t > 0.$$

4. *The nominal exchange rate is given by*

$$e_t^L = [1 - \mu + (t+1)\kappa] \cdot \mathbf{A}.$$

5. *The Home interest rate is given by $r_t^L = 0$, with the interest differential between Home and Foreign*

$$r_t^L - r_t^{*,L} = -\left[(1-\mu)^2 - \kappa\mu\right] \cdot \mathbf{A}, \tag{42}$$

resulting from a change in the Foreign interest rate only.

Proof. With strict producer-price inflation targeting, $\pi_{H,t} = 0$ (item (2.)) by design. Then, from Phillips curve (22), we have that $y_t + \upsilon \cdot m_t = 0$. Add $\upsilon \cdot m_t$ to each side of the risk sharing condition (26) and use $y_t + \upsilon \cdot m_t = 0$ to simplify. This gives $m_t = -y_t^* = (1-\mu)\mathbf{A}$, where the last step uses the law of motion for Foreign output from Proposition 1. Using this, one arrives at the expression for y_t^L in item (1.) of Proposition 6. With $\pi_{H,t} = 0$ (from the policy regime) and $s_t = 0$ (from Proposition 2), the definition of the terms of trade in (24) gives $\pi_{H,t}^* = \pi_t^*$. From (25) on, then, has that $\Delta e_t = \Delta m_t - \pi_t^*$. With the expression for m_t derived earlier and the law of motion for π_t^* from Proposition 1, this gives item (4.) of the proposition. Item (3.) follows from the definition of CPI inflation, equation (27), along with the earlier results. Last, the interest differential in item (5.) follows from UIP, the derivation of which is described in the proof of Proposition 5. To see that the $r_t^L = 0$, compare (42) to the Foreign interest rate response in (32). □

Under a dominant currency regime, targeting producer price inflation insulates producer prices but neither domestic output nor consumer price inflation. Output in Home falls along with Foreign output, and the more so, the more open the economy is (the lower home bias is, that is, the closer υ to unity). The partial insulation of output that there is originates from a sharp depreciation on impact, accommodated by a more accommodative monetary policy in Home than in Foreign. Indeed, the interest rate in Home does not move at all upon the monetary shock in Foreign; refer to equation (32) to see that the response of the interest differential in (42) is due only to the Foreign interest rate. In sum, in a dominant-currency regime, flexible exchange rates do not afford insulation of output at its natural level as long as monetary policy targets inflation, be it producer price inflation (Proposition 6 above) or consumer-price inflation (Proposition 5 in the main text).

G Producer currency pricing

For comparison, it is useful to inspect, if only briefly, producer currency pricing (PCP, henceforth). This is because PCP underpins the classic notion that flexible exchange rates provide automatic insulation. Under PCP, targeting the producer price level amounts to targeting the natural level of output. So the two regimes are equivalent, as Proposition 7 states. Under producer currency pricing, equation (23) is replaced by the law of one price:

$$\pi^*_{H,t} = \pi_{H,t} - (e_t - e_{t-1}), \tag{43}$$

rendering the law-of-one-price gap zero ($m_t = 0$ throughout).

Proposition 7. ***Divine coincidence under PCP.*** *Consider the economy of Section 5. Let pricing be given by PCP. Let the shocks be as described in Section 5.5. Let Home monetary policy target the natural level of output (or, equivalently, target producer-price stability $\pi_{H,t} = 0$). Then, while the foreign monetary shock lasts, the following is true.*

1. *The terms of trade and output follow their natural values, so $s^L_t = -y^*_L$ and $y_t = 0$.*
2. *Producer price inflation is zero $\pi^L_{H,t} = 0$.*
3. *Consumer price inflation is given by*

$$\pi^L_0 = (1-\mu)\upsilon \cdot \mathbf{A}, \text{ and } \pi^L_t = 0 \text{ for } t > 0.$$

4. *The nominal exchange rate is given by*

$$e^L_t = [(1-\mu) + (t+1)\kappa] \cdot \mathbf{A} = s^L_t - (t+1) \cdot \pi^*_L.$$

5. *The interest rate in Home is $r^L_t = 0$, with the interest differential*

$$r^L_t - r^{*,L}_t = -[(1-\mu)^2 - \kappa\mu] \cdot \mathbf{A},$$

resulting from a change in the Foreign interest rate only.

Proof. With strict producer-price inflation targeting, $\pi_{H,t} = 0$ by definition. Then, from Phillips curve (22) we have that $y_t + \upsilon \cdot m_t = 0$. With producer currency pricing $m_t = 0$ (easily verified using (25)), so that $y_t = 0$. From risk sharing (26), then, $s_t = -y^*_t$. Together this establishes items (1.) and (2.) of the proposition. Using the law of one price, (43), with $\pi_{H,t} = 0$, gives $\pi^*_{H,t} = -\Delta e_t$. Using this in the definition of the terms of trade, (24), yields $\Delta e_t = \Delta s_t - \pi^*_t$, which together with the law of motion for Foreign output from Proposition 1 and $s_t = -y^*_t$ yields item (4.) of the proposition. Item (3.) follows from the definition of consumer price inflation in (27) and the earlier results. Item (5.) follows from UIP, where we derived UIP itself in the proof of Proposition 5. To see that the $r^L_t = 0$, compare the interest differential in the proposition here to the Foreign interest rate response in (32). □

Compare Proposition 7 here to the corresponding Propositions 3 and 6 for the dominant currency regime. As is well known, under PCP exchange rate adjustment lines up expenditure switching with domestic output gap stabilization. In particular, in response to the fall in Foreign demand, when monetary policy in Home targets producer prices, output in Home is perfectly stabilized. And so is consumer price inflation in all but the initial period. Indeed, on impact, the CPI inflation in Home rises, in line with the depreciation of the nominal exchange rate. Note further that, in the special case shown here, the interest rate in Home need not move *at all.* Rather, the interest gap required for the exchange rate to depreciate reflects the response of the foreign interest rate only.

The evolution of the economy under fixed exchange rates is identical under PCP and DCP, see Proposition 8. So, with fixed exchange rates, also under PCP, the economy would evolve as in Proposition 4.

Proposition 8. ***Fixed exchange rate under PCP****. Consider the same assumptions as in Proposition 7, but let Home monetary policy target fixed exchange rates ($e_t = 0$). Then, the evolution of the economy under PCP is identical to the evolution under DCP described in Proposition 4. That is, under fixed exchange rates, the equilibrium of the PCP economy is the same as in the DCP economy.*

Proof. The key to seeing this is that the DCP and PCP economy have the same equilibrium, whenever $m_t = 0$ in the DCP economy (that is, if the law of one price holds under DCP). This is the case here; see the proof of Proposition 4 in the main text. □

What remains to be discussed is consumer-price inflation targeting under PCP. Also under producer currency pricing shielding domestic activity from foreign shocks requires some initial consumer-price inflation (compare Proposition 7). It may, therefore, be useful to spell out the consequences of consumer price inflation targeting under PCP. We do so in Proposition 9.

