

The Exchange Rate Insulation Puzzle

Giancarlo Corsetti, Keith Kuester,
Gernot J. Müller, and Sebastian Schmidt*

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—Preliminary and incomplete—

Abstract

According to classical theory, flexible exchange rates insulate a country from foreign shocks. In this paper we exploit a unique data set and characterize the spillovers of monetary, real, and financial shocks in the euro area on its neighbor countries. As we condition spillovers on the exchange rate regime in the neighbor countries, we document an exchange rate insulation puzzle: flexible exchange rates do not provide any more macroeconomic insulation than exchange rate pegs. We show that this pattern is consistent with the predictions of the workhorse New Keynesian model once we assume—in line with the evidence—that export and import prices are sticky in the euros as the dominant currency. In this environment, monetary authorities face a trade off between internal and external objectives. Central banks that opt for stabilizing domestic inflation keep exchange rate movements moderate and accept considerable economic slack in response to foreign shocks. However, we also show that flexible exchange rates do provide sizable insulation against external shocks whenever monetary policy is constrained by the effective lower bound.

Keywords: External shock, International spillovers, Exchange rate, Insulation,
Monetary Policy, Dominant currency pricing, Effective lower bound

JEL-Codes: F41, F42, E31

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1 Introduction

How much insulation can flexible exchange rates afford the open economy? The classics argue: a lot—because flexible exchange rates permit international relative prices to adjust in response to external shocks (Eichengreen and Sachs, 1985; Friedman, 1953; Meade, 1951). According to this line of reasoning, flexible exchange rates also enhance the effectiveness of monetary policy by aligning its internal and external effects on economic activity. This view has been challenged on the ground that either exports are priced to market (Devereux and Engel, 2003), or that international trade as a whole uses a vehicle currency hindering the adjustment of relative prices (Gopinath et al., 2019). Further skepticism has been fostered by the notion of a US-dominated global financial cycle (Rey, 2013). One possible and benevolent conclusion in light of these complications is that the exchange rate regime is simply not of first-order importance for countercyclical policies. Hence, the choice of the exchange rate regime may reflect other considerations, for instance the need to anchor inflation expectations by an exchange rate peg and, more generally, the need to discipline the macroeconomic policy framework.

In this paper we reconsider the empirical evidence and the theoretical models underpinning this debate. First, we provide novel and systematic evidence for cross-border spillovers of identified monetary, credit and aggregate supply shocks. We look at the euro area as a source of these external shocks, and study how these shocks affect twenty of its neighbors, conditional on their time-varying currency regime. An advantage of focusing on the euro area as a source of shocks is that we so steer away from global (US-based) financial cycle-induced comovement in the data, hence controlling for Rey’s “dilemma.” Our key result is that the spillovers from these shocks are similar where countries pursue a currency peg to the euro, and or operate a float. Second, we analyze theoretically the extent to which spillovers that are similar across currency regimes may reflect a policy choice *by floaters*. To this end, we employ a New Keynesian open-economy model of a small open economy (Galí and Monacelli, 2005) augmented with euro-pricing of trade (Gopinath et al.’s, 2019, modeling of a dominant currency). This model suggests that the empirical findings hinge on *how* floaters float. The theory is in line with the empirical findings provided that floaters engage in domestic inflation targeting. We emphasize that a dominant currency in export pricing rules out the possibility of a “divine coincidence” in policymaking. Rather, monetary authorities face a trade-off between internal and external objectives. To the extent that floaters resolve the trade-off in favor of inflation over output gap stabilization, floaters do not achieve the *domestic and inter-temporal* expenditure switching required for insulation.¹ Further, in equilibrium, inflation targeting mutes (without completely eliminating) exchange rate volatility relative to the case of policies targeting the output gap. The potential to insulate should become apparent when large external shocks bring domestic policy rates to their effective lower bound, causing a deviation from inflation targeting. In these important circumstances, a large upfront adjustment in the nominal exchange rate allows the country to insulate from any deflationary drifts abroad, shielding at least in part economic activity from a foreign downturn. The data bear out this prediction of the theory.

¹The current paper is concerned with interpreting the positive aspects of international transmission. An important growing literature analyzes the implications for optimal monetary policy in a world where pricing in cross-border trade is dominated by one currency (Corsetti and Pesenti, 2005; Corsetti et al., 2020; Egorov and Mukhin, 2020; Gopinath et al., 2019).

In light of the importance of the policy debate on the exchange rate, systematic evidence on spillovers from identified shocks is actually in short supply. We base our study on a data set that includes 4,800 monthly observations of the main macro aggregates for 20 neighboring countries of the euro area. The sample spans the period since the inception of the euro up until the end of 2018. In these data, the exchange rate regime vis-à-vis the euro varies not only across neighboring countries, but also over time. It is therefore important to control for this variation, and exploit it to assess how the exchange-rate regime affects the impact of shocks that originate in the euro area on the economies in the euro-area periphery.

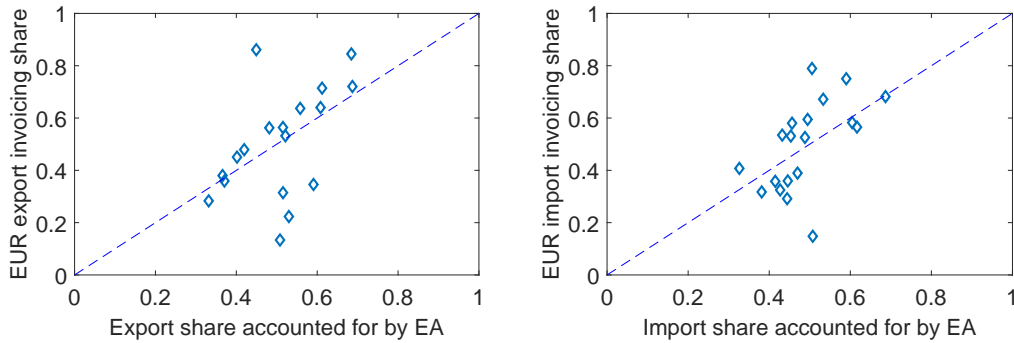
We rely on three different types of shocks: monetary policy shocks as identified by Jarociński and Karadi (2020), a series of credit supply shocks as in Gilchrist and Mojon (2018), and aggregate supply shocks that we identify based on long-run restrictions (Blanchard and Quah, 1989). We pool the data for the neighboring countries, allowing for country fixed effects. Using local projections (Jordá, 2005), we estimate how neighbors respond to euro-area shocks and, in particular, if and how the response depends on the exchange rate regime. Building on Ilzetzki et al., 2019, in our baseline we classify about one third of the observations as floaters and two thirds as pegs.

Our main result is clear cut: irrespectively of the type of shock we consider, the shocks that originate in the euro area generate sizeable spillovers on its neighbor countries. The impact on economic activity is about the same as in the euro area. More importantly still, there is no systematic difference in terms of spillovers across exchange rate regimes. The only noticeable, if unsurprising, difference across all three shock scenarios is that the exchange rate responds much more strongly if neighbor countries operate a flexible exchange rate regime. What may be surprising, however, is that this seems not to matter for the overall spillovers of the euro area shocks on its neighbors: the responses of industrial production, the unemployment rate, consumer prices, and the short-term interest rate are very similar. In sum, it seems as if flexible exchange rates provide the small open economy little insulation when faced with an external shock.²

We build a New Keynesian model to explain those findings and deduce testable implications. In the model, the euro serves as the dominant currency for regional trade, following ample evidence such as Gopinath (2015) or Amiti et al. (2018). Figure 1 further illustrates this evidence. For 19 of the 20 neighboring countries in our sample, the left panel compares their share of exports invoiced in euros (vertical axis) and the shares of exports destined to the euro area (horizontal axis). Each diamond represents a neighboring country. The right panel compares the neighbors' shares of imports invoiced in euros, and the shares of imports from the euro area. Consistent with our modeling choice, in both panels most countries lie close to the 45-degree line. Apart from the focus on dominant-currency pricing (“DCP”), which in our case could be specialized as “euro-currency-pricing” (“ECP”), the model is the small-open-economy limit of a standard two-country New Keynesian model. International financial markets are complete, but goods

²Related, Miranda-Agrippino and Rey (2019) show that contractionary US monetary policy shocks induce sizable spillovers to other countries, including in Europe. They 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 operative for the euro-area spillovers. This does not contradict that US-based global financial cycles are important drivers of international business cycles.

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.

markets are not fully integrated because of home bias. We show analytically and in a calibrated version that the model aligns well with the estimated spillovers of foreign shocks. Then we use that theory to infer the extent to and conditions under which flexible exchange rates can provide insulation to external shocks.

In order to determine the equilibrium allocations in the domestic economy, there are four relevant state variables: foreign output, foreign inflation, and the foreign discount factor (shock), and the lagged terms of trade (in case the country operates a fixed exchange rate regime). We solve a linear approximation of the model in closed form and characterize the solution for alternative monetary policy regimes. Our solutions accommodate a wide range of shocks and policy regimes in the large open economy (the one that is the source of shocks). In particular, they cover the transmission in normal times as much as when the large open economy is constrained by the effective lower bound.

In the model, we show how domestic monetary policy could provide *complete insulation* of economic activity from contractionary external shocks. To achieve this, monetary policy would need to accommodate a large currency depreciation (through a lower nominal rate of interest) and it would need to stimulate domestic demand (through a lower real rate of interest). Output gap stabilization, however, would come at the cost of high producer-price and consumer-price inflation. The reason is that international expenditure switching is limited under DCP. Exports to the euro area being priced in euros, a depreciation does not affect relative prices for euro-area based consumers. Instead, stabilization has to be achieved *domestically*. The exchange-rate depreciation ensures domestic expenditure switching from imports to domestically-produced goods. And the interest-based demand stimulus induces domestic households to increase consumption demand intertemporally. Both of this substitutes for a lack of foreign demand. We point out that, depending on the underlying shock, changes in foreign activity also shift the small-open economy's natural level of output. To the extent that its central bank targets inflation, it will by and large let shocks to the natural rate feed through to domestic economic activity—even under output gap stabilization, the economy will experience a contraction. In sum, under flexible exchange rates the central bank *could* insulate domestic production from foreign shocks. Yet, it may not be optimal to do so. A dominant currency in export pricing rules out the possibility

of a “divine coincidence” in policymaking—monetary authorities face adverse trade off between internal and external objectives, which may be resolved in favor of inflation over output gap stabilization. As a result, the global move toward inflation targeting, in a DCP context, may mask the insulation properties of flexible exchange rates. In this sense, our results generalize the notion of a “fear of floating” which has originally been put forward in the context of emerging economies (Calvo and Reinhart, 2002).

The model suggests a test case for this statement. Namely, to look at variations in the policy regimes within neighboring economies that opt for a float. The theory suggests that these variations should make the insulation properties of flexible exchange rates apparent. In particular, suppose that domestic monetary policy temporarily deviates from targeting inflation, by not responding to external shocks. Then, in response to foreign contractionary shocks output should fall less under flexible exchange rates than under fixed. We take this proposition to the data, focusing on periods when the effective lower bound was binding in our small open economies in the sample. We find the prediction confirmed: in those episodes, floaters’ output was less susceptible to recessionary external shocks than peggers’.

Next, we review the related literature. In Section 2 we present evidence that exchange rate flexibility affords little insulation in the euro-area periphery. Section 3 outlines the model. Section 4 presents the main arguments of the paper for a linearized version of the model. Section 5 provides results from model simulations and the test case with the effective lower bound. A final section concludes.

Further related literature

The current paper reconsiders the insulation property of flexible exchange rates, both empirically and theoretically. Empirically, we provide novel evidence that seconds the view that flexible exchange rates do not necessarily insulate domestic economic activity. Next to those mentioned in the main text, over the years, a number of influential studies have looked into the extent of monetary policy independence 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. Seminal studies on how the exchange rate regime alters transmission of external shocks include (Bayoumi and Eichengreen, 1994) and Broda (2004). Last, Giovanni and Shambaugh (2008) document that foreign interest rates impact domestic output growth adversely if the exchange rate is fixed.

On the theory side, the DCP paradigm follows Gopinath et al., 2019. We focus on an environment in which for the domestic (small-open) economy import prices are sticky in the currency of the foreign producers (euros), as in the more conventional producer currency-pricing framework of Galí and Monacelli (2005). Earlier important contributions departed from the assumption of “producer currency pricing” and considered “local currency pricing,” instead, Engel (2011). For an early New Keynesian model with limited exchange rate pass-through see also Monacelli (2005). In our setting, local currency pricing applies to domestic exporters, who price in euros, the export market’s currency.

Our paper highlights that, under exchange-rate flexibility, insulating domestic output from

shocks through a monetary expansion would require the monetary authority to tolerate a large relative price adjustment of domestically-produced in terms of imported goods in the domestic market—not corresponding to any gains in price competitiveness in world markets. This is reminiscent of the classical adjustment in models featuring non-trade goods and a homogenous traded good (with a price set exogenously in international markets), recently reconsidered by Schmitt-Grohé and Uribe (2016). In our model, as in theirs, macroeconomic adjustment to negative external shocks can imply deeper recessions under fixed than under flexible exchange rates. We add to this the observation that full insulation does require extra stimulus of domestic demand.

There is an interesting link also to a recent influential paper by (Guerrieri et al., 2020). These authors focus on a two-sector closed economy, illustrating that adverse spillovers from (supply) shocks to one sector to (demand in) other sectors depend crucially on the flexibility of prices and/or monetary policy. This is a framework close to our two-country model with fixed exchange rates (or flexible exchange rates combined with inflation targeting): a similar reasoning applies to the transmission of shocks to the open economy (see also Corsetti et al., 2008, 2010).

Last, we wish to be clear that our analysis is mostly positive in nature, although we draw extensively on the literature that has assessed the implications of DCP for optimal monetary policy (Corsetti et al., 2020; Egorov and Mukhin, 2020; Gopinath et al., 2019).

2 Evidence from Europe

In this section we establish new evidence on international spillovers across Europe and, in particular, on the extent to which these spillovers depend on the exchange-rate regime in the country which is exposed to an external shock. In our analysis the euro area is the country of origin, that is, the country where the shock originates, while the neighbor countries of the euro area are the “receiving” economies. As we study the effect of three distinct shocks, we build on previous work. First, we consider euro area monetary policy shocks as identified by Jarociński and Karadi (2020). Second, we identify credit supply shocks following Gilchrist and Mojon (2018). Last, we use the approach of (Blanchard and Quah, 1989) to identify euro-area supply shocks. In the first two instances, we perform the analysis at monthly frequency, while the supply shocks are identified at quarterly frequency.