Proposition 9. ***Targeting consumer price inflation under PCP****. Consider the same assumptions as in Proposition 7, but Home monetary policy target consumer price stability (target $\pi_t = 0$). Then, while the foreign monetary shock lasts, the following is true.*

1. *Output follows*
$$\begin{aligned} y_t^L &= \left[-(1-\mu) + \tfrac{1-\alpha^{t+1}}{1-\alpha}\tfrac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa}\right] \cdot \mathbf{A} \\ &= y_L^* + \tfrac{1-\alpha^{t+1}}{1-\alpha}\tfrac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa} \cdot \mathbf{A}, \end{aligned}$$
where $\alpha = 1 + \kappa/(2\upsilon) - \sqrt{\kappa^2/(4\upsilon^2) + \kappa/\upsilon} \in (0,1)$. And the terms of trade follow
$$s_t^L = \frac{1-\alpha^{t+1}}{1-\alpha}\frac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa} \cdot \mathbf{A}.$$
2. *Producer price inflation is*
$$\pi_{H,t}^L = -\upsilon\alpha^t \frac{\kappa(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa} \cdot \mathbf{A}.$$
3. *Consumer price inflation is zero, by construction.*
4. *The nominal exchange rate is given by*
$$e_t^L = \left[\frac{1-\alpha^{t+1}}{1-\alpha}\frac{(1-\upsilon)(1-\mu)}{\upsilon[2-\alpha-\mu]+\kappa} + (t+1)\right]\kappa \cdot \mathbf{A}.$$
5. *The interest differential is given by*
$$r_t^L - r_t^{*,L} = \frac{1}{\upsilon[2-\mu-\alpha+\kappa]}\left(-(1-\alpha^{t+1})(1-\mu)(1-\upsilon) + \mu[1-\mu+\upsilon(1-\alpha)+\kappa]\right)\cdot\kappa\cdot\mathbf{A}.$$

Proof. Use the law of one price, (43), to substitute for $\pi^*_{H,t}$ in (24). Then, use the definition of consumer price inflation (27) and $\pi_t = 0$ (item (3.)) to simplify. This yields $\pi_{H,t} = \upsilon(s_{t-1} - s_t)$. Substitute for $\pi_{H,t}$ in Phillips curve (22). Having substituted, too, for y_t from (26) this yields

$$\upsilon[s_{t-1} - s_t] = \upsilon[s_t - E_t s_{t+1}] + \kappa[s_t + y^*_t].$$

Solving the difference equation in s_t for the stationary solution by the method of undetermined coefficients, gives item (1.). Item (2.) follows from $\pi_{H,t} = \upsilon(s_{t-1} - s_t)$. Item (4.) follows using the above solutions and the definition of consumer price inflation, (27), with $\pi_t = 0$. Item (5.) follows from UIP, where we derived UIP itself in the proof of Proposition 5. □

From this, CPI inflation targeting, also under PCP invites output spillovers. This is so, in particular if prices are rather rigid. Indeed, in the limit, as $\kappa \to 0$, the evolution of the economy with PCP and CPI targeting converges to that of a regime of fixed exchange rates.

H More general analytical solutions

Section 5 in the main text and the corresponding Appendix F and Appendix G have analyzed the transmission of one shock to the Home economy: a foreign monetary policy shock. In addition, for tractability, they had focused on the limit $\beta \to 1$ and they had restricted labor supply to be infinitely elastic, setting $\varphi = 0$. We did so for the sake of tractability.

This appendix, instead, provides more general results that relax the three assumptions. The appendix spells out the response of the Home economy to any of the foreign shocks discussed above. It allows labor supply to be inelastic. And it allows for any $\beta \in (0, 1)$. We retain the Markov structure of shocks, however, and continue to look at a linear approximation around the non-stochastic steady state.

H.1 Linearized economy

So as to make this self-contained, we spell out all model equations even if this means that we duplicate some from the main text. For the Home economy, all that matters in Foreign is the evolution of the foreign level of output, y_t^*, the foreign inflation rate, π_t^*, and the foreign interest rate, r_t^*, and the foreign demand preference shock ξ_t^*. The reason why the latter matters is international consumption-risk sharing. For any shock, instead, that does not directly shift consumption preferences, knowledge of the evolution of triple (y_t^*, π_t^*, r_t^*) suffices to derive the evolution of the Home economy. Note that the evolution in Foreign will be induced by a combination of Foreign shocks and the response of Foreign monetary policy. Once the mapping is done, however, foreign shocks other than preference shocks would not matter for Home independently of the equilibrium triple (y_t^*, π_t^*, r_t^*). In this sense, the structure that we present here is not confined to a particular subset of shocks, but would allow for other shocks in Foreign as well. This is the reason why, further below, we report the response in Home in terms of (y_t^*, π_t^*, r_t^*) and ξ_t^*.

The international risk sharing condition combined with the demand for Home-produced goods

$$y_t = s_t + y_t^* - (1 - \upsilon)\xi_t^* + (1 - \upsilon)m_t. \tag{44}$$

In equilibrium, Home output relates positively to the terms of trade, Foreign output, and the demand shock in relative terms. The Home New Keynesian Phillips curve links Home producer-price inflation to expected inflation and marginal costs:

$$\pi_{H,t} \quad = \quad \beta E_t \pi_{H,t+1} + \kappa \left[(1 + \varphi) \, y_t + \upsilon m_t - \upsilon \xi_t^* \right]. \tag{45}$$

Home marginal costs depend on the Home wage. The wage rises with demand for the domestic good. Hence it is increasing in output. In addition, the wage will depend on preference shocks affecting the relative desire of Home and Foreign households to consume in the current period.Export-price inflation differs across pricing scenarios. Under DCP we have

$$\pi_{H,t}^* = \beta E_t \pi_{H,t+1}^* + \kappa \left[(1 + \varphi) \, y_t - (1 - \upsilon) m_t - \upsilon \xi_t^* \right]. \tag{46}$$

Alternatively, under PCP we have from the law of one price for exports: $\pi^*_{H,t} = \pi_{H,t} - \Delta e_t$. From (10), linearizing the Home terms of trade we have:

$$s_t = s_{t-1} + \pi^*_t - \pi^*_{H,t}. \tag{47}$$

Where π marks the inflation rate of the respective price indexes. The law-of-one-price gap, m_t takes the following form

$$m_t = m_{t-1} + e_t - e_{t-1} + \pi^*_{H,t} - \pi_{H,t}. \tag{48}$$

As in the main text, consumer-price inflation in Home is given by the average of inflation rates in the Home consumer's basket

$$\pi_t = (1 - \upsilon)\pi_{H,t} + \upsilon(\pi^*_t + \Delta e_t). \tag{49}$$

The dynamic IS-relation in Home is derived by combining the first-order condition for consumption and saving of Home households with the Home goods-market clearing condition, the risk-sharing condition and the definition of the Home consumer-price index:

$$y_t \quad = \quad E_t y_{t+1} - \left(r_t - E_t(\pi_{H,t+1} + \upsilon \Delta m_{t+1}) + \upsilon E_t \Delta \xi^*_{t+1}\right). \tag{50}$$

y_t, is Home output, r_t the nominal interest rate in Home. Last, we would need to specify Home monetary policy. We will do so below, in a way that binds r_t, e_t, or $\pi_{H,t}$. Combined with a monetary policy rule and armed with the Foreign variables, the monetary policy rule and equations (44) to (50) then form a system of eight variables in eight unknowns all of which are linked to the evolution of the domestic economy.

The equations for the large foreign economy follow the conventional closed-economy New Keynesian model. That is, the intertemporal IS equation in Foreign is given by

$$y^*_t \quad = \quad E_t y^*_{t+1} - \left(r^*_t - E_t(\pi^*_{t+1}) + E_t \Delta \xi^*_{t+1}\right), \tag{51}$$

and the New Keynesian Phillips curve in Foreign is given by

$$\pi^*_t = \beta E_t \pi^*_{t+1} + \kappa (1 + \varphi) [y^*_t - Z^*_t]. \tag{52}$$

A foreign interest-rate rule completes the model environment. From here, as before, one could derive the conventional UIP condition, (41).

H.2 Flex-price benchmark

The natural level of output in Home is given by

$$y^n_t = \frac{\upsilon}{1 + \varphi} \xi^*_t. \tag{53}$$

Not surprisingly, the natural level of output is not affected by the invoicing regime whatsoever. The natural terms of trade while the shocks last are given by

$$s_t^n = \frac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_t^* - y_t^*. \tag{54}$$

H.3 The transmission of shocks in Foreign

As in the main text, we assume that all shocks originate in Foreign, and that these shocks follow Markov processes and induce a Markov structure for foreign inflation, foreign output, the foreign interest rate. We do so for tractability. Shocks may occur (and disappear) jointly, or individually. The essence of the results below is not affected by this choice. Starting from the non-stochastic steady state, in the first period there is a shock or a combination of shocks that induces a response of foreign variables. In the next period, the shock remains present at that level with probability μ. Else, the shock ceases. That is, we shall assume that while the shock lasts $\pi_t^* = \pi_L^*$, $y_t^* = y_L^*$, $r_t^* = r_L^*$, and $\xi_t^* = \xi_L^*$, for some values π_L^*, y_L^*, r_L^*, and ξ_L^*. Once the shock ends, foreign variables immediately return to their steady state. Note that we do not need to spell out exactly how the combination of the four Foreign variables (π_L^*, y_L^*, r_L^*, and ξ_L^*) comes to pass. The following proposition summarizes one example.

Proposition 10. *Consider the large economy sketched in Appendix H.1 and the shock structure of Appendix H.3. For better readability, mark the external shocks in bold font ($\boldsymbol{\epsilon}_t^{m*}$, $\boldsymbol{\xi}_t^*$, and $\mathbf{Z}_t^*$) Suppose monetary policy in Foreign perfectly stabilizes prices and output in Foreign once the shocks cease. Suppose that while the shocks last, monetary policy in Foreign follows a Taylor rule*

$$r_t^* = \phi\pi_t^* + \gamma y_t^* + \boldsymbol{\epsilon}_t^{m*}, \tag{55}$$

where ϵ_t^{m*} is a monetary shock that follows said Markov structure. Suppose that parameters are such that there is determinacy. Then, while shocks last, output in Foreign will be

$$y_L^* = \frac{1}{1-\mu+\gamma+\frac{\kappa(1+\varphi)}{1-\beta\mu}(\phi-\mu)}\left[\frac{\kappa(1+\varphi)}{1-\beta\mu}(\phi-\mu)\ \cdot\ \mathbf{Z}_L^* + (1-\mu)\ \cdot\ \boldsymbol{\xi}_L^*\ -\ \boldsymbol{\epsilon}_L^{m*}\right].$$

Inflation in Foreign will be

$$\Pi_L^* = \frac{\frac{\kappa(1+\varphi)}{1-\beta\mu}}{1-\mu+\gamma+\frac{\kappa(1+\varphi)}{1-\beta\mu}(\phi-\mu)}\left[-\big[(1-\mu)+\gamma\big]\ \cdot\ \mathbf{Z}_L^* + (1-\mu)\ \cdot\ \boldsymbol{\xi}_L^*\ -\ \boldsymbol{\epsilon}_L^{m*}\right].$$

The Foreign interest rate will be

$$\begin{aligned} r_L^* \quad = \quad & -\frac{1}{1-\mu+\gamma+\frac{\kappa(1+\varphi)}{1-\beta\mu}(\phi-\mu)}\frac{\kappa(1+\varphi)}{1-\beta\mu}\left[\phi(1-\mu)+\gamma\mu\right]\ \cdot\ \mathbf{Z}_L^* \\ & +\frac{1}{1-\mu+\gamma+\frac{\kappa(1+\varphi)}{1-\beta\mu}(\phi-\mu)}\left[\phi\frac{\kappa(1+\varphi)}{1-\beta\mu}+\gamma\right](1-\mu)\ \cdot\ \boldsymbol{\xi}_L^* \\ & +\frac{1}{1-\mu+\gamma+\frac{\kappa(1+\varphi)}{1-\beta\mu}(\phi-\mu)}\frac{(1-\mu)(1-\beta\mu)-\kappa(1+\varphi)\mu}{1-\beta\mu}\ \cdot\ \boldsymbol{\epsilon}_L^{m*}. \end{aligned}$$

Proof. Straightforward algebra using (51) and (52) along with Taylor rule (55) and the Markov structure of shocks. □

The following corollary highlights that Proposition 10 nests several special cases.

Corollary 2. *Proposition 10 nests two important scenarios as a special case.*

a) Inflation targeting in Foreign. *Nested as* $\phi \to \infty$ *and* $\gamma = 0$*. Then,* $y^*_L = \mathbf{Z}^*_L$, $\Pi^*_L = 0$, *and*

$$r^*_L \;=\; v(1-\mu) \;\cdot\; \Big[\boldsymbol{\xi}^*_L - \mathbf{Z}^*_L\Big]$$

b) The effective lower bound binds in Foreign. *Suppose that while the shocks last, monetary policy in Foreign does not respond to shocks, but keeps* $r^*_L = 0$*. Nested with* $\phi = \gamma = \epsilon^{m*}_L = 0$*. Then,*

$$y^*_L = \frac{1-\beta\mu}{(1-\mu)(1-\beta\mu) - \kappa(1+\varphi)\mu}\Bigg[-\frac{\kappa(1+\varphi)\mu}{1-\beta\mu}\;\cdot\;\mathbf{Z}^*_L + (1-\mu)\;\cdot\;\boldsymbol{\xi}^*_L\Bigg].$$

$$\Pi^*_L = \frac{\kappa(1+\varphi)}{(1-\mu)(1-\beta\mu) - \kappa(1+\varphi)\mu}\Bigg[-(1-\mu)\;\cdot\;\mathbf{Z}^*_L + (1-\mu)\;\cdot\;\boldsymbol{\xi}^*_L\Bigg].$$

Proof. The results follow directly from Proposition 10. □

H.4 The response in Home under DCP

We are interested in understanding the role of the exchange rate as a shock absorber, in relation to the choice of monetary policy regime. Therefore, we solve the model under alternative monetary and exchange rate regimes for Home, focusing on three of the scenarios that we had also discussed in the main text. First, we look at a policy that stabilizes the natural rate of output. This gives one end of the spectrum in terms of insulating domestic activity. Second, we look at a policy that stabilizes domestic producer price inflation. We use this policy so as to highlight that under DCP a focus on inflation implies output spillovers. Third, we look at a policy that stabilizes the exchange rate (that is, a fixed exchange rate).[30] We do this for both, producer currency pricing and dominant-currency pricing. We start with dominant-currency pricing. Appendix H.5 below shows the results for PCP. Throughout, we report the response of the key variables while the shock lasts.