Our sample covers 20 years of data and consists of monthly and quarterly observations for the period 1999–2018.³

Our empirical strategy relies on the variation of exchange rate policies in the neighbor countries of the euro area—both across time and space. Some of countries maintain a fixed exchange vis-à-vis the euro for the entire sample period (e.g., Denmark), others operate a flexible exchange rate regime (e.g., Norway). Most interestingly perhaps, there are several countries which have joined the euro area within our sample period (e.g., Greece or Latvia). Our empirical strategy is designed to exploit this variation in order to identify the role of the exchange rate regime for the transmission of external shocks. We first describe our data set. Afterwards we outline the

³There are some limitations however. Eurostat provides data for industrial production and unemployment for most countries in our sample only since 2000M1. In case we lack observations of an outcome variable, we report results for the subsample for which observations are available, we discuss details below.

construction of our shock measures and our econometric specification. In a last subsection we present results.

2.1 Sample and data

We obtain most time series directly from Eurostat which account for the changing composition of the euro area.⁴ In order to specify our sample of neighbor countries we start from the 28 countries of the European Union at the end of our sample period. Hence, the UK is one of the neighbor countries because it left the EU in early 2020 only. We add to the EU countries the countries of the European Free Trade Association (EFTA) except for Lichtenstein: Iceland, Norway and Switzerland. At the time of its inception 11 countries had joined the euro. Once we subtract these 11, we are left with 20 neighbor countries: Bulgaria (BG), Croatia (HR), Cyprus (CY), Czechia (CZ), Denmark (DK), Estonia (EE), Greece (EL), Hungary (HU), Iceland (IS), Latvia (LV), Lithuania (LT), Malta (MT), Norway (NO), Poland (PL), Romania (RO), Slovakia (SK), Slovenia (SI), Sweden (SE), Switzerland (CH) and the United Kingdom (UK).⁵ Some of these countries joined the euro area during our sample period. We assume that they are small enough such that do not contribute in a meaningful way to the euro area shock measure.⁶

We classify exchange rate regimes as “pegs” and “floaters” on the basis of Ilzetzki et al. (2019) to whom we refer as IRR for short.⁷ IRR rely on an algorithm to classify the de facto exchange rate regime and to identify the anchor country. The choice of the anchor country is less of an issue for our sample. Countries either limit exchange fluctuations vis-à-vis the euro or not at all.⁸ In case there is an official exchange rate arrangement, IRR verify whether an exchange rate follows the pre-announced rule. Otherwise countries are classified on the basis of actual exchange rate volatility. For instance, to qualify as a peg, the exchange rate may change by no more than 1% in absolute value for 80% of consecutive monthly observations (see IRR for further details).

In our analysis below, we condition our estimate of spillovers on whether the exchange rate regime is flexible or not on the basis of a dummy-variable approach. Towards this end, we further narrow down the six coarse categories of IRR to three. Specifically, in our baseline we use a deliberately *narrow* definition of a floating exchange rate. We classify as floaters all countries with an exchange rate policy that permits exchange-rate fluctuations of 2 percent or more. In an alternative specification we extend our classification of floaters to include countries with intermediate regimes (Pre announced crawling peg, Pre announced crawling band that is narrower than or equal to $\pm 2\%$, De facto crawling peg, De facto crawling band that

⁴EA11: 1999–2000, EA12: 2000–2006, EA13: 2007, EA15: 2008, EA16: 2009–2010, EA17: 2011–2013, EA18:2014–2015, EA19: since 2015. An exception is the series for industrial production. In this case we use EA19.

⁵We also rely on Eurostat as a data source for those countries. An exception is the time series for the CPI in Switzerland (OECD) and the time series for unemployment for Switzerland (IMF). For some countries our data does not cover the entire sample period for all variables. We drop those countries from the sample once we study the response of specific variables.

⁶Below we check whether our results change once we drop countries which have joined the euro in our sample period in order to address the concerns that these countries, even though relatively small, had a significant impact on monetary policy in euro area.

⁷Their data runs up to 2016M9 or 2016M10. For the remaining observations we leave the classification unchanged. We maintain their classification except for Czechia for reasons given below.

⁸An exception is Lithuania which maintained a soft peg vis-à-vis the dollar up to January 2002.

1999M01	2	1	1	1	1	3	1	3	3	3	3	2	3	3	3	3	1	1	2	2
1999M02	2	1	1	1	1	3	1	3	3	3	3	2	2	3	3	3	1	1	2	2
2000M11	2	1	1	1	1	3	1	3	3	3	3	2	2	3	3	3	1	1	3	2
2001M01	2	1	1	1	1	3	1	3	2	3	3	2	2	3	3	3	1	0	3	2
2001M09	2	1	1	1	1	2	1	3	2	3	3	1	2	3	3	3	1	0	3	2
2005M01	2	1	1	1	1	3	1	3	2	3	3	1	2	3	3	3	1	0	3	2
2006M07	2	1	1	1	1	3	1	3	2	3	2	1	2	3	3	3	1	0	3	2
2007M01	2	1	1	1	1	3	1	3	2	3	2	0	2	3	3	3	1	0	3	2
2008M01	2	1	1	1	0	3	1	3	0	3	2	0	2	3	3	3	1	0	3	2
2008M09	2	1	1	1	0	3	1	3	0	3	2	0	3	3	3	3	1	0	3	2
2009M01	2	1	1	1	0	3	1	3	0	3	2	0	3	3	3	3	1	0	3	1
2009M04	2	1	1	1	0	3	1	2	0	3	2	0	3	3	3	3	1	0	3	0
2009M07	2	1	1	1	0	1	1	2	0	3	2	0	3	3	3	3	1	0	3	0
2011M01	2	1	0	1	0	1	1	2	0	3	2	0	3	3	3	3	1	0	3	0
2011M09	2	1	0	1	0	1	1	2	0	3	2	0	3	3	3	1	1	0	3	0
2012M03	2	1	0	1	0	1	1	2	0	2	2	0	3	3	3	1	1	0	3	0
2012M12	2	1	0	1	0	1	1	2	0	2	1	0	3	3	3	1	1	0	3	0
2014M01	2	1	0	1	0	0	1	2	0	2	1	0	3	3	3	1	1	0	3	0
2015M02	2	1	0	1	0	0	0	2	0	2	1	0	3	3	3	3	1	0	3	0
2017M04	3	1	0	1	0	0	0	2	0	2	1	0	3	3	3	3	1	0	3	0
	Czechia	Denmark	Estonia	Croatia	Cyprus	Latvia	Lithuania	Hungary	Malta	Poland	Romania	Slovenia	Sweden	United Kingdom	Norway	Switzerland	Bulgaria	Greece	Iceland	Slovakia

Table 1: Exchange rate regimes 1999–2018. 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 refer to more flexible exchange rates. “3” indicates flexible exchange rates. “2” corresponds to “Pre announced crawling peg”, “Pre announced crawling band that is narrower than or equal to $\pm 2\%$ ”, “De factor crawling peg”, or “De facto crawling band that is narrower than or equal to $\pm 2\%$ ”, “1” is “Pre announced peg or currency board arrangement”, “Pre announced horizontal band that is narrower than or equal to $\pm 2\%$ ”, and “De facto peg”; “0” corresponds to membership in the euro area. Sources: National central banks, ECB and Ilzetzki et al. (2019).

is narrower than or equal to $\pm 2\%$). In the baseline these countries are classified as pegs, alongside those countries without a separate legal tender, with a pre announced peg or currency board arrangement, a pre-announced horizontal band that is narrower than or equal to $\pm 2\%$, and a de facto peg.

Table 1 provides an overview of the exchange rate regimes in our sample. Each column refers to one country 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 darkly shaded cells or, equivalently, the number 3 indicates a flexible exchange rate regime. The brighter a cell, the less flexible the exchange rate regimes: regular blue cells (“2”) refer to soft pegs (treated as pegs in the baseline), light blue cells (“1”) instead refer to hard pegs. In the baseline, they are treated

in the same way as countries that actually joined the euro area, indicated by the white cells (“zeros”) in the table.

During our sample period 1999–2018 the euro became legal tender in eight countries: in Greece (2001), in Slovenia (2007), in Cyprus and Malta (2008), in Slovakia (2009), in Estonia (2011), in Latvia (2014), and in Lithuania (2015). Under the Maastricht treaty’s convergence criteria, the adoption of the euro requires membership of in the European Exchange Rate Mechanism (ERM) II for at least to years. This rules out exchange rate fluctuations larger than 15% around an agreed exchange rate between the euro and the country’s currency. This is a fairly wide range and according to our classification membership in ERM II would not qualify as a peg. Still, with the exception of Malta, the countries in our sample operated a de facto peg for a significant period prior to joining the euro.

Croatia and Denmark have pegged the their currency to the euro during the entire sample period, but did not join the euro. Bulgaria pegs its currency to the euro through a currency board. Hungary and Poland have limited the exchange rate flexibility vis-à-vis the euro. Hungary de facto operates a crawling band that is narrower than or equal to $\pm 2\%$ since April 2009 as does Poland since March 2012. Prior to that their exchange rate was fully flexible according to our classification. Monetary policy in Czechia pursues an inflation target, but limited exchange rate fluctuations to 2 percent around a crawling band. This changed in April 2017 when the Czech National Bank announced to lift a floor on the euro-koruna exchange rate. Romania operated a managed float from April 2001–June 2006, afterwards a crawling band up until November 2012 and a de facto peg since then.

Sweden limited its exchange rate flexibility somewhat during the period between 1999M2 and 2008M8. Since then the exchange rate is fully flexible. Hence, except for that period, it is part of the group of floaters just like in the UK, Norway, Iceland and Switzerland. In Switzerland the exchange-rate flexibility was limited during the period between 2011M9 and 2014M01. During that period it is not part of the floaters in our baseline specification. In our baseline there are 1572 observations for floaters out of a total of 4800 monthly observations.

2.2 Estimating the impact of euro-area shocks

We estimate the effects of shocks that originate in the euro area—both on euro-area variables and the spillover effects in the neighbor countries. We pursue a two-step approach. In the first step we obtain the shock measure, mostly by relying on earlier work by other authors.

We consider three distinct euro area shocks. First, we use a shock series of monetary policy shocks provided by Jarociński and Karadi (2020). They combine a high-frequency approach to identification with sign restrictions. Specifically, they consider monetary surprises around policy announcements and disentangle monetary policy shocks from central bank information shocks on the basis of the response of the stock market. Monetary policy shocks are shocks which generate a positive interest rate response and a negative response of the stock market.

Second, we also consider credit supply shocks that we identify on the basis of 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), the EONIA in a VAR model.⁹ We identify the credit shock recursively, assuming that the variables in the VAR are pre-determined relative to the credit spread. Gilchrist and Mojon (2018) consider alternative approaches, namely a FAVAR and identification by means of an external instrument but report results that 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 credit supply shocks covers the period 1999M7–2018M12.

Third, we follow the classic approach of Blanchard and Quah (1989) and use a long-run restriction to identify supply shocks. Specifically, we estimate a bivariate VAR model featuring quarterly output growth and the unemployment rate and impose the identification restriction that only supply shock may have permanent output effects.¹⁰

In the second step we estimate the effect of these shocks on the variables of interest. For this we propose we rely on local projections (Jordá, 2005).¹¹ Formally, given a time-series of one of the three shocks identified in the first step, ε_t , we estimate the following model on euro-area data:

$$x_{t+h} = \alpha_h + \psi_h \varepsilon_t + \gamma Z_{i,t} + u_{t+h}. \quad (1)$$

Here x_{t+h} is an outcome variable in period h after impact, e.g. industrial production or consumer prices. Z_t is a set of control variables (thus far containing lags of the dependent variable and the shock). $\alpha_{i,h}$ is a constant for horizon h , and $u_{i,t+h}$ is an iid error term with zero mean.¹² The estimated coefficients ψ_h provide a direct measure for the impulse response at month h after impact.

Eventually we are interested in the spillovers of euro-area shocks on its neighbor countries and here, in particular, in whether flexible exchange rates provide some insulation against these spillovers. Our empirical framework is particularly suited to assess this issue since it can accommodate interaction effects in a straightforward way. Formally, use $i = 1 \dots 20$ to index the neighbor countries of the euro area and define a time-varying indicator variable, $I_{i,t}$ which takes on a value of unity whenever country i operates a flexible exchange rate regime vis-à-vis the euro, and zero otherwise. We estimate the following model:

$$x_{i,t+h} = \alpha_{i,h} + I_{i,t-1} \psi_{f,h} \varepsilon_t + (1 - I_{i,t-1}) \psi_{p,h} \varepsilon_t + \gamma Z_{i,t} + u_{i,t+h}. \quad (2)$$

Here, as before, $x_{i,t+h}$ is an outcome variable in country i and $Z_{i,t}$ is a set of control variables. We condition on the value of the indicator variable in the period prior to the shock in order to allow for the possibility that the exchange-rate regime may be adjusted in response to shocks. Given the definition of $I_{i,t}$, $\psi_{f,h}$ provides a direct estimate for the impulse response of floaters at month h after impact. Likewise, $\psi_{p,h}$ is the response in countries with a less than fully flexible exchange rate.

⁹We 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>.

¹⁰We use four lags and observations for the period 1995Q2–2019Q4. In our analysis below we use the supply shocks for the period 1999Q1–2018Q4.

¹¹Plagborg-Møller and Wolf (2019) provide a detailed analysis of how they relate to more traditional VAR estimators.

¹²The estimated shocks ε_t are generated regressors in the local projection. Pagan (1984) shows that the standard errors on the generated regressors are asymptotically valid under the null hypothesis that the coefficient is zero; see also the discussion in Coibion and Gorodnichenko (2015).

2.3 Results

In what follows we present the results for the euro area and the neighbors country jointly. We focus, in turn, on the impulse responses to monetary policy, credit shocks, and supply shocks—all originating the euro area and, potentially, affecting the neighbor countries, too. Figure 2 shows the adjustment to a contractionary monetary policy shock. In each panel the horizontal axis measures time in months, the vertical axis measures the deviation of a variable from its pre-shock level. Here, and in what follows, the shaded area indicates 68 and 90 percent confidence intervals, while the solid line corresponds to the point estimate.