H.4.1 Natural-output policy under DCP, $y_t = y^n_t$

The first scenario assumes that the domestic central bank sets interest rates so as to anchor output at the natural level of output. Because of DCP, we know that there is no 'divine coincidence:' closing the output gap does not stabilize inflation, and exchange rate movements do not bring about efficient expenditure switching. As in the main text, in the following, we let a superscript L on a variable, e.g., s^L_t, mark the variable while the shocks last.

Proposition 11. *Consider the small Home economy discussed in Section H.1. Let pricing be given by DCP. Let the shocks be as described in Section H.3, with the first period of the shock being period 0. Let Home monetary policy target the natural level of output. Then, while the shocks last, the following is true.*

[30] These are the most tractable cases algebraically. For $\varphi > 0$, depending on monetary policy in Home, the model may have two endogenous state-variables, s_{t-1} and m_{t-1}. This renders solutions in which the central bank targets consumer price inflation algebraically cumbersome. The numerical simulations in Section 6 look at targeting domestic consumer price inflation and producer prices.

1. *The terms of trade are given by*

$$s_t^L = (1 + \alpha_{y^n} + ... + \alpha_{y^n}^t)\gamma_{y^n}\left[\pi_L^*(1-\beta\mu) - \kappa y_L^* + \kappa\frac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_L^*\right], \tag{56}$$

with $\alpha_{y^n} = \frac{1+\beta+\kappa}{2\beta} - \frac{1}{2\beta}\sqrt{(1+\beta+\kappa)^2 - 4\beta}$, *and* $\gamma_{y^n} = 1/(1+\beta+\kappa-\beta\alpha_{y^n}-\beta\mu)$. *One can show that* $0 < \alpha_{y^n} < 1$ *and* $0 < \gamma_{y^n} < \frac{1}{\kappa}$.

2. *Home output is given by the natural level of output in* (53).
3. *Home producer price inflation is given by*

$$\pi_{H,t}^L = -\frac{\upsilon}{1-\upsilon}[\pi_L^* - \Delta s_t^L]. \tag{57}$$

4. *Home consumer price inflation is given by*

$$\pi_t = \upsilon(\Delta s_t + \Delta e_t). \tag{58}$$

5. *The nominal exchange rate is given by*

$$e_t^L = -\frac{1}{1-\upsilon}\left(\left[y_L^* - \frac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_L^*\right]\right) - (t+1)\frac{1}{1-\upsilon}\cdot\pi_L^*. \tag{59}$$

6. *The interest differential between Home and Foreign is given by*

$$r_t^L - r_t^{*,L} \quad = \quad \tfrac{1}{1-\upsilon}\left[-\mu\pi_L^* + (1-\mu)y_L^* - (1-\mu)\tfrac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_L^*\right]. \tag{60}$$

Proof. By the assumption on policy, $y_t = y_t^n = \frac{\upsilon}{1+\varphi}\xi_t^*$, where the last equation follows from (53). Use this in Phillips curve (46), to get

$$\pi_{H,t}^* = \beta E_t \pi_{H,t+1}^* - \kappa(1-\upsilon)m_t.$$

Use the risk sharing condition (44) along with the equilibrium y_t to solve for

$$(1-\upsilon)m_t = \frac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_t^* - s_t - y_t^*.$$

Substitute this into the Phillips curve above. From the definition of the terms of trade (47) solve for $\pi_{H,t}^*$ and substitute this in the Phillips curve, giving

$$\pi_t^* + s_{t-1} - s_t = \beta E_t\left\{\pi_{t+1}^* + s_t - s_{t+1}\right\} - \kappa\frac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_t^* + \kappa s_t + \kappa y_t^*.$$

Solving this for s_t^L using the method of undetermined coefficients and the Markov structure of the model yields the expression for s_t^L as the unique non-explosive solution (item (1.)). Next, observe from the two Phillips curves (45) and (46) and the solution for y_t that $(1-\upsilon)\pi_{H,t} + \upsilon\pi_{H,t}^* = 0$, so that

$$\pi_{H,t} = -\frac{\upsilon}{1-\upsilon}\pi_{H,t}^* = -\frac{\upsilon}{1-\upsilon}\left[\pi_t^* - \Delta s_t\right],$$

that is, equation (57) follows (item (2.)). The law of motion of the nominal exchange rate (item (4.)) then follows from (48) using the intermediate solutions for m_t and $\pi_{H,t}^*$, $\pi_{H,t}$. The interest spread (item (5.)) follows from the UIP condition, which takes the familiar form (41). Item (3.) follows from the definition of consumer price inflation, (49). □

In order to put verbal content to this, consider – for the sake of exposition – an isolated fall in foreign demand $y^*_L = -1$, with $\pi^*_L = r^*_L = \xi^*_L = 0$. This fall in foreign output does not affect the natural level of output in Home, recall equation (53). A policy that stabilizes the output gap, therefore, completely insulates output in the Home economy from the fall in foreign economic activity. Under a policy of output gap targeting, the Home terms of trade deteriorate when foreign output falls (Home-produced goods sold in Foreign become cheaper relative to Foreign-produced goods sold in Foreign), $0 < s^L_0 = \kappa\gamma_{y^n} < 1$. Foreign demand being given by $\upsilon\left[\widehat{s}^L_t + \widehat{y}^*_L\right]$ (compare (16)), the deterioration of the terms of trade leads to expenditure switching by foreign households. This alone is not sufficient, however, to perfectly stabilize domestic output. Rather, perfect stabilization is achieved by the added effect of expenditure switching in Home. The nominal exchange rate depreciates disproportionately, see equation (59). Recalling that under DCP there is full pass-through of the exchange rate to *import* prices in Home, the depreciation is key to expenditure switching by Home households toward Home-produced goods. Note that this switching occurs in spite of the price level of Home-produced goods expressed in Home currency rising on impact, equation (57). Combining this with the pass-through in import prices from the exchange rate depreciation, consumer price inflation rises persistently, (58). Yet domestic consumption is crowded in by a persistent cut in nominal interest rates (60). In sum, insulating Home output from a fall in foreign economic activity means stimulating domestic demand and tolerating producer-price *and* consumer-price inflation.

H.4.2 Stabilizing producer price inflation under DCP, $\pi_{H,t} = 0$

We now consider a monetary policy that stabilizes producer price inflation (i.e. domestic marginal costs) in all periods $\pi_{H,t} = 0$. Again, lacking the divine coincidence property, stabilizing marginal costs does not coincide with stabilizing the output gap. If monetary policy resolves to stabilize producer prices, it positions itself in this trade-off.

Proposition 12. *Consider the same conditions as in Proposition 11, but let Home monetary policy target $\pi_{H,t} = 0$. Then, while the shocks last, the following is true.*

1. *The terms of trade are given by*

$$s^L_t = (1 + \alpha_{\pi_H} + ... + \alpha^t_{\pi_H})\gamma_{\pi_H}\left[\pi^*_L(1 - \beta\mu) - \kappa\frac{1+\varphi}{1+\varphi(1-\upsilon)}y^*_L + \kappa\xi^*_L\right], \tag{61}$$

with $\alpha_{\pi_H} = \frac{1+\beta+\kappa\frac{1+\varphi}{1+\varphi(1-\upsilon)}}{2\beta} - \frac{1}{2\beta}\sqrt{\left[1+\beta+\kappa\frac{1+\varphi}{1+\varphi(1-\upsilon)}\right]^2 - 4\beta}$, and $\gamma_{\pi_H} = 1/(1 + \beta + \kappa\frac{1+\varphi}{1+\varphi(1-\upsilon)} - \beta\alpha_{\pi_H} - \beta\mu)$. One can show that $0 < \alpha_{\pi_H} < 1$ and $0 < \gamma_{\pi_H} < \frac{1}{\kappa}\frac{1+\varphi(1-\upsilon)}{1+\varphi}$. Further, $\alpha_{\pi_H} < \alpha_y$.

2. *Home output is given by*

$$y^L_t = \frac{\upsilon}{1+\varphi(1-\upsilon)}(s^L_t + y^*_L). \tag{62}$$

3. *By design, $\pi^L_{H,t} = 0$.*
4. *Home consumer price inflation is given by*

$$\pi^L_0 = \upsilon\left[\xi^*_L - \frac{\varphi\upsilon}{1+\varphi(1-\upsilon)}s^L_0 - \frac{1+\varphi}{1+\varphi(1-\upsilon)}y^*_L\right] \tag{63}$$

in the initial period, and by

$$\pi_t^L = -\upsilon \frac{\varphi \upsilon}{1+\varphi(1-\upsilon)} \alpha_{\pi_H}^t s_0^L, \; \textit{for } t > 1.$$

5. *The nominal exchange rate is given by*

$$e_t^L = -\left(1 + \alpha_{\pi_H} + ... + \alpha_{\pi_H}^t\right) \frac{\varphi \upsilon}{1+\varphi(1-\upsilon)} s_0^L + \xi_L^* - \frac{1+\varphi}{1+\varphi(1-\upsilon)} y_L^* - (t+1)\pi_L^*. \quad (64)$$

6. *The interest differential between Home and Foreign is given by*

$$\begin{array}{rcl} r_t^L - r_t^{*,L} & = & (1-\mu)\frac{\varphi\upsilon}{1+\varphi(1-\upsilon)}(1-\alpha_{\pi_H})s_t^L \\ & & -\mu\left[1+\alpha_{\pi_H}^{t+1}\frac{\varphi\upsilon}{1+\varphi(1-\upsilon)}\gamma_{\pi_H}(1-\beta\mu)\right]\pi_L^* \\ & & -\left[(1-\mu)+\mu\alpha_{\pi_H}^{t+1}\frac{\varphi\upsilon}{1+\varphi(1-\upsilon)}\gamma_{\pi_H}\kappa\right]\xi_L^* \\ & & +\frac{1+\varphi}{1+\varphi(1-\upsilon)}\left[(1-\mu)+\mu\alpha_{\pi_H}^{t+1}\frac{\varphi\upsilon}{1+\varphi(1-\upsilon)}\gamma_{\pi_H}\kappa\right]y_L^* \end{array} \quad (65)$$

Proof. Item (2.), $\pi_{H,t} = 0$, follows from the assumption on policy. Use Phillips curve (45) to observe that under this policy $(1+\varphi)y_t + \upsilon(m_t - \xi_t^*) = 0$. Using this expression in the risk sharing condition (44) implies the expression for output in the proposition, (62). Substitute from here in Phillips curve (46) such that inflation is forced by the terms of trade and foreign variables only. Substitute for $\pi_{H,t}^*$ from (47). Solving by the method of undetermined coefficients for a bounded solution yields (66). This proves item (1.). The other terms are determined in a manner analogous to lines sketched in Proposition 11. □

As before, for the verbal exposition we focus on a fall in foreign demand in isolation, $y_L^* = -1$. If the Home central bank targets domestic producer price inflation, the terms of trade still deteriorate (as in the previous case). But now the foreign output shock *does* spill over to Home output, see equation (62): Home output unambiguously falls. Relative to the case of natural output targeting, with PPI targeting the nominal exchange rate (64) depreciates by less, and domestic households do not switch expenditures to the same extent. Still, the consumer price level in Home rises on impact, compare equation (63).

In sum, a focus on inflation stabilization induces shocks to foreign demand to translate into a fall of domestic activity. The numerical simulations of Section 6 in the main text show that consumer price inflation targeting curbs the domestic demand stimulus (amid rising inflation) to a still larger extent. This brings the response of output closer still to the case of fixed exchange rates (a regime which prevents domestic demand stimulus altogether).

H.4.3 Stabilizing consumer price inflation under DCP, $\pi_t = 0$

We now consider a monetary policy that stabilizes consumer price inflation (i.e. domestic marginal costs) in all periods $\pi_t = 0$. For the special case of an infinitely elastic labor supply, $\varphi = 0$, the following proposition summarizes the response of the Home economy to the external shocks.

Proposition 13. *Consider the same conditions as in Proposition 11, but let Home monetary policy target $\pi_t = 0$ and let $\varphi = 0$. Then, while the shocks last, the following is true.*

1. *The terms of trade are given by*

$$s_t^L = (1 + \alpha_\pi + ... + \alpha_\pi^t)\gamma_\pi \left[\pi_L^*(1 - \beta\mu) - \kappa y_L^* + \kappa \xi_L^* \right], \tag{66}$$

with $\alpha_\pi = \frac{1+\beta+\kappa}{2\beta} - \frac{1}{2\beta}\sqrt{[1+\beta+\kappa]^2 - 4\beta}$, *and* $\gamma_\pi = 1/(\kappa + 1 + \beta - \beta\alpha_\pi - \beta\mu)$. *One can show that* $0 < \alpha_\pi < 1$ *and* $0 < \gamma_{\pi_H} < \frac{1}{\kappa}$.

2. *Home output is given by*

$$\begin{aligned} y_t^L \;\; = \;\; & \left[(1-\upsilon)[1 + a_m + ... + a_m^t]\kappa\gamma_m + \upsilon[1 + \alpha_\pi + ... + \alpha_\pi^t]\kappa\gamma_\pi - (1-\upsilon) \right] \cdot \xi_L^* \\ & + \left[1 - (1-\upsilon)[1 + \alpha_m + ... + \alpha_m^t]\kappa\gamma_m - \upsilon[1 + \alpha_\pi + ... + \alpha_\pi^t]\kappa\gamma_\pi \right] \cdot y_L^* \\ & + (1-\mu\beta)\upsilon[1 + \alpha_\pi + ... + \alpha_\pi^t]\gamma_\pi\pi_L^*, \end{aligned} \tag{67}$$

with $\alpha_m = \frac{1+\beta+\kappa/\upsilon}{2\beta} - \frac{1}{2\beta}\sqrt{[1+\beta+\kappa/\upsilon]^2 - 4\beta}$ *and* $\gamma_m = 1/(\kappa + \upsilon[1 + \beta - \beta\alpha_m - \beta\mu])$.