In the left column, we show the response of euro-area variables, based on the estimated model (1). In the middle column we show the response for countries that operate a float, and in right column the responses for countries with less than fully flexible exchange rates. In this case, the responses correspond to the estimates of $\psi_{f,h}$ and $\psi_{p,h}$ in model (2), respectively. As indicators for real activity we show the response of industrial production and the unemployment rate in the top rows of the figure. Our key finding is rather clear cut: a monetary contraction in the euro area slows down economic activity not only in the euro area, but also in its neighbor countries—the spillovers are sizeable. In fact, the contraction seems even more pronounced in the neighbor countries than in the euro area itself. More remarkably, still, there is now evidence that flexible exchange insulate economic activity in the neighbor counties. The contraction for countries with a flexible exchange rate is not weaker than in those countries where the exchange rate is not fully flexible.

The responses of the price index (harmonized consumer price index, HICP) are shown in the third row. Prices decline somewhat in the euro area, but also in this case we observe that the response in the neighbor countries is of the same sign as in the euro area and certainly not weaker. It is noteworthy that the response for floaters is less tightly estimated. In this sense, prices appear somewhat more stable in case the exchange rate is flexible compared to the case of an exchange rate peg.

We show interest rate responses in the fourth row. Recall that we study the effect of a monetary contraction, as identified by Jarociński and Karadi (2020). In the figure we report the response of the interest rate on a one year government bond. It does increase on impact, but only marginally so. Jarociński and Karadi (2020) report similar results. For the neighbor countries we report the difference of the short-term interest rate relative to short rate in the euro area. This allows us to capture the relative monetary stance. Once more, we observe a very similar adjustment patterns across both groups of neighbor countries: interest rates increase relative to the interest rate in the euro area, both with flexibly exchange rates and without.

In the last row of the figure, we display the response of the exchange rate. We define the exchange rate as the price of foreign currency expressed in terms of domestic currency. The effective exchange rate of the euro, shown in the left-most column, is appreciating on impact and keeps on appreciating for an extended time period. For the neighbors we focus in each instance on the bilateral euro exchange rate. We find that in neighbors with a flexible exchange rate, the currency depreciates strongly against the euro. As expected, the effect is much weaker in countries with out fully exchange rate flexibility (right column).

Next we turn the effects of a credit shock originating in the euro area and show results in Figure

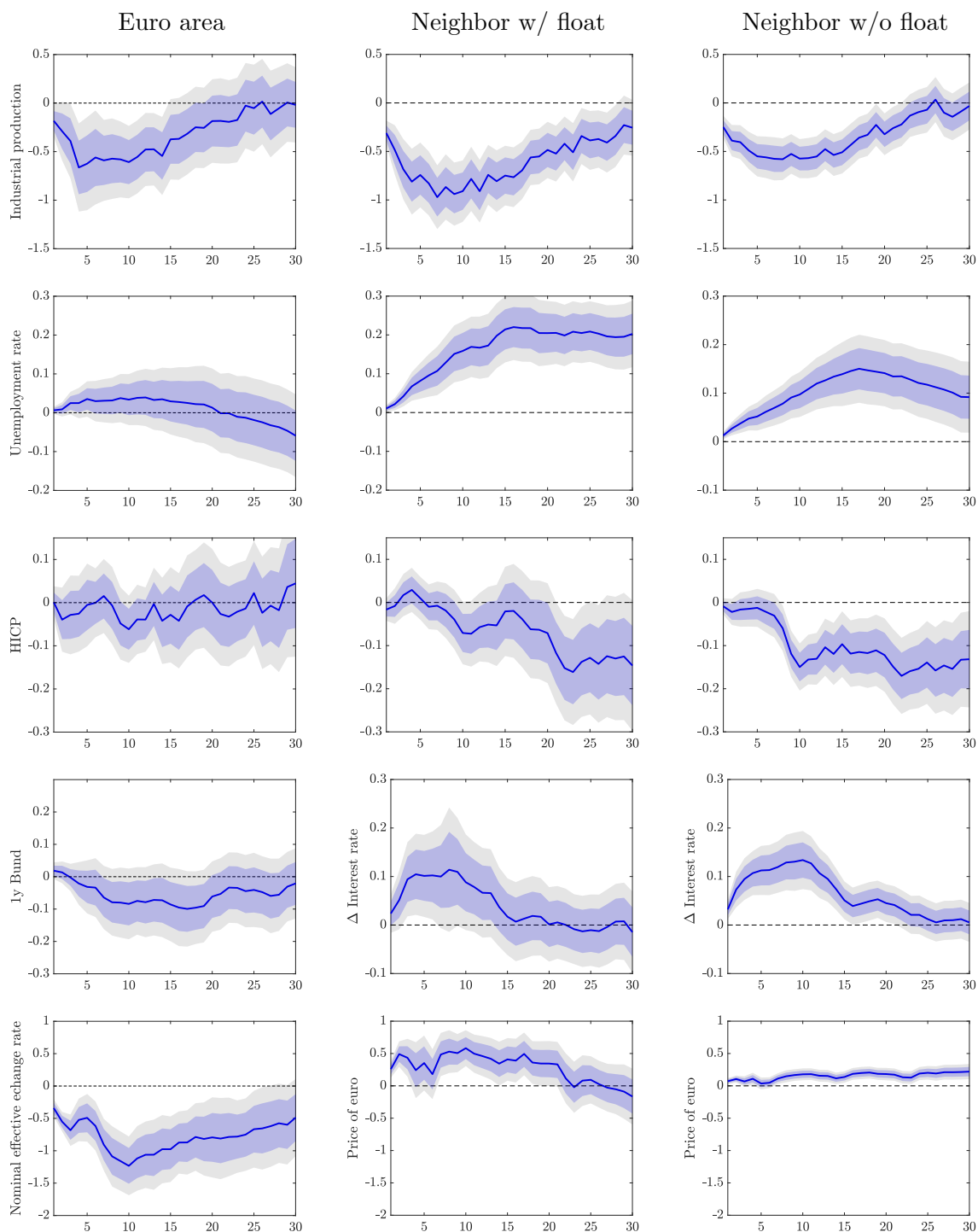


Figure 2: Impulse responses to monetary policy shock in the euro area. Identification: Jarociński and Karadi (2020). Left column response of Euro area variable, middle column: response in neighbor countries with flexible exchange rate, narrowly defined (category 3 in Table 1 above), right column: response in neighbor countries w/o flexible exchange rate. 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.

3. The figure is organized as in the same way as Figure 2 above. In particular, we show the response of industrial production and unemployment in the top rows. We find, just like in case

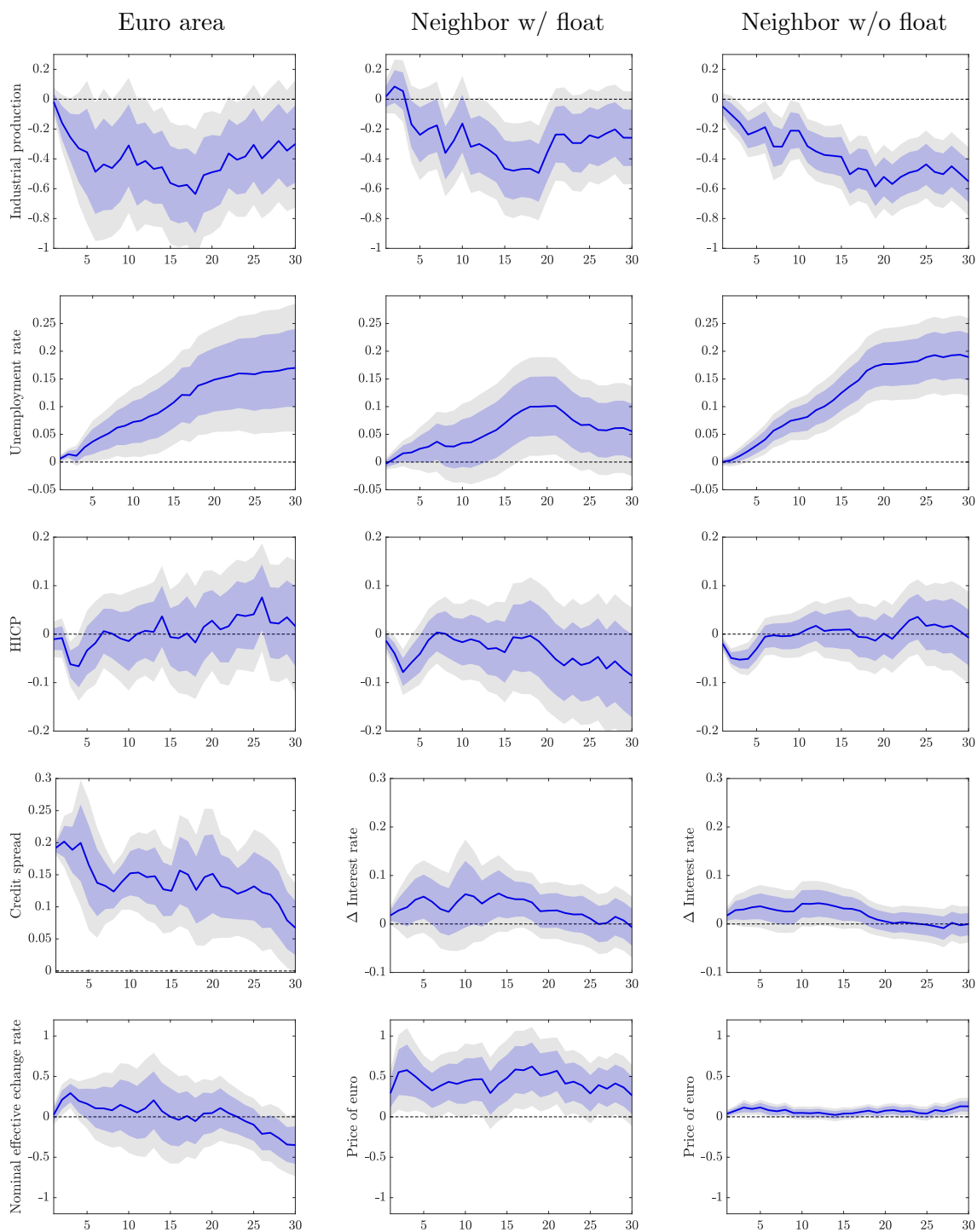


Figure 3: Impulse responses to credit-supply shock in the euro area. Identification: recursive VAR estimated using time series of bank credit spread (Gilchrist and Mojon, 2018). Left column response of Euro area variable, middle column: response in neighbor countries with flexible exchange rate, narrowly defined (category 3 in Table 1 above), right column: response in neighbor countries w/o flexible exchange rate. 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.

of a monetary policy shock, that the contractionary effect of a credit shock is not limited to the euro area. Its neighbors are affected in basically the same way—although we note that the response is somewhat muted in the case of flexible exchange rates. That said, we stress that flexible exchange rates offer not much insulation against a credit shock that originates in the euro area.

We find that prices, shown in the third row, do not respond much, neither in the euro area, nor in the neighbor countries. For their sample, which runs up to October 2013, Gilchrist and Mojon (2018) find that inflation declines moderately in the euro area in response to a credit shock. The credit shock raises the credit spread persistently. This is shown in the fourth row of the figure (left panel). Just like for the monetary policy shock discussed above, we find again a positive interest rate differential in the neighbor countries in response to the euro area credit shock—both, in case the exchange rate flexible and in case it is not.

Lastly, we show the response of the exchange in rate (bottom row). We find that the euro depreciates (increases) against the currencies of the major trading partners of the euro area (effective exchange rate). The neighbor countries with a flexible exchange rate, in turn, see their currency depreciate against the euro, an effect we do not observe in the neighbor countries with limited exchange rate flexibility.

Finally, we turn to effects of supply shocks, identified via long-run restrictions as in Blanchard and Quah (1989). Note that in this case we use quarterly data since we restrict output growth in order to achieve identification and it is only available at quarterly frequency. Figure 4 shows the results. It is organized in the same way as the two previous figures. We show the responses for euro-area variables as well as for the neighbor countries.

The top row shows the response of output. We find our main result for the other shocks confirmed: there are sizeable output spillovers and, importantly, these spillovers are in the same ballpark independently of whether a country operates a flexible exchange regime or not. We show the responses of prices in the second row. We observe that the impact response of prices is negative, but the response is very much muted. Instead the supply shock in the euro area pushes up prices in the neighbor countries rather strongly, and more so in case the exchange rate flexible.

Lastly, we observe that the supply shock depreciates the euro on impact, a result consistent with earlier work on how the real exchange rate responds to technology shocks (Corsetti et al., 2008; Enders et al., 2011). Instead the exchange rate of the neighbor countries appreciates against the euro. Unsurprisingly, this effect is again considerably more pronounced in case there is exchange rate flexibility.

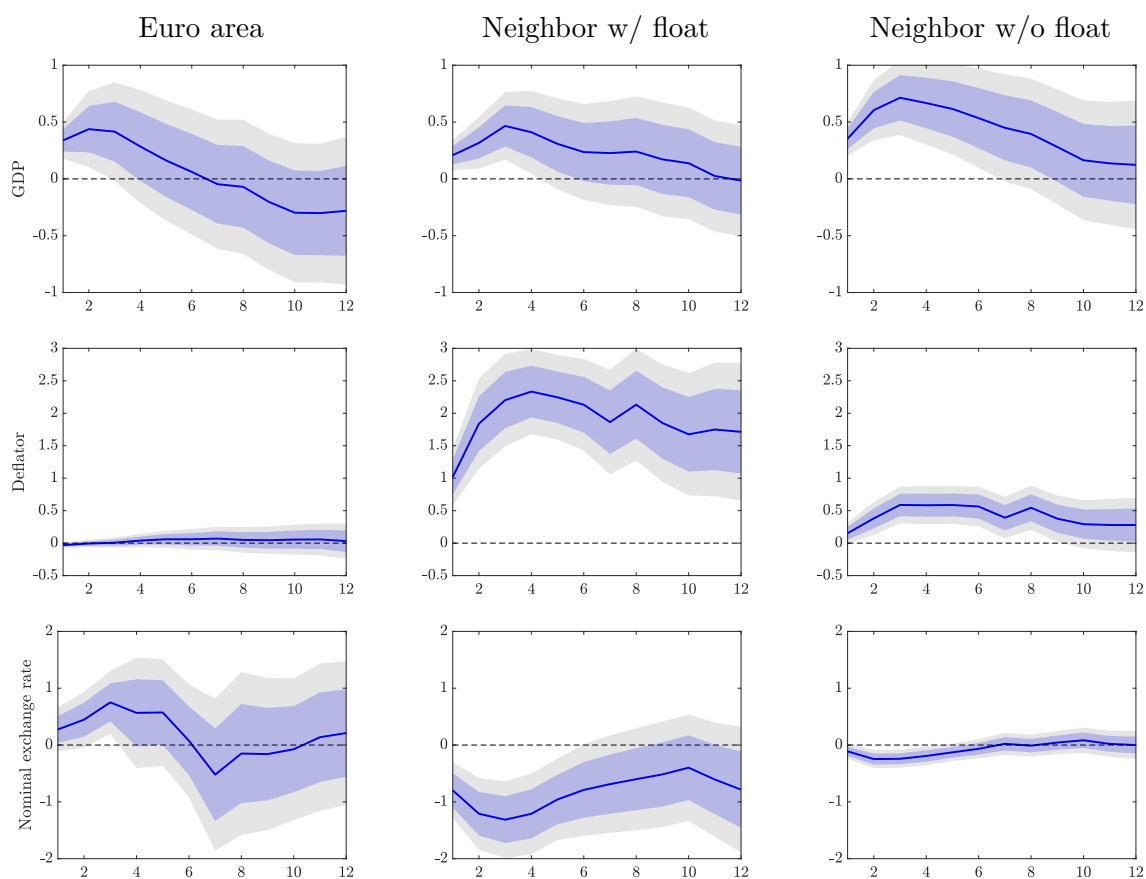


Figure 4: Impulse responses to supply shock in the euro area. Quarterly observations. Identification: VAR with long-run restrictions as in (Blanchard and Quah, 1989). Left column response of Euro area variable, middle column: response in neighbor countries with flexible exchange rate, narrowly defined (category 3 in Table 1 above), right column: response in neighbor countries w/o flexible exchange rate. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in quarters. Vertical axis measure deviation in percent/percentage points.

3 A New Keynesian two-country model

We consider a tractable, if stylized open economy model. There are two countries, Home and Foreign, that have identical structures. They differ, though, in terms of size, and monetary policies, and 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 ($n \rightarrow 0$). 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.¹³

The structure of the model starts from earlier work of ours, on which we draw in our exposition (Corsetti et al., 2017). The novel aspect of the current paper is that we consider the possibility that prices of domestic exporters are sticky in the currency of the large foreign country, the “dominant currency.” In this regard our specification follows Gopinath et al. (2019). We also abstract from the fiscal sector. The main building blocks of the model are standard. In the following, we thus provide a compact exposition of the model while focusing on Home. When necessary, we refer to Foreign variables by means of an asterisk.

3.1 Households

There is a representative household in each country. 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

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

$\beta \in (0, 1)$ 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.

In our baseline, the household trades a complete set of state-contingent securities with the rest of the world. Letting \mathcal{X}_{t+1} denote the payoff in units of domestic currency in period $t+1$ of the portfolio held at the end of period t , the budget constraint of the household 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 (C_t^*) is defined as a Dixit-Stiglitz aggregator of Home and

¹³This explicit consideration of Foreign sets apart our exercise from the typical treatment of a small open economy. Apart from this, Home is identical to the small open economy of Galí and Monacelli (2005). For tractability we restrict preferences to log-utility.

Foreign bundles of goods

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

$$C_t^* = \left[(nv)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + (1 - nv)^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}. \quad (5)$$

Here $C_{H,t}$ ($C_{F,t}$) is the Home-produced (Foreign-produced) bundle consumed in Home, $\eta > 0$ is the elasticity of substitution between the two bundles, and $v \in [0, 1]$ measures the home bias in consumption.¹⁴

The consumer price indexes in Home and Foreign are given by

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

$$P_t^* = \left[nv P_{H,t}^{1-\eta} + (1 - nv) P_{F,t}^{1-\eta} \right]^{\frac{1}{1-\eta}}, \quad (7)$$

where $P_{H,t}$ ($P_{F,t}^*$) is the price of the bundle of domestic goods and $P_{F,t}$ ($P_{H,t}^*$) is the price of the bundle of imported goods.

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

$$C_{H,t} = \left[\left(\frac{1}{n} \right)^{\frac{1}{\epsilon}} \int_0^n C_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \quad C_{F,t} = \left[\left(\frac{1}{1-n} \right)^{\frac{1}{\epsilon}} \int_n^1 C_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}}, \quad (8)$$

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.

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

$$P_{H,t} = \left[\frac{1}{n} \int_0^n P_{H,t}(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}, \quad P_{F,t} = \left[\frac{1}{1-n} \int_n^1 P_{F,t}(j)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}}. \quad (9)$$

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, marks a nominal depreciation from Home's perspective. The law of one price does not necessarily hold, as Home's export prices may be sticky in foreign currency. We define M_t as the resulting law-of-one-price gap for domestic goods such that:

$$M_t P_{H,t} = \mathcal{E}_t P_{H,t}^*. \quad (10)$$

¹⁴This specification of home bias follows Sutherland (2005) and De Paoli (2009). With $v = 1$, 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 v implies that the fraction of domestically produced goods in final goods exceeds the share of domestic production in the world economy. If $v = 0$, there is full home bias and no trade across countries.

The reverse is not true, since we consider a “dominant currency paradigm” and assume that the dominant currency is Foreign’s currency. For imported goods, the law of one price holds.

$$P_{F,t} = \mathcal{E}_t P_{F,t}^*. \quad (11)$$

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 (“dollars”):

$$S_t = \frac{P_{F,t}^*}{P_{H,t}^*} = \frac{\mathcal{E}_t P_{F,t}^*}{M_t P_{H,t}} \quad (12)$$

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. Domestic demand for a generic intermediate good produced in Home is given by

$$Y_t^D(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\epsilon} \left[\left(\frac{P_{H,t}}{P_t} \right)^{-\eta} (1 - (1 - n)v) C_t \right]. \quad (13)$$

Demand from the rest of the world is given by

$$Y_t^{D*}(j) = \left(\frac{P_{H,t}^*(j)}{P_{H,t}^*} \right)^{-\epsilon} \left[\left(\frac{P_{H,t}^*}{P_t^*} \right)^{-\eta} (1 - n)v C_t^* \right]. \quad (14)$$

3.2 Firms

Intermediate goods producers sell under monopolistic competition and use a production function that is linear in labor:

$$Y_t(j) = Z_t H_t(j), \quad (15)$$

where $H_t(j)$ denotes labor services employed by firm $j \in [0, n]$ in period t and Z_t is a stationary productivity shock.

We assume that firms have to pay a cost when adjusting goods prices. Regarding the pricing of exports, we consider two alternative assumptions. In the first scenario, we assume producer currency pricing (PCP): export prices are given by $P_{H,t}(j)^* = P_{H,t}(j)/\mathcal{E}_t$, that is the law of one price holds for exports and $M_t = 1$. Hence, in this case, for a given value of $P_{H,t}(j)$ the export price is determined by the exchange rate. Alternatively, there is a dominant currency paradigm. In this case, we assume that exports are priced and invoiced in foreign currency. Imports to Home are always priced in the dominant currency.

3.2.1 Producer currency pricing

Under producer-currency pricing, firm j sets $P_{H,t}(j)$ so as to maximize the expected discounted value of net profits:

$$\begin{aligned} \max_{\{P_{H,t+k}(j)\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \rho_{t,t+k} & \left\{ (1 + \nu) P_{H,t+k}(j) [Y_{t+k}^D(j) + Y_{t+k}^{D*}(j)] - \frac{W_{t+k}}{Z_{t+k}} [Y_{t+k}^D(j) + Y_{t+k}^{D*}(j)] \right. \\ & - \frac{\omega}{2} \left[(1 - (1 - n)\nu) \left(\frac{P_{H,t+k}(j)}{P_{H,t+k-1}(j)} - 1 \right)^2 P_{H,t+k} Y_{t+k}^D \right. \\ & \left. \left. + (1 - n)\nu \left(\frac{P_{H,t+k}(j)^*}{P_{H,t+k-1}(j)^*} - 1 \right)^2 P_{H,t+k} Y_{t+k}^{D*} \right] \right\} \\ \text{s.t. } & (13), (14), \end{aligned}$$

where Y_{t+k}^D marks aggregate consumption demand from Home and Y_{t+k}^{D*} from Foreign.

3.2.2 Dominant-currency pricing

Under dominant currency pricing, Home producers solve separate price-setting problems for the domestic and the foreign market. For the home market

$$\begin{aligned} \max_{\{P_{H,t+k}(j)\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \rho_{t,t+k} & \left\{ (1 + \nu) P_{H,t+k}(j) Y_{t+k}^D(j) - \frac{W_{t+k}}{Z_{t+k}} Y_{t+k}^D(j) \right. \\ & \left. - \frac{\omega}{2} \left[(1 - (1 - n)\nu) \left(\frac{P_{H,t+k}(j)}{P_{H,t+k-1}(j)} - 1 \right)^2 P_{H,t+k} Y_{t+k}^D \right] \right\} \\ \text{s.t. } & (13). \end{aligned}$$

The price in the foreign market is determined through

$$\begin{aligned} \max_{\{P_{H,t+k}^*(j)\}_{k=0}^{\infty}} \sum_{k=0}^{\infty} E_t \rho_{t,t+k} & \left\{ (1 + \nu) \mathcal{E}_{t+k} P_{H,t+k}^*(j) Y_{t+k}^{D*}(j) - \frac{W_{t+k}}{Z_{t+k}} Y_{t+k}^{D*}(j) \right. \\ & \left. - \frac{\omega}{2} \left[(1 - n)\nu \left(\frac{P_{H,t+k}(j)^*}{P_{H,t+k-1}(j)^*} - 1 \right)^2 P_{H,t+k} Y_{t+k}^{D*} \right] \right\} \\ \text{s.t. } & (14). \end{aligned}$$

3.3 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

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

and demand from foreign households is

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

Total demand for goods is

$$Y_t = \left[\left(\frac{P_{H,t}}{P_t} \right)^{-\eta} (1 - (1 - n)v) C_t \right] \left(1 + \frac{\omega}{2} \left(\frac{P_{H,t+k}}{P_{H,t+k-1}} - 1 \right)^2 \right) + \left[\left(\frac{P_{H,t}^*}{P_t^*} \right)^{-\eta} (1 - n)v C_t^* \right] \left(1 + \frac{\omega}{2} \left(\frac{P_{H,t+k}^*}{P_{H,t+k-1}^*} - 1 \right)^2 \right). \quad (16)$$

The labor markets clear if

$$H_t = Y_t / Z_t. \quad (17)$$

3.4 Small open economy

From here onward, we will focus only on the limiting case $n \rightarrow 0$. The Foreign consumption basket will almost exclusively contain Foreign-produced goods. 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 via financial markets and trade.

4 Insights for a special case

Later we will present simulations based on the non-linear model economy sketched above. In order to build intuition first, however, this section presents a linear approximation of the equilibrium conditions around a deterministic and symmetric zero-inflation steady state. We focus on the special case of a unitary trade elasticity, $\eta = 1$, as this is the most tractable. As before, Foreign variables are indexed with an asterisk. Small letters generally refer to log deviations of the variable from its steady-state value.

4.1 Linearized domestic economy

For the Home economy, what matters from 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^* . Note that this evolution will be induced by a combination of foreign shocks and foreign monetary policy. Once the mapping is done, however, foreign monetary and productivity shocks would not matter independently. In this sense, the model structure is more general, and a variety of model structures in Foreign would be consistent with the analysis here. The one foreign shock that we need to keep track of independently, though, is the foreign demand shock ξ_t^* . The reason being international consumption-risk sharing. The current paper focuses on three Foreign shocks only, so let the domestic demand shock and the domestic technology shock be equal to zero, $\xi_t = 0$ and $Z_t = 0$.

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

$$y_t = s_t + y_t^* - (1 - v)\xi_t^* + (1 - v)m_t. \quad (18)$$

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:

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \kappa [(1 + \varphi) y_t + v m_t - v \xi_t^*]. \quad (19)$$

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

$$\pi_{H,t}^* = \beta E_t \pi_{H,t+1}^* + \kappa [(1 + \varphi) y_t - (1 - v)m_t - v \xi_t^*]. \quad (20)$$

Alternatively, under PCP we have from the law of one price for exports: $\pi_{H,t}^* = \pi_{H,t} - \Delta e_t$.

From (12), linearizing the Home terms of trade we have:

$$s_t = s_{t-1} + \pi_t^* - \pi_{H,t}^*. \quad (21)$$

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

$$m_t = m_{t-1} + e_t - e_{t-1} + \pi_{H,t}^* - \pi_{H,t}. \quad (22)$$

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:

$$y_t = E_t y_{t+1} - (r_t - E_t(\pi_{H,t+1} + v \Delta m_{t+1}) + v E_t \Delta \xi_{t+1}^*). \quad (23)$$

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, equations (18) to (23) then form a system of seven variables in seven 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

$$y_t^* = E_t y_{t+1}^* - (r_t - E_t(\pi_{t+1}^*) + E_t \Delta \xi_{t+1}^*), \quad (24)$$

and the New Keynesian Phillips curve in Foreign is given by

$$\pi_t^* = \beta E_t \pi_{t+1}^* + \kappa(1 + \varphi)(1 + \varphi)[y_t^* - Z_t^*]. \quad (25)$$

A foreign interest-rate rule completes the model environment.

4.2 Flex-price benchmark

The natural level of output in Home is given by

$$y_t^n = \frac{v}{1 + \varphi} \xi_t^*. \quad (26)$$

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

$$s_t^n = \frac{1 + \varphi(1 - v)}{1 + \varphi} \xi_t^* - y_t^*. \quad (27)$$

4.3 External Shocks and Evolution in Foreign

In all that follows, we will 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 a set of examples.

Proposition 1. *Consider the large economy sketched in Section 4 and the shock structure of Section 4.3. For better readability, mark the external shocks in bold font (ϵ_t^{m*} , ξ_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*

$$r_t^* = \phi \pi_t^* + \gamma y_t^* + \epsilon_t^{m*}, \quad (28)$$

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

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

Inflation in Foreign will be

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

Foreign interest rates will be

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

Proof. Straightforward algebra using the equations for Foreign in Section 4.1 along with Taylor rule (28). \square

The following corollary makes clear that this nests two cases

Corollary 1. *Proposition nests two important scenarios as a special case.*

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

$$r_L^* = v(1-\mu) \cdot \left[\boldsymbol{\xi}_L^* - \mathbf{Z}_L^* \right]$$

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 $\phi = \gamma = \epsilon_L^{m*} = 0$. Then,

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

Proof. Follows directly from Proposition 1. \square

4.4 Responses under dominant-currency pricing

We are interested in understanding the role of the exchange rate as a shock absorber, in relation to constraints on monetary policy. Therefore, we solve the model under alternative monetary and exchange rate regimes for Home, focusing on three scenarios. First, we look at a policy that stabilizes the natural rate of output. Second, we look at a policy that stabilizes domestic producer price inflation. Third, we look at a policy that stabilizes the exchange rate (a fixed exchange rate).¹⁵ We do this for both, producer currency pricing and dominant-currency pricing. We start with dominant-currency pricing. Throughout, we report the response of the key variables while the shock lasts.