3. *Producer price inflation is given by*

$$\pi_{H,t}^L = -\upsilon\alpha_m^t\gamma_m\kappa[\xi_L^* - y_L^*]. \tag{68}$$

4. *By design, Home consumer price inflation is given by* $\pi_t = 0$.

5. *The nominal exchange rate is given by*

$$e_t^L = (1-\upsilon)\left(1 + \alpha_m + ... + \alpha_m^t\right)\gamma_m\kappa[\xi_L^* - y_L^*] - (t+1)\pi_L^*. \tag{69}$$

6. *The interest differential between Home and Foreign is given by*

$$\begin{aligned} r_t^L - r_t^{*,L} \;\; = \;\; & -\mu\pi_L^* \\ & + (1-\upsilon)\gamma_m\kappa[a_m^{t+1} - (1-\mu)] \cdot [\xi_L^* - y_L^*]. \end{aligned} \tag{70}$$

Proof. For all the derivations here assume that $\varphi = 0$. To derive item (1.), use risk sharing condition (44) in the Phillips curve for exports (46). In the resulting relation, use the definition of the terms of trade (47) to substitute for $\pi_{H,t}^*$. Solving the resulting second-order difference equation for s_t (and observing the Markov structure of the shocks give the terms of trade. Next, CPI targeting means $\pi_t = 0$, item (4.). With the definition of CPI inflation from (49), this gives $\Delta e_t = -\pi_t^* - \frac{1-\upsilon}{\upsilon}\pi_{H,t}$. Use this to substitute for Δe_t in (48). This gives $\pi_{H,t} = -\upsilon\Delta[m_t + s_t]$. Use this to substitute for $\pi_{H,t}$ in Phillips curve (45). This gives a second-order difference equation in $m_t + s_t$. Solving this equation for the stable root gives $m_t + s_t = \alpha_m[m_{t-1} + s_{t-1}] + \gamma_m\kappa[\xi_t^* - y_t^*]$. With this, solve for $\pi_{H,t}$. This gives item (3.). Item (2.) follows from using the above results along with the risk sharing condition (44). Item (5.) follows from $\Delta e_t = -\pi_t^* - \frac{1-\upsilon}{\upsilon}\pi_{H,t}$ and the solution for $\pi_{H,t}^L$ in item (3.). Last, item (6.) follows from uncovered interest parity.

□

As before, for the verbal exposition we focus on a fall in foreign demand in isolation, $y_L^* = -1$. If the Home central bank targets domestic consumer price inflation, the terms of trade still deteriorate (as in the previous case). The foreign output shock *does* spills over to Home output, see equation (67). The nominal exchange rate (64) depreciates. Producer prices fall on impact, compare equation (68).

H.4.4 Fixed exchange rates under, DCP/PCP, $e_t = 0$

We now turn to the case of a fixed exchange rate. We consider a monetary policy that stabilizes the exchange rate in all periods— the exchange-rate regime is assumed to be perfectly credible. In the model spelled out above, when the exchange rate is credibly pegged, prices and allocations are identical under DCP and PCP, the reasoning of Proposition 8 applying here, too; namely, $m_t = 0$ under DCP (see the proof to Proposition 14 below).

Proposition 14. *Consider the same conditions as in Proposition 11, but let Home monetary policy target $e_t = 0$. Then, while the shocks last, the following is true.*

1. *The terms of trade are given by*

$$s_t^L = (1 + \alpha_e + ... + \alpha_e^t)\gamma_e\left(\pi_L^*(1 - \beta\mu) + \kappa[1 + \varphi(1 - \upsilon)]\xi_L^* - \kappa(1 + \varphi)y_L^*\right), \tag{71}$$

with $\alpha_e = \frac{1+\beta+\kappa(1+\varphi)}{2\beta} - \frac{1}{2\beta}\sqrt{[1 + \beta + \kappa(1 + \varphi)]^2 - 4\beta}$, and $\gamma_e = 1/(1 + \beta + \kappa(1 + \varphi) - \beta\alpha_e - \beta\mu)$. One can show that $0 < \alpha_e < \alpha_{\pi_H} < 1$ and $0 < \gamma_e\kappa(1 + \varphi) < 1$.
Home output is given by

$$y_t^L = s_t^L + y_L^* - (1 - \upsilon)\xi_L^*. \tag{72}$$

2. *Home producer price inflation is given by*

$$\pi_{H,t}^L = \pi_L^* - \alpha_e^t\gamma_e\left(\pi_L^*(1 - \beta\mu) + \kappa[1 + \varphi(1 - \upsilon)]\xi_L^* - \kappa(1 + \varphi)y_L^*\right). \tag{73}$$

3. *Home consumer price inflation is given by*

$$\pi_t^L = \pi_L^* - (1 - \upsilon)\alpha_e^t s_0^L. \tag{74}$$

4. *The nominal exchange rate is given by $e_t = 0$.*
5. *The interest differential between Home and Foreign is given by*

$$r_t^L - r_t^{*,L} = 0. \tag{75}$$

The same would be true under PCP.

Proof. With fixed exchange rates item (4.) follows by assumption. Use the Phillips curves (45) and (46) to arrive at the expression

$$\pi_{H,t}^* - \pi_{H,t} = \beta E_t\left\{\pi_{H,t+1}^* - \pi_{H,t+1}\right\} - \kappa \cdot m_t.$$

From (48), with fixed exchange rates $\pi_{H,t}^* - \pi_{H,t} = m_t - m_{t-1}$. Substituting this for the differences in the Phillips curves yields a linear homogeneous difference equation in m_t. Hence, $m_t = 0$, whence $\pi_{H,t}^* = \pi_{H,t}$. In Phillips curve (45), substitute for y_t from the risk sharing condition (44) and use $m_t = 0$. Use (47) with $\pi_{H,t} = \pi_{H,t}^*$ to substitute for $\pi_{H,t}$ in the Phillips curve. The result is a difference equation in s_t and Foreign driving terms. Solving this for s_t results in the stable solution (71). Home output, then, follows from the risk sharing condition, giving item (1.) in the proposition. Home producer price inflation then follows from (47) (with $\pi_{H,t} = pi_{H,t}^*$), giving item (2.). Consumer price inflation follows directly from definition (49), using the aforementioned results, item (3.). The interest spread, item (5.) immediately follows from UIP. Last, observe that since $\pi_{H,t} = \pi_{H,t}^*$ and $e_t = 0$, $\pi_{H,t}^* = \pi_{H,t} - \Delta e_t$. The latter equation substitutes for Phillips curve (46) under PCP. Since this is the only difference, and both equations hold, the same derivations apply to PCP as well. □

A fixed exchange rate means that Home monetary policy no longer can provide domestic demand stimulus through the interest rate, equation (75). Buffering a fall in foreign demand, thus, relies entirely on expenditure switching by domestic and foreign households. At the same time, domestic expenditure switching is limited—driven by price adjustment only. Also under a peg, the terms of trade deteriorate in response to a contraction in foreign output, favoring expenditure switching by foreign households. In order to have domestic expenditure switching in Home, producer price inflation in Home has to fall. It does, but only gradually, (73). In addition, home CPI inflation falls (74). Output unambiguously falls, and more strongly so than in the previous scenarios, see equation (72). In sum, an exchange rate peg means that a Foreign fall in demand results in a fall in inflation in Home, and a fall in output in Home. That is, a fixed exchange rate neither achieves stabilization of inflation, nor of output.