¹⁵These are the most tractable cases algebraically. The numerical simulations in Section 5 will also look at targeting domestic consumer price inflation and producer prices in both the domestic and the export market.

4.4.1 Natural-output policy under DCP, $y_t = y_t^n$

The first scenario assumes that the domestic central bank sets interest rates so as to anchor output at the natural level of output. In the following, let a superscript L mark a variable while the shocks last.

Proposition 2. *Consider the economy in Section 4. Let pricing be given by DCP. Let the shocks be as described in Section 4.3, 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 terms of trade are given by*

$$s_t^L = (1 + \alpha_{y^n} + \dots + \alpha_{y^n}^t) \gamma_{y^n} \left[\pi_L^* (1 - \beta\mu) - \kappa y_L^* + \kappa \frac{1 + \varphi(1 - v)}{1 + \varphi} \xi_L^* \right], \quad (29)$$

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

Domestic output is given by the natural level of output in (26).

Domestic producer price inflation is given by

$$\pi_{H,t}^L = -\frac{v}{1 - v} [\pi_L^* - \Delta s_t^L]. \quad (30)$$

The nominal exchange rate is given by

$$e_t^L = -\frac{1}{1 - v} \left(\left[y_L^* - \frac{1 + \varphi(1 - v)}{1 + \varphi} \xi_L^* \right] \right) - (t + 1) \frac{1}{1 - v} \cdot \pi_L^*. \quad (31)$$

Home CPI inflation is given by

$$\pi_t = v(\Delta s_t + \Delta e_t). \quad (32)$$

Last, the interest differential between Home and Foreign is given by

$$r_t^L - r_t^{*,L} = \frac{1}{1 - v} \left[-\mu \pi_L^* + (1 - \mu) y_L^* - (1 - \mu) \frac{1 + \varphi(1 - v)}{1 + \varphi} \xi_L^* \right]. \quad (33)$$

Proof. Derivations to be added to the appendix. \square

In order to put content to this, consider a pure fall in foreign demand $y_L^* = -1$. In response to this, the Home terms of trade deteriorate (Home-produced goods sold in Foreign cheaper relative to Foreign-produced goods sold in Foreign), $0 < s_0^L = \kappa \gamma_{y^n} < 1$. Foreign demand being given by $v[\widehat{s}_t^L + \widehat{y}_L^*]$ (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. Perfect stabilization is achieved by the added effect of expenditure switching in Home. The nominal exchange rate depreciates disproportionately, see equation (31). 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 inspite of the price level of Home-produced goods rising on impact, (32). With this, and the pass-through from the exchange rate consumer price inflation rises persistently, (33). The crowding in of domestic consumption, in turn, is supported by a persistent cut in nominal interest rates (33).

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

Next, we consider a monetary policy that stabilizes producer price inflation in all periods $\pi_{H,t} = 0$.

Proposition 3. *Consider the same conditions as in Proposition 2, but let Home monetary policy target $\pi_{H,t} = 0$. Then, while the shocks last, the terms of trade are given by*

$$s_t^L = (1 + \alpha_{\pi_H} + \dots + \alpha_{\pi_H}^t) \gamma_{\pi_H} \left[\pi_L^* (1 - \beta\mu) - \kappa \frac{1 + \varphi}{1 + \varphi(1 - v)} y_L^* + \kappa \xi_L^* \right], \quad (34)$$

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

$$y_t^L = \frac{v}{1 + \varphi(1 - v)} (s_t^L + y_L^*). \quad (35)$$

By design, $\pi_H^L = 0$. The nominal exchange rate, in turn, is given by

$$e_t^L = - (1 + \alpha_{\pi_H} + \dots + \alpha_{\pi_H}^t) \frac{\varphi v}{1 + \varphi(1 - v)} s_0^L + \xi_L^* - \frac{1 + \varphi}{1 + \varphi(1 - v)} y_L^* - (t + 1) \pi_L^*. \quad (36)$$

Home CPI inflation is given by

$$\pi_0^L = v \left[\xi_L^* - \frac{\varphi v}{1 + \varphi(1 - v)} s_0^L - \frac{1 + \varphi}{1 + \varphi(1 - v)} y_L^* \right],$$

and

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

Last, the interest differential is given by

$$\begin{aligned} r_t^L - r_t^{*,L} &= (1 - \mu) \frac{\varphi v}{1 + \varphi(1 - v)} (1 - \alpha_{\pi_H}) s_t^L \\ &\quad - \mu \left[1 + \alpha_{\pi_H}^{t+1} \frac{\varphi v}{1 + \varphi(1 - v)} \gamma_{\pi_H} (1 - \beta\mu) \right] \pi_L^* \\ &\quad - \left[(1 - \mu) + \mu \alpha_{\pi_H}^{t+1} \frac{\varphi v}{1 + \varphi(1 - v)} \gamma_{\pi_H} \kappa \right] \xi_L^* \\ &\quad + \frac{1 + \varphi}{1 + \varphi(1 - v)} \left[(1 - \mu) + \mu \alpha_{\pi_H}^{t+1} \frac{\varphi v}{1 + \varphi(1 - v)} \gamma_{\pi_H} \kappa \right] y_L^* \end{aligned} \quad (37)$$

Proof. Derivations to be added to the appendix. \square

For concreteness, consider again a pure shock for foreign demand, $y_L^* = -1$. If the domestic central bank targets domestic producer price inflation, the terms of trade still deteriorate. Now, however, the foreign output shock does spill over to Home output, (3): Home output unambiguously falls. Indeed, the nominal exchange rate, (36) depreciates by less than under natural output targeting. Domestic households do not switch expenditures to the same extent as under the regime. Even in this monetary regime, however, the consumer price level in Home rises. In Section 5, we will show numerical simulations for two further cases, both of which curb to a stronger extent the depreciation that would help absorb the foreign drop in demand. Namely, we look at the central bank targeting the domestic consumer price index and the central bank targeting the producer price inflation for Home-produced goods, measured in both the Home and the Foreign market. Each of these cases brings the response of output closer still to the case

of fixed exchange rates, which we discuss next.

4.4.3 Fixed exchange rate, DCP/PCP, $e_t = 0$

Next, we consider a monetary policy that stabilizes the exchange rate in all periods. In the model spelled out above, when the exchange rate is pegged, prices and allocations are identical under DCP and PCP.

Proposition 4. *Consider the same conditions as in Proposition 2, but let Home monetary policy target $e_t = 0$. Further, while the shocks last, the terms of trade are given by*

$$s_t^L = (1 + \alpha_e + \dots + \alpha_e^t) \gamma_e \left(\pi_L^* (1 - \beta \mu) + \kappa [1 + \varphi (1 - v)] \xi_L^* - \kappa (1 + \varphi) y_L^* \right), \quad (38)$$

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

$$y_t^L = s_t^L + y_L^* - (1 - v) \xi_L^*. \quad (39)$$

The nominal exchange rate is fixed by assumption. Home producer price inflation is given by

$$\pi_{H,t}^L = \pi_L^* - \alpha_e^t \gamma_e \left(\pi_L^* (1 - \beta \mu) + \kappa [1 + \varphi (1 - v)] \xi_L^* - \kappa (1 + \varphi) y_L^* \right). \quad (40)$$

Home CPI inflation is given by

$$\pi_t^L = \pi_L^* - (1 - v) \alpha_e^t s_0^L.$$

Last, by uncovered interest parity,

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

Proof. Derivations to be added to the appendix. □

Again, the terms of trade deteriorate, providing expenditure switching by foreign households. With interest rates and exchange rates fixed, however, expenditure switching in Home is limited. In order to have domestic expenditure switching, producer price inflation in Home has to fall. It does, but only gradually, (40)

4.5 Producer currency pricing

Next, we turn to producer currency pricing. Under PCP, targeting the producer price level amounts to targeting the natural level of output. So the two regimes are equivalent, as Proposition 5 states.

Proposition 5. *Consider the economy of Section 4. Let pricing be given by PCP. Let the shocks be as described in Section 4.3, 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 terms of trade are given by*

$$s_t^L = \frac{1 + \varphi(1 - v)}{1 + \varphi} \xi_L^* - y_L^*, \quad (41)$$

that is, the terms of trade are constant. Output is given by (??), producer price inflation by $\pi_{H,t} = 0$.

The nominal exchange rate is given by

$$e_t^L = \frac{1 + \varphi(1 - v)}{1 + \varphi} \xi_L^* - y_L^* - (t + 1) \cdot \pi_L^*. \quad (42)$$

Home CPI inflation is given by

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

with

$$\pi_t^L = 0, \quad t > 0.$$

Last, the interest differential is given by

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

Proof. Derivations to be added to the appendix. \square

4.6 Focusing on foreign output shocks

Appendix ?? provides the impact responses of endogenous variables for all regimes discussed above. Rather than focusing on all of these, this section focuses on pure foreign output shocks only. In addition, we look at a special case with infinitely elastic labor supply.

Proposition 6. *Consider the scenarios spelled out in Propositions 2 through 5. Suppose that $\varphi \rightarrow 0$ (an infinite labor supply elasticity). Focus on a recessionary foreign output shock only $y_L^* = 1$, $\pi_L^* = \xi_L^* = r_L^* = 0$. Then, the terms of trade evolve independent of the policy response. In addition, with parameter α_{y^n} being as defined in Proposition 2, the impact responses on the nominal exchange rate, output, and the nominal interest rate are as provided in the following table.*

Table 2: Impact responses to drop in foreign output

	DCP		DCP/PCP	PCP
	$y_t = y_t^n$	$\pi_{H,t} = 0$	$e_t = 0$	$y_t = y_t^n = \pi_{H,t} = 0$
y_0^L	0	$-v < -v \frac{1+\beta-\beta\alpha-\beta\mu}{1+\beta+\kappa-\beta\alpha-\beta\mu} < 0$	$-1 < -\frac{1+\beta-\beta\alpha-\beta\mu}{1+\beta+\kappa-\beta\alpha-\beta\mu} < 0$	0
e_0^L	$\frac{1}{1-v} > 1$	1	0	1
r_0^L	$-(1-\mu) \frac{1}{1-v} < -(1-\mu)$	$-(1-\mu)$	0	$-(1-\mu)$

Notes: Impact responses in Home for unitary recessionary output drop in Foreign $y_L^* = -1$, with no other foreign variable moving. Shown in the limiting case $\varphi \rightarrow 0$. A positive sign for e_0 means the nominal exchange rate depreciates.

Proof. Derivations to be added to the appendix. \square

4.7 Foreign fundamental shock

Combining the closed-form solution for Home-economy variables with the New Keynesian structure of the large foreign economy (24), (25), and (28) allows us to characterize the (impact) response of Home variables to foreign fundamental shocks, such as foreign monetary policy

shocks and foreign technology shocks. These foreign fundamental shocks can be interpreted as weighted averages of pure foreign output shocks and pure foreign inflation shocks.

Proposition 7. *Consider the scenarios spelled out in Propositions 2 through 5. Suppose that foreign monetary policy follows interest-rate rule (28) with $\phi \in (1, \infty)$. Focus on a contractionary foreign monetary policy shock $\epsilon_L^{m*} > 0$. Then, the signs of the impact responses of output, domestic producer price inflation, the nominal exchange rate, and the terms of trade are unambiguously determined as provided in the following table.*

Table 3: Signs of impact responses to foreign monetary policy shock

	DCP		DCP/PCP	PCP
	$y_t = y_t^n$	$\pi_{H,t} = 0$	$e_t = 0$	$y_t = y_t^n = \pi_{H,t} = 0$
y_0^L	= 0	< 0	< 0	= 0
$\pi_{H,0}^L$	> 0	= 0	< 0	= 0
e_0^L	> 0	> 0	= 0	> 0
s_0^L	< 0	< 0	= 0	> 0

Notes: Sign of impact responses in Home for contractionary monetary policy shock in Foreign $\epsilon_L^{m*} > 0$. A positive sign for e_0 means the nominal exchange rate depreciates. A positive sign for s_0 means the terms of trade depreciate.

Proof. Derivations to be added to the appendix. □

5 Simulations

We now extend our analysis of the role of the exchange rate as a shock absorber to the more generic case without a unitary trade elasticity. As before, we focus on the transmission of Foreign impulses to the Home economy, and therefore abstract from domestic shocks in Home.

Unlike in the case of a unitary trade elasticity, the generic natural level of output in Home is a function of output in Foreign

$$y_t^n = v \frac{(1 - \eta)(2 - \nu)y_t^* + (1 - (1 - \eta)(2 - \nu))\xi_t^*}{1 + \varphi - (1 - \eta)(2 - \nu)v\varphi}, \quad (43)$$

and the natural real rate of interest in Home is a function of the expected change in the level of foreign output¹⁶

$$real_t^n = v\varphi \frac{(\eta - 1)(2 - \nu) (E_t y_{t+1}^* - y_t^*) - (1 - (1 - \eta)(2 - \nu)) (E_t \xi_{t+1}^* - \xi_t^*)}{1 + \varphi - (1 - \eta)(2 - \nu)v\varphi}. \quad (44)$$

The model is solved numerically. Table 4 documents the baseline parameterization. The trade elasticity is smaller than one, as is customary. Together with log-utility in consumption this implies that composite goods produced in Home and Foreign are complements. The slope of the Phillips curve reasonably flat.

¹⁶Here, we follow the common approach and define the natural real rate of interest as the flexible price counterpart to the ex-ante real interest rate obtained from deflating the nominal interest rate with expected producer price inflation. Alternatively, the natural real rate can be defined as the flexible price counterpart to the real interest rate obtained from deflating the nominal rate with expected consumer price inflation. In this case, we have $real_t^n = \frac{(1+\varphi)-(1-\eta)(2-\nu)\varphi}{1+\varphi-(1-\eta)(2-\nu)v\varphi} v (E_t y_{t+1}^* - y_t^*) + \frac{-v(1+\varphi(2-\nu)+(1-\eta)(2-\nu)v\varphi)}{1+\varphi-(1-\eta)(2-\nu)v\varphi} (E_t \xi_{t+1}^* - \xi_t^*)$.

Table 4: Baseline parameterization

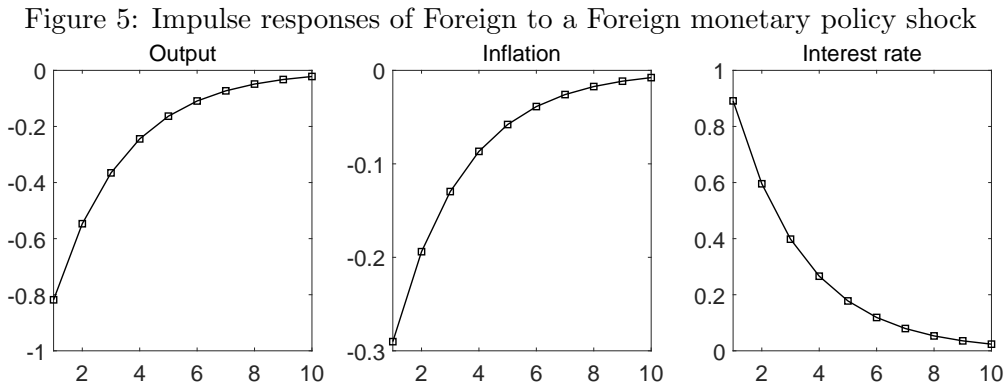
Parameters	Description	Values
β	Discount factor	0.99
φ	Inverse of labor supply elasticity	1
ϵ	Elasticity of substitution between intermediate goods	7.5
η	Trade elasticity	2/3
v	Share of imported goods in domestic consumption basket	0.4
ω	Price adjustment costs	500

5.1 Foreign monetary policy shock

We first present impulse responses to a Foreign monetary policy shock of 100 basis points (annualized). The Foreign policy rate follows a Taylor-type feedback rule

$$r_t^* = \rho_{r^*} r_{t-1}^* + (1 - \rho_{r^*}) \alpha_{\pi^*} \pi_t^* + \varepsilon_t^*, \quad (45)$$

where ε_t^* is an *iid* shock. We set $\rho_{r^*} = 0.75$ and $\alpha_{\pi^*} = 1.5$. In order to map this into the insights from the simple special case of Section 4, bear in mind that this monetary shock affects the foreign interest rate as much as foreign output and foreign inflation. Figure 5 shows the responses of Foreign variables. The increase in the interest rate leads to a decline in Foreign output and inflation.



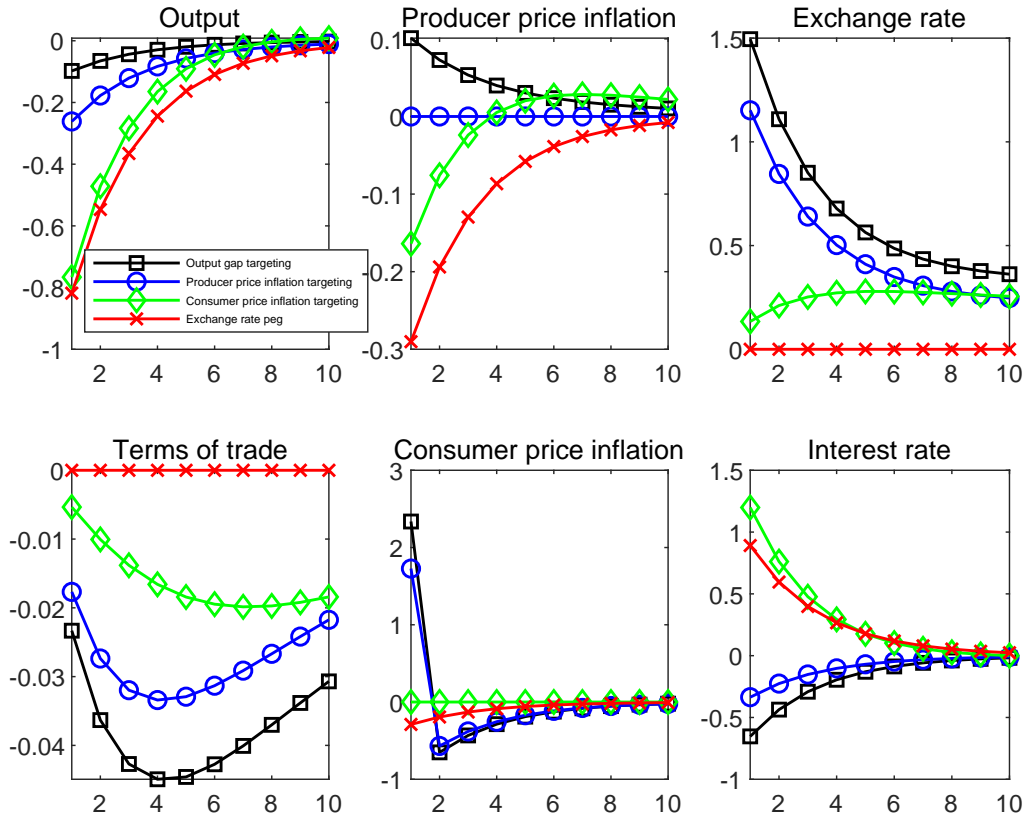
Note: Inflation rates and interest rates are expressed in annualized percentage deviations from steady state.

Figure 6 shows the responses of Home variables under DCP for four alternative monetary policy regimes.

Under the exchange rate peg (red lines with crosses), Home variables inherit the responses of their counterparts in Foreign. The terms of trade do not move, and hence Home output declines one-for-one with foreign output, consistent with the analytical results from the previous section. Under consumer price inflation targeting (green lines with diamonds), the exchange rate depreciates over several periods.¹⁷ This exchange rate depreciation makes imported goods relatively more expensive for Home households, giving rise to an expenditure switching effect toward Home-produced goods. However, under DCP, the role of the exchange rate as a shock absorber

¹⁷Consumer price inflation satisfies $\pi_t = (1 - v)\pi_{H,t} + v(\Delta e_t + \pi_t^*)$.

Figure 6: Impulse responses of Home to a Foreign monetary policy shock



Note: Inflation rates and interest rates are expressed in annualized percentage deviations from steady state.

is limited. Since exports are priced in the Foreign currency and those export prices are rigid, the exchange rate depreciation in Home does not induce immediate expenditure switching by Foreign households toward Home-produced goods. Indeed, the terms of trade barely move on impact. The change in the composition of consumption by Home households induced by the exchange rate response slightly mitigates the decline in output. However, quantitatively, the improvement in the output response is small. This is due to the reduced effectiveness of flexible exchange rates under DCP, and the rather muted exchange rate depreciation. A more aggressive nominal depreciation would put upward pressure on import prices, and thereby on consumer prices, in Home.

Under output gap targeting (black lines with squares), there is a much larger exchange rate depreciation on impact compared to the one under consumer price inflation targeting, leading to a spike in both producer and consumer price inflation. The strong exchange rate response is necessary in order to induce a sufficiently large change in the composition of consumption by Home households toward domestically-produced goods. This expenditure switching by Home households materially mitigates the decline in Home output compared to the decline in Foreign output. Output still falls slightly on impact, reflecting the fact that with a trade elasticity smaller than one, the decline in Foreign output induces a decline in Home potential output (see equation (43)). It is thus still possible for a central bank of a small-open economy to keep

domestic output at potential, but only if it is willing tolerate potentially large movements in inflation.

Finally, under (domestic) producer price inflation targeting (blue lines with circles), output falls less than under consumer price inflation targeting but more than under output gap targeting. That is, the output gap is negative on impact, consistent with the analytical results in the previous section. To avoid an increase in producer price inflation, the decline in the interest rate and the depreciation of the nominal exchange rate is smaller than under output gap targeting.

5.2 Foreign monetary policy shock cum ZLB

In the previous simulation exercise, the interest rate in Home was free to adjust in line with the respective policy regime. Next, we consider the effects of a contractionary Foreign monetary policy shock when monetary policy in Home is constrained by the zero lower bound (ZLB) on nominal interest rates. We assume that monetary policy in Home pursues flexible producer price inflation targeting—i.e. a combination of producer price inflation targeting and output gap targeting

$$r_t = \max \left(\alpha_\pi \pi_{P,t} + \alpha_{ygap} (y_t - y_t^n), -\frac{1-\beta}{\beta} \right), \quad (46)$$

where $\pi_{P,t} \equiv \pi_{H,t} + \nu(M_t - M_{t-1})$ is Home producer price inflation between periods $t-1$ and t . Foreign monetary policy follows a similar monetary policy rule, augmented with an *i.i.d.* shock.¹⁸ We solve the model using global methods. [APPENDIX TO BE ADDED]

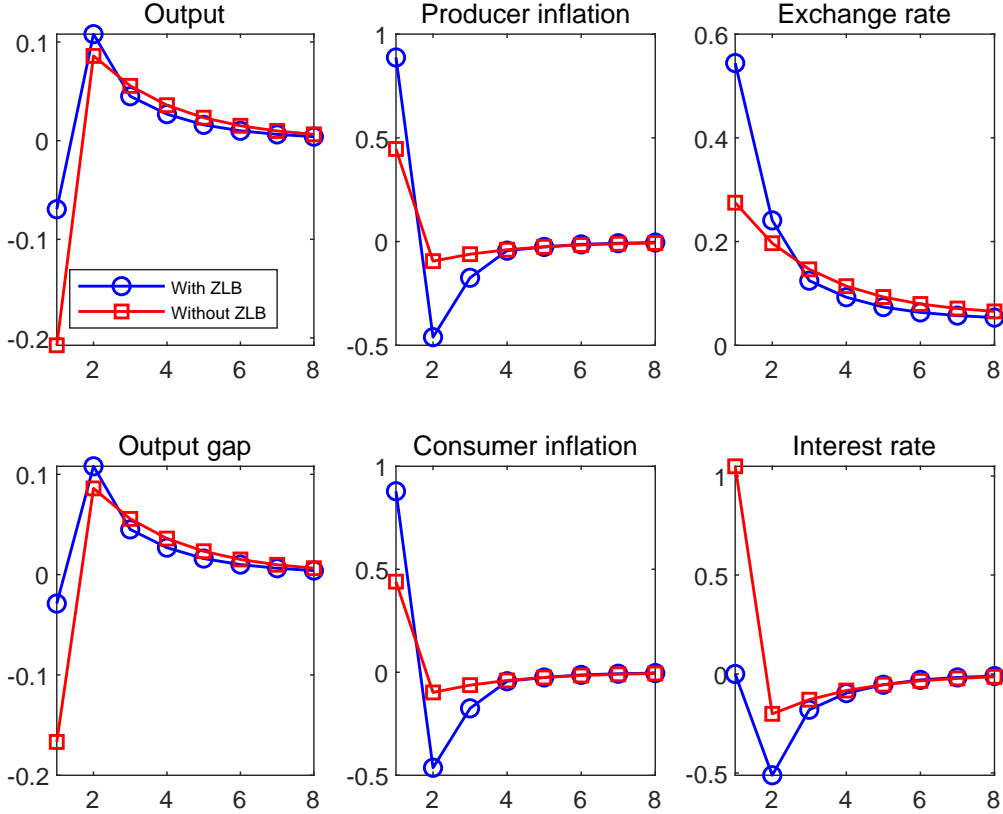
Impulse responses to the Foreign monetary policy shock with a binding ZLB in Home are constructed as follows. We conduct two simulations of the model. In the first simulation, we buffer the economies with a negative global demand shock $\xi_t^* = \xi_t < 0$ that drives the Home interest rate to the ZLB. In the second simulation, the global demand shock is augmented with a temporary contractionary monetary policy shock in Foreign, $\varepsilon_t^* > 0$. We then subtract the responses obtained in the first simulation from those obtained in the second simulation.¹⁹

Figure 7 shows the responses of Home variables for the case with a ZLB constraint in Home (blue lines with circles) and for the case without a ZLB constraint in Home (red lines with squares). In the case with the ZLB, the ZLB constraint is binding in the initial period so that the interest rate in Home does not respond to the Foreign monetary policy shock. In contrast, in the scenario without the ZLB, the monetary authority in Home raises the interest rate on impact because the Foreign monetary policy shock mitigates the decline in Home producer price inflation induced by the global demand shock. The Home exchange rate thus depreciates by more in the scenario with the ZLB than in the scenario without the ZLB. Both, intertemporal substitution and expenditure switching towards domestically produced goods mitigate the decline in Home output in the case with the ZLB compared to the case without the ZLB. Put differently, at the ZLB and with flexible exchange rates, monetary policy in Home is conducted *as if* the monetary authority in Home responded temporarily more strongly to the output gap relative to inflation.

¹⁸We do not explicitly account for the ZLB constraint in Foreign.

¹⁹We set $\alpha_\pi = 2.5$ and $\alpha_{ygap} = 0.1$. The global preference shock follows a stationary AR(1) process with a coefficient of 0.8.

Figure 7: Impulse responses of Home to a Foreign monetary policy shock with ZLB



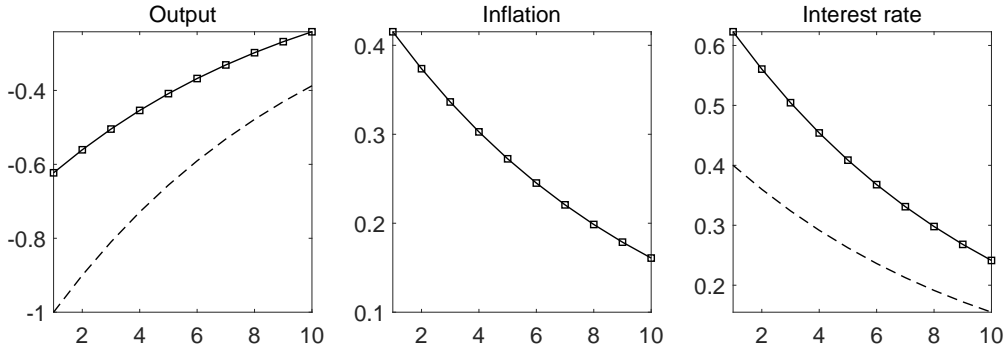
Note: In percentage point deviations from the baseline.

5.3 Foreign technology shock

Finally, we present impulse responses to an adverse foreign technology shock. The shock follows a stationary AR(1) process with a coefficient of 0.9. We abstract from inertia in the Foreign monetary policy rule, $\rho_{r^*} = 0$. Figure 8 shows the responses of Foreign variables. The adverse technology shock leads to a decline in Foreign’s potential output (dashed line, left panel) and to an increase in the natural real rate of interest (dashed line, right panel). Firms’ marginal costs increase and inflation jumps up. The central bank in Foreign raises the policy rate to mitigate these inflationary pressures. Output contracts, but by less than potential output. Hence, the shock leads to inflation and a positive output gap.