H.5 The response in Home under PCP

For comparison, it is useful to inspect, if only briefly, producer currency pricing. This is because PCP underpins the classic notion that flexible exchange rates provide automatic insulation. Under PCP, targeting the producer price level amounts to targeting the natural level of output. So the two regimes are equivalent, as Proposition 15 states. We wish to emphasize that the two parameter restrictions that we keep entertaining are $\eta = 1$ (a unitary trade elasticity), and $\alpha = 0$ (no use of intermediate inputs in production). All other parameters are left unrestricted. The result, thus, is true for any of the shocks that we entertain, any labor supply elasticity, and any Foreign monetary policy.

Proposition 15. *Consider the economy of Section H.1. Let pricing be given by PCP. Let the shocks be as described in Section H.3, with the first period of the shock being period 0. Let Home monetary policy target the natural level of output (or, equivalently, target producer-price stability $\pi_{H,t} = 0$). Then, while the shocks last, the following is true.*

1. *The terms of trade are given by*

$$s_t^L = \frac{1 + \varphi(1 - \upsilon)}{1 + \varphi} \xi_L^* - y_L^*, \tag{76}$$

   that is, the terms of trade are constant.
   Output is given by (53).

2. *Home producer price inflation by $\pi_{H,t} = 0$.*
3. *Home consumer price inflation is given by*

$$\pi_0^L = -\upsilon y_L^* + \upsilon \frac{1 + \varphi(1 - \upsilon)}{1 + \varphi} \xi_L^*, \tag{77}$$

   and

$$\pi_t^L = 0, \; t > 0. \tag{78}$$

4. The nominal exchange rate is given by

$$e_t^L = \frac{1+\varphi(1-\upsilon)}{1+\varphi}\xi_L^* - y_L^* - (t+1)\cdot\pi_L^*. \tag{79}$$

5. The interest differential is given by

$$r_t^L - r_t^{*,L} = -\mu\pi_L^* + (1-\mu)\left(y_L^* - \frac{1+\varphi(1-\nu)}{1+\varphi}\xi_L^*\right). \tag{80}$$

The nominal rate in Home, in turn is given by

$$r_t^L = (1-\mu)\,\upsilon\,\frac{\varphi}{1+\varphi}\xi_L^*.$$

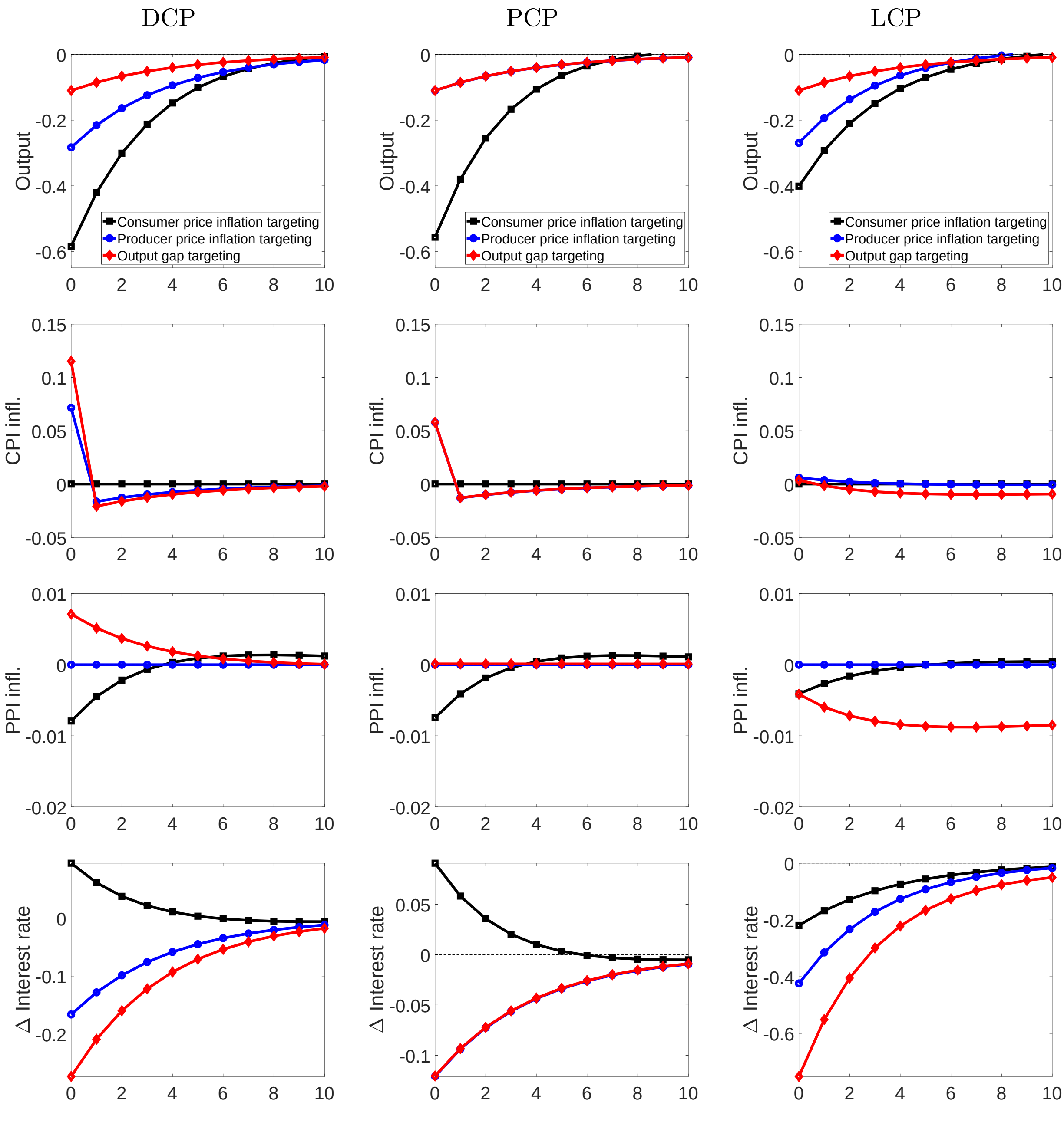
Proof. With $\pi_{H,t} = 0$, the Phillips curve (45) gives that output is equals natural output, and *vice versa*, establishing item (2.). The risk sharing condition (44) can then be used to solve for the terms of trade, (76), establishing item (1.). The evolution of the nominal exchange rate (item (4.)) follows from (47) and the law of one price (that prevails under PCP and translates to $\pi_{H,t}^* = \pi_{H,t} - \Delta e_t$). Given these results, the interest differential (item (5.)) follows from UIP. The nominal rate in Home follows by deriving and substituting r_t^* from (51) using the Markov structure. Consumer price inflation (item (3.)) follows from definition (49). □

As is well known, under PCP exchange rate adjustment lines up expenditure switching with domestic output gap stabilization. In particular, in response to the fall in Foreign demand, when monetary policy in Home targets producer prices, output in Home is perfectly stabilized. And so is consumer price inflation in all but the initial period, see equation (78). Indeed, on impact, the consumer price inflation in Home rises, equation (77), in line with the depreciation of the nominal exchange rate, (79), which – in turn – is brought about by a cut in Home's interest rate in response to a fall in Foreign demand. Producer currency pricing underlies much of the intuition of flexible exchange rates serving as an optimal stabilizer. Proposition 15 shows why. Namely, for all shocks other than the preference shocks (which affect natural output) full insulation of output is achieved without any change (in equilibrium) of Home's interest rate.