Turning to the Home country, Figure 9 shows the responses of Home variables under PCP. The PCP case is instructive because in the absence of currency misalignments, a policy that tracks the natural real rate of interest also closes the output gap and stabilizes producer prices. Output gap targeting (black lines with squares) belongs to this class of policies. Under output gap targeting, the response of output thus coincides with the response of potential output, and the response of the policy rate coincides with the response of the natural real rate of interest. The technology-induced contraction in Foreign output lowers potential output in Home. Potential output in Home and Foreign thus move in lockstep. However, the adverse foreign supply shock—while raising the natural real rate of interest in Foreign—*lowers* the natural real rate of interest

Figure 8: Impulse responses of Foreign to a Foreign technology shock



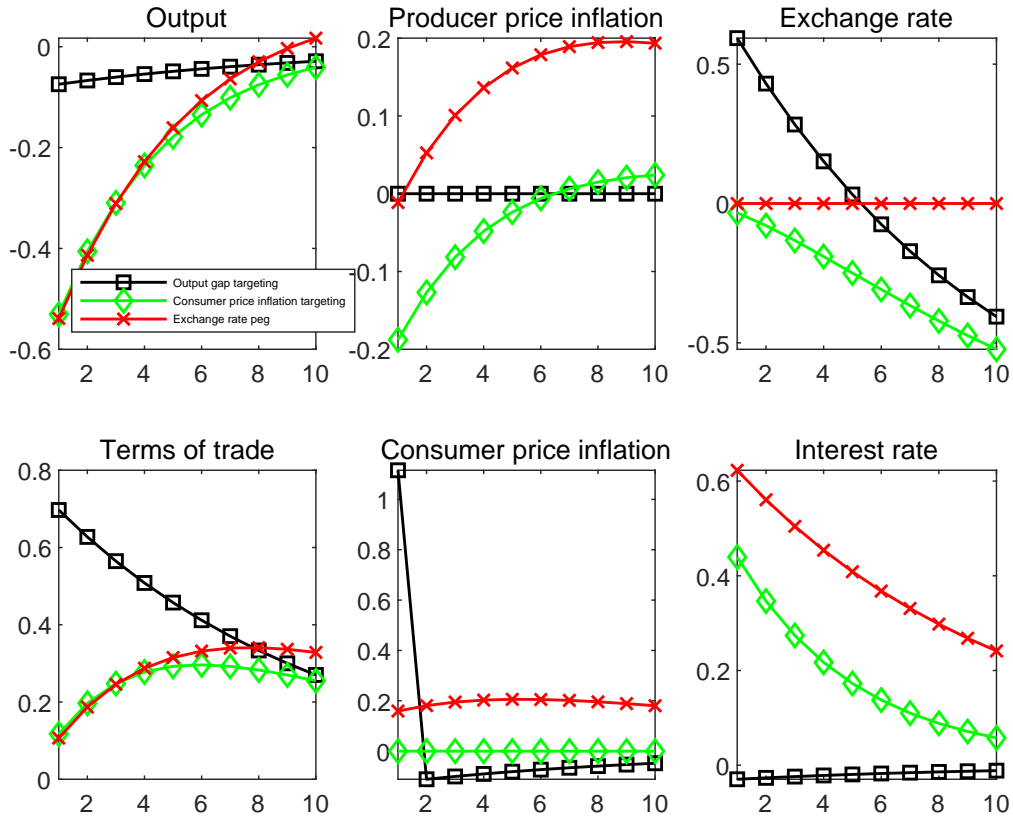
Note: Inflation rates and interest rates are expressed in annualized percentage deviations from steady state. The dashed line in the left panel depicts potential output, and the dashed line in the right panel depicts the natural real rate of interest.

in Home. In other words, in the absence of a policy response in Home, the contractionary supply shock in Foreign triggers a decline in Home aggregate demand below potential. This holds true whenever Home and Foreign goods are complements, as can be seen from equation (44).²⁰ To prevent the decline in aggregate demand and the ensuing deflationary pressures from materializing, the interest rate in Home has to fall. The opposing interest rate responses in Home and Foreign, in turn, result in a depreciation of the exchange rate in Home. Under the exchange rate peg (red lines with crosses), the Home interest rate tracks the Foreign interest rate rather than the Home natural real rate. Consequently, the interest rate increases in response to the shock. The contractionary monetary policy response exacerbates the decline in aggregate demand, and output falls by more than potential. However, even under the exchange rate peg, the Home terms of trade depreciate over time, since only Foreign exporters' production costs are directly raised by the adverse foreign technology shock.

Finally, Figure 10 shows the responses of Home variables under DCP. When Home imports and exports are both sticky in Foreign currency, tracking the natural real rate of interest is no longer sufficient to stabilize the output gap. Under output gap targeting (black lines with squares), the interest rate now declines by more than the natural real rate of interest, and the initial depreciation of the Home exchange rate is stronger than under PCP. The larger exchange rate response is necessary to compensate for the lack of any immediate expenditure switching by Foreign households by means of a sufficiently large change in the composition of consumption by Home households toward domestically-produced goods. Responses are similar under produce price inflation targeting (blue lines with circles), though the initial exchange rate depreciation is somewhat smaller and the decline in output somewhat larger than under output gap targeting. Under consumer price inflation targeting (green lines with diamonds), the interest rate increases in response to the shock. The Home exchange rate appreciates slightly on impact and keeps appreciating in subsequent periods. Consequently, there is no expenditure switching by households in Home from Foreign goods to Home goods, and the intertemporal substitution effect depresses aggregate demand in Home. At the same time, the Home terms

²⁰This result is consistent with the finding in Guerrieri et al. (2020) that in a closed economy with two sectors a decline in potential output of one sector results in a decline in the natural real rate of the other sector, if the two sectors are complements.

Figure 9: Impulse responses of Home to a Foreign technology shock under PCP



Note: Inflation rates and interest rates are expressed in annualized percentage deviations from steady state.

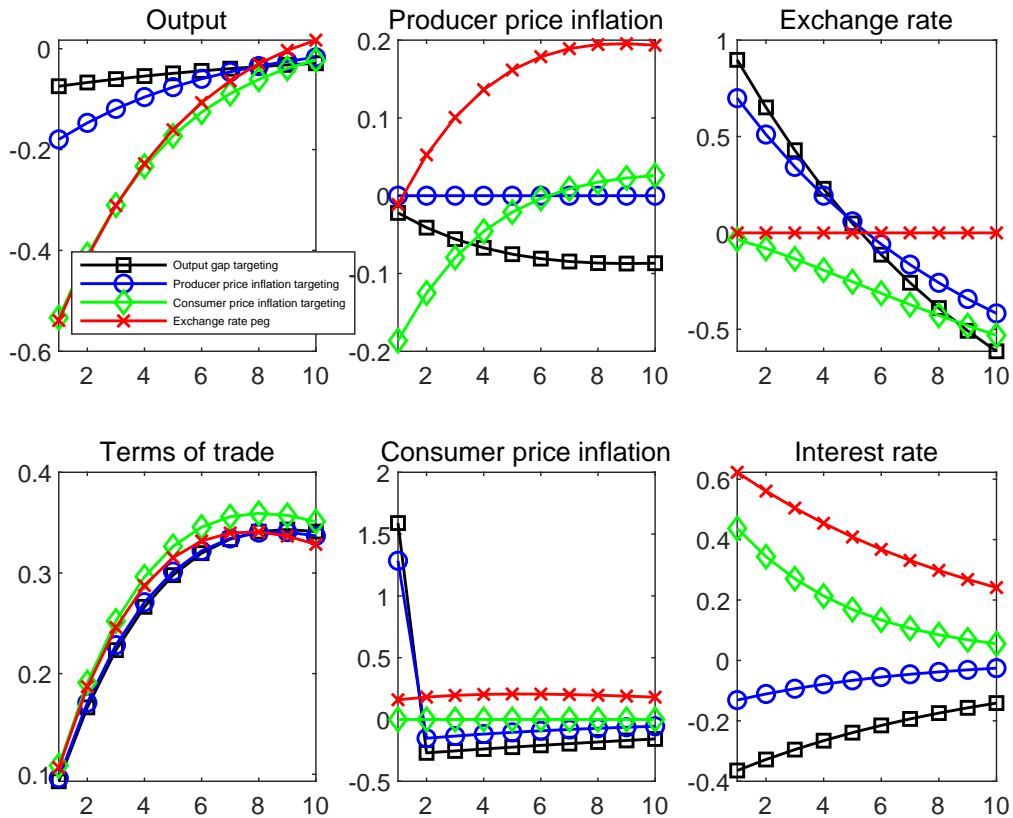
of trade depreciate over time, thereby supporting expenditure switching by Foreign households towards Home goods. That's because exporters of Home goods are not directly affected by the contractionary Foreign technology shock, so they can post lower prices than their Foreign competitors. All in all, the decline in Home output is as large as under the exchange rate peg (red lines with crosses).

6 Back to the data: the ELB

Our model based analysis suggests that monetary policy could insulate domestic production from foreign shocks if the exchange rate is flexible. Yet, it may not *choose* do so. The global move toward inflation targeting, thus, may mask the insulation properties of flexible exchange rates.

The model suggests a test case for this statement. Namely, to look at variations in the policy regimes within neighboring economies that opt for a float. Theory suggests that these should make the insulation properties of flexible exchange rates apparent. In particular, suppose that domestic monetary policy temporarily deviates from targeting inflation, by not responding to external shocks. Then, in response to foreign contractionary shocks output should fall less under flexible exchange rates than under fixed.

Figure 10: Impulse responses of Home to a Foreign technology shock under DCP



Note: Inflation rates and interest rates are expressed in annualized percentage deviations from steady state.

A first look at the data supports this conjecture. We show in Figure 11 inflation in the euro area as well as average inflation for countries with floating exchange rates and without. We observe that while there is generally a lot of co-movement of inflation, there is considerably less during the global financial crisis and during the euro-area crises. During those periods inflation declined considerably less in countries with a flexible exchange rate. Instead countries with a peg experienced an inflation decline in sync with the euro area.

IN WHAT FOLLOWS WE WILL INVESTIGATE THIS MORE SYSTEMATICALLY USING ONCE MORE THE LOCAL PROJECTION...