I Alternative pricing regimes

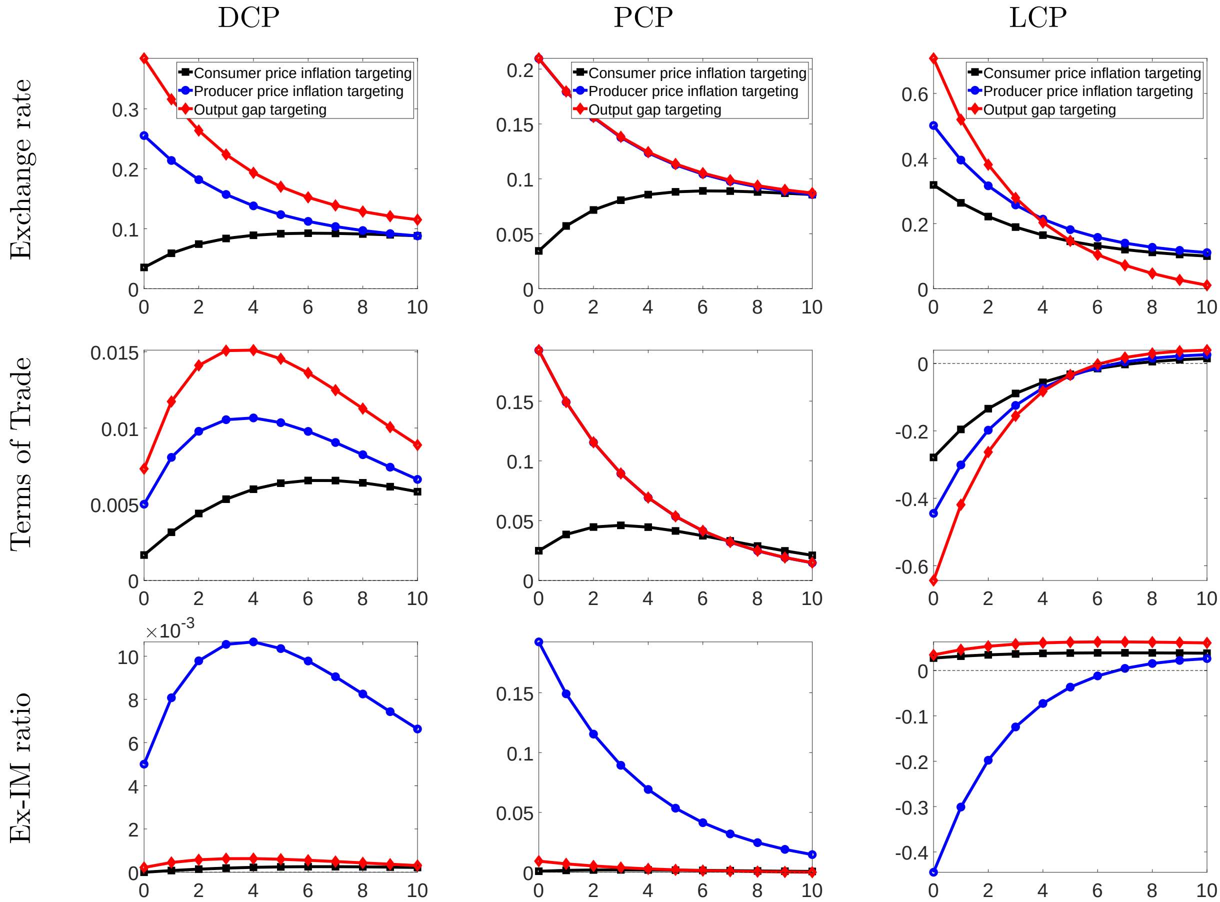
Our baseline model used in the main text features DCP. For comparison, we here present simulation results for two alternative pricing regimes, producer currency pricing (PCP) and local currency pricing (LCP). Figures (I.11) and (I.12) show the responses of the Home economy to a Foreign monetary policy shock. The parameter calibration is identical to the one used in the main text. We focus on the case of a floating exchange rate, since the responses under an exchange rate peg are invariant to the pricing regime.

Figure I.11: Adjustment to Foreign monetary policy shock: Alternative pricing regimes



Note: CPI inflation is consumer-price inflation (not annualized), PPI inflation is producer-price inflation (not annualized). Interest rates are expressed in annualized percentage deviations from steady state. Δ Interest rate denotes the difference between the response of the Home and Foreign interest rate.

Figure I.12: Adjustment to Foreign monetary policy shock: Alternative pricing regimes



The left columns of the two figures show responses under DCP, the case discussed in the main text. The middle columns show responses under PCP. When the Home monetary authority pursues consumer price inflation targeting, the responses of Home variables are very similar to those under DCP. That is, consistent with our empirical results, the drop in output is essentially as large as under a peg. We observe more substantial differences between DCP and PCP, when the Home monetary authority targets producer price inflation. Under PCP, the so-called divine coincidence holds, meaning that stable producer prices are commensurate with a closed output gap. Consequently, the drop in output is much smaller under PCP than under DCP. Under PCP, the depreciation of the Home exchange rate deteriorates the Home terms of trade and leads to expenditure switching of both Home and Foreign households and firms towards goods produced in Home, as shown by the increase in the Home export-import ratio.

The right columns of the two figures show responses under LCP. When prices in both countries are sticky in local currency, consumer price inflation targeting is associated with a somewhat smaller drop in output than under DCP. That's because when Home import prices are sticky in domestic currency, the Home monetary authority lowers the interest rate more aggressively in response to the shock and allows the exchange rate to depreciate without compromising stable consumer prices. Producer price inflation targeting and output gap targeting feature output responses that are similar to those under DCP, though there are more pronounced differences in the responses of some other Home variables.[31] For instance, the interest rate response in Home is more accommodative under LCP than under DCP, and this is reflected in a stronger depreciation of the Home exchange rate. The terms of trade, on the other hand, appreciate under LCP whereas they remain largely unaffected by the foreign shock under DCP.

All in all, our two main results from the main text are robust to assuming either PCP or LCP instead of DCP. First, when the Home monetary authority targets consumer price inflation, then the output response to a Foreign monetary policy shock under a floating exchange rate is similar in magnitude to the one under an exchange rate peg. Second, under a floating exchange rate, lack of output insulation is first and foremost a policy choice. That is, the Home monetary authority can, in principle, choose a monetary policy strategy that insulates Home output from the Foreign monetary policy shock.

[31] Under LCP, we consider the same path of Home natural output as under DCP and PCP, i.e. we consider a flexible-price equilibrium for the Home economy where the law of one price holds for goods imported from the Foreign economy.