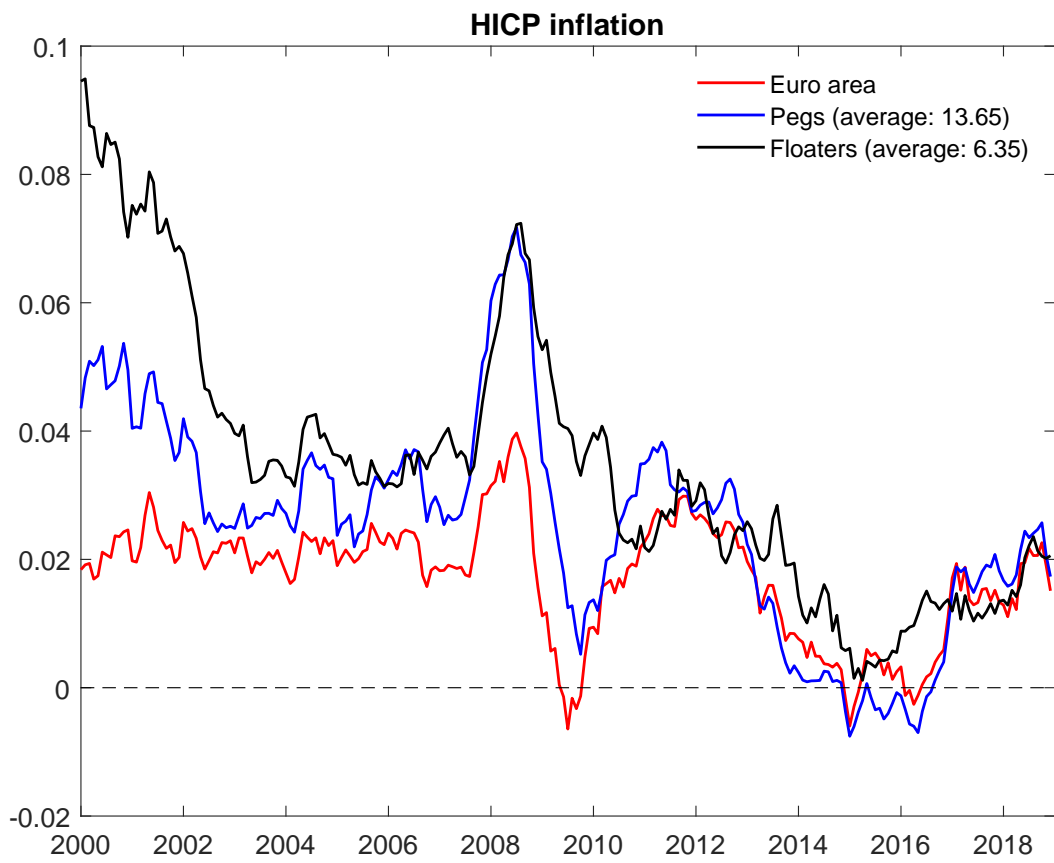


Figure 11: Inflation

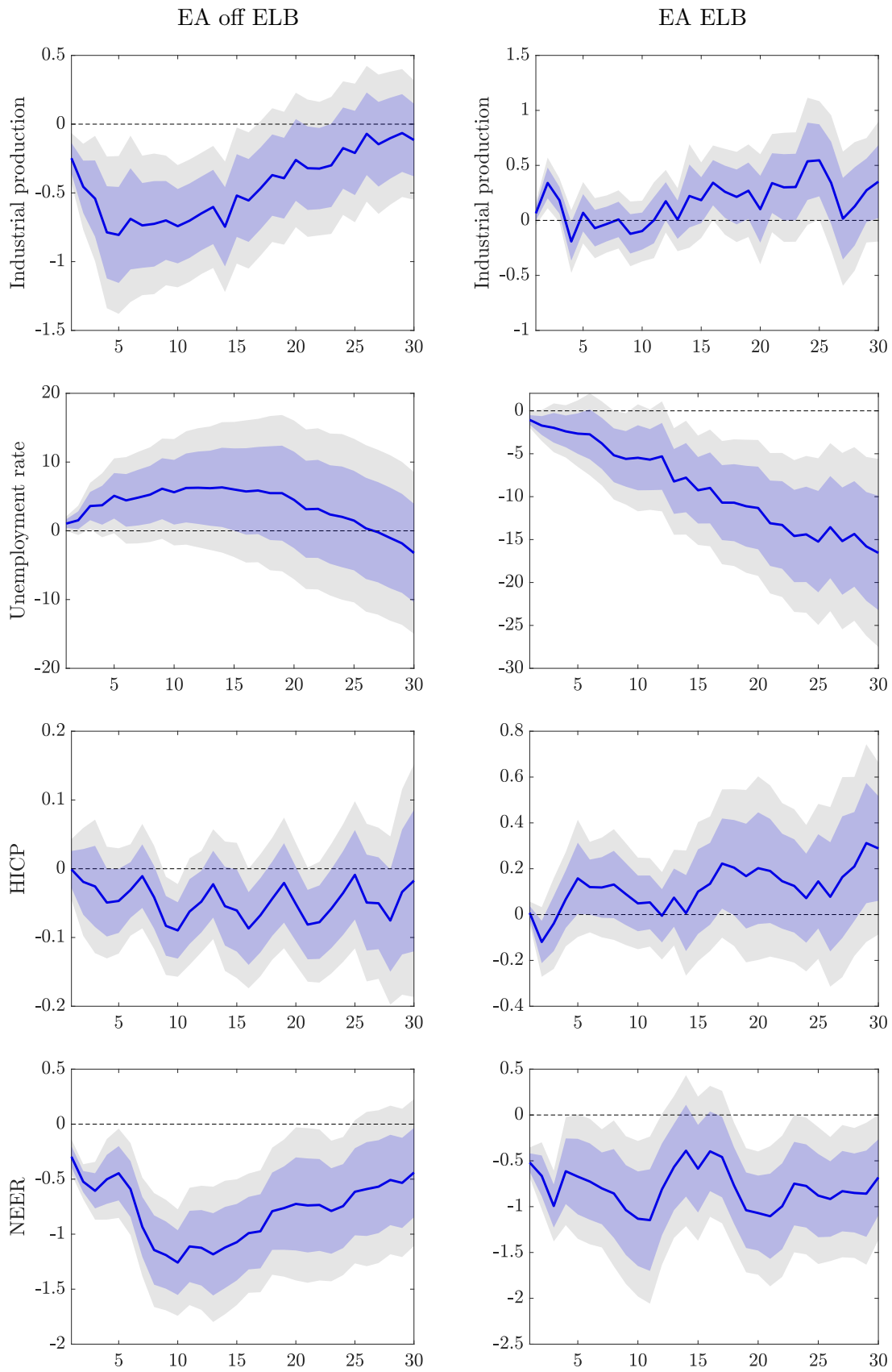


Figure 12: Euro area adjustment to euro area monetary policy shock. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Decline of exchange rate reflects appreciation.

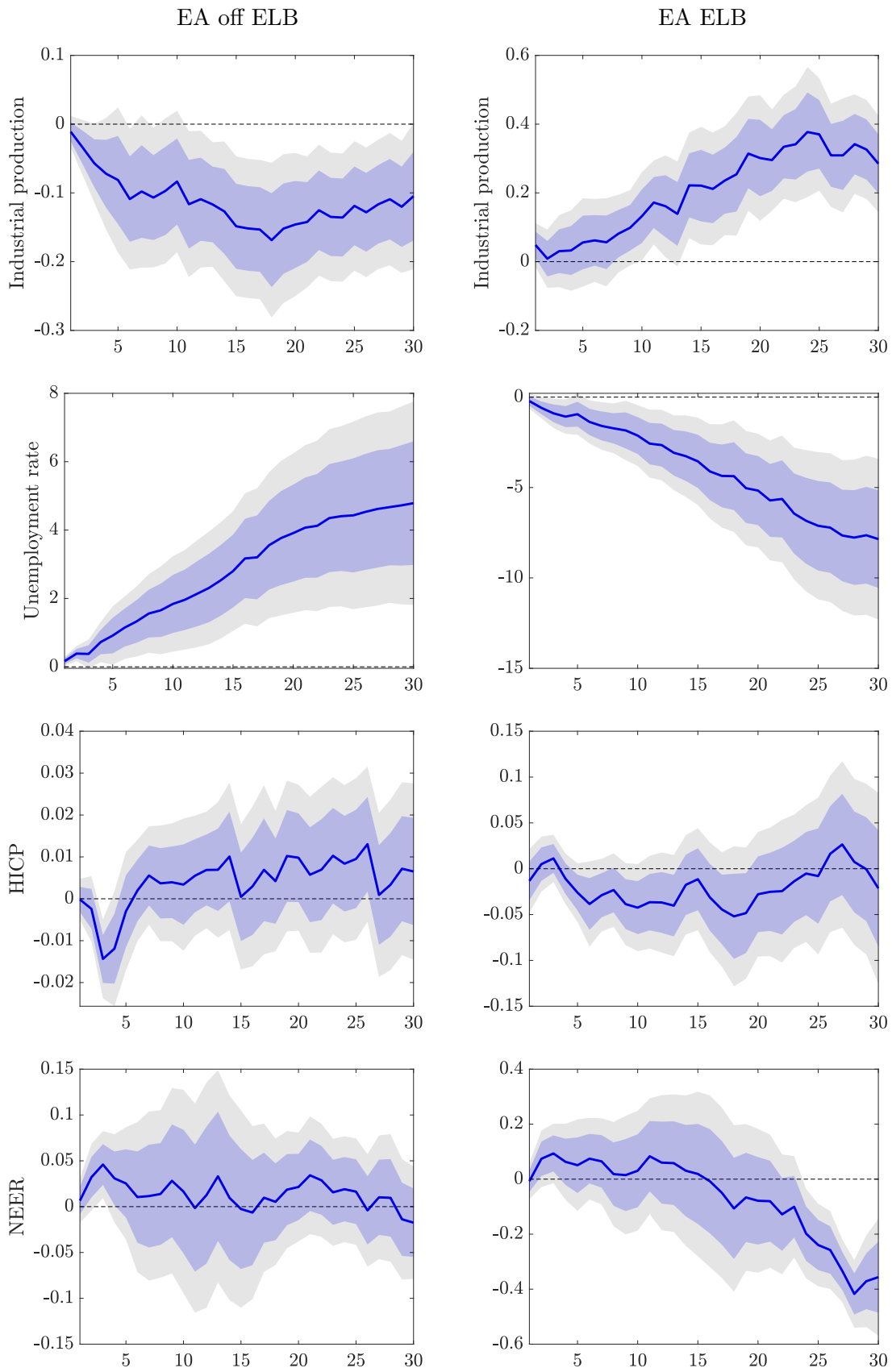


Figure 13: Euro area adjustment to euro area credit shock. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Decline of exchange rate reflects appreciation.

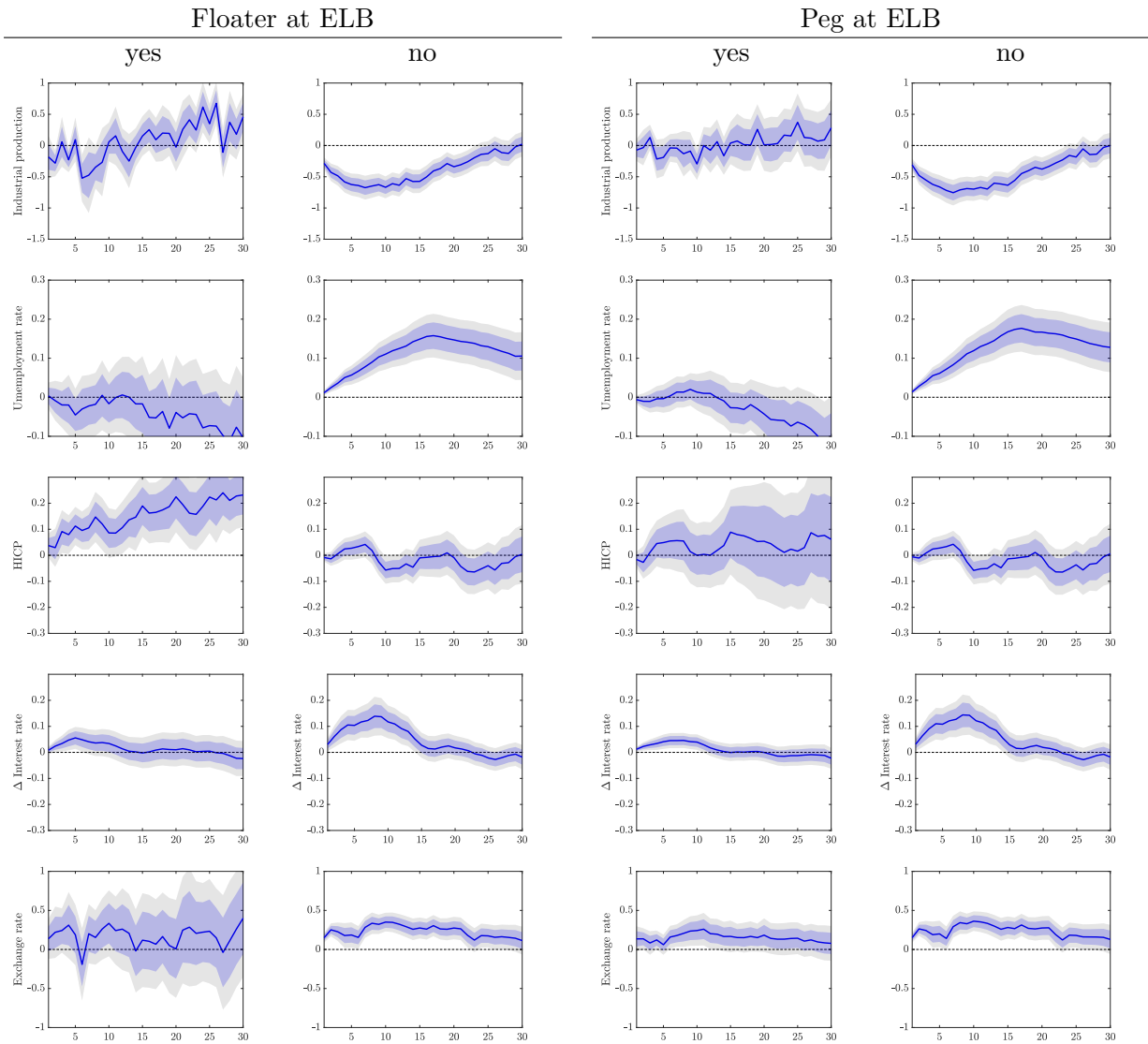


Figure 14: Spillover effect of euro area monetary policy shock. Baseline: float broadly defined (category 3 and 2 in table 1 above). Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.

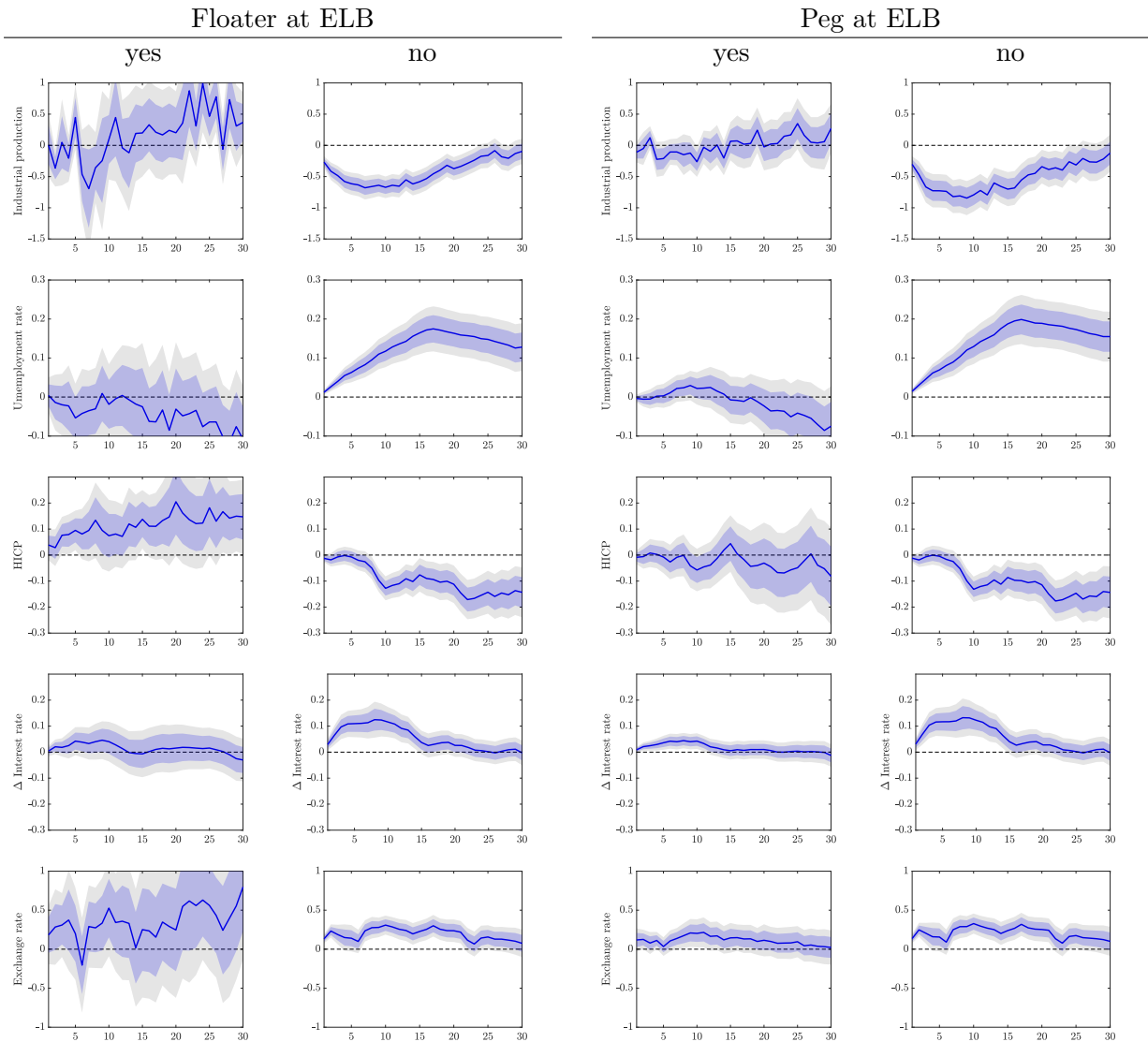


Figure 15: Spillover effect of euro area monetary policy shock. Baseline: float narrowly defined (category 3 in table 1 above). Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.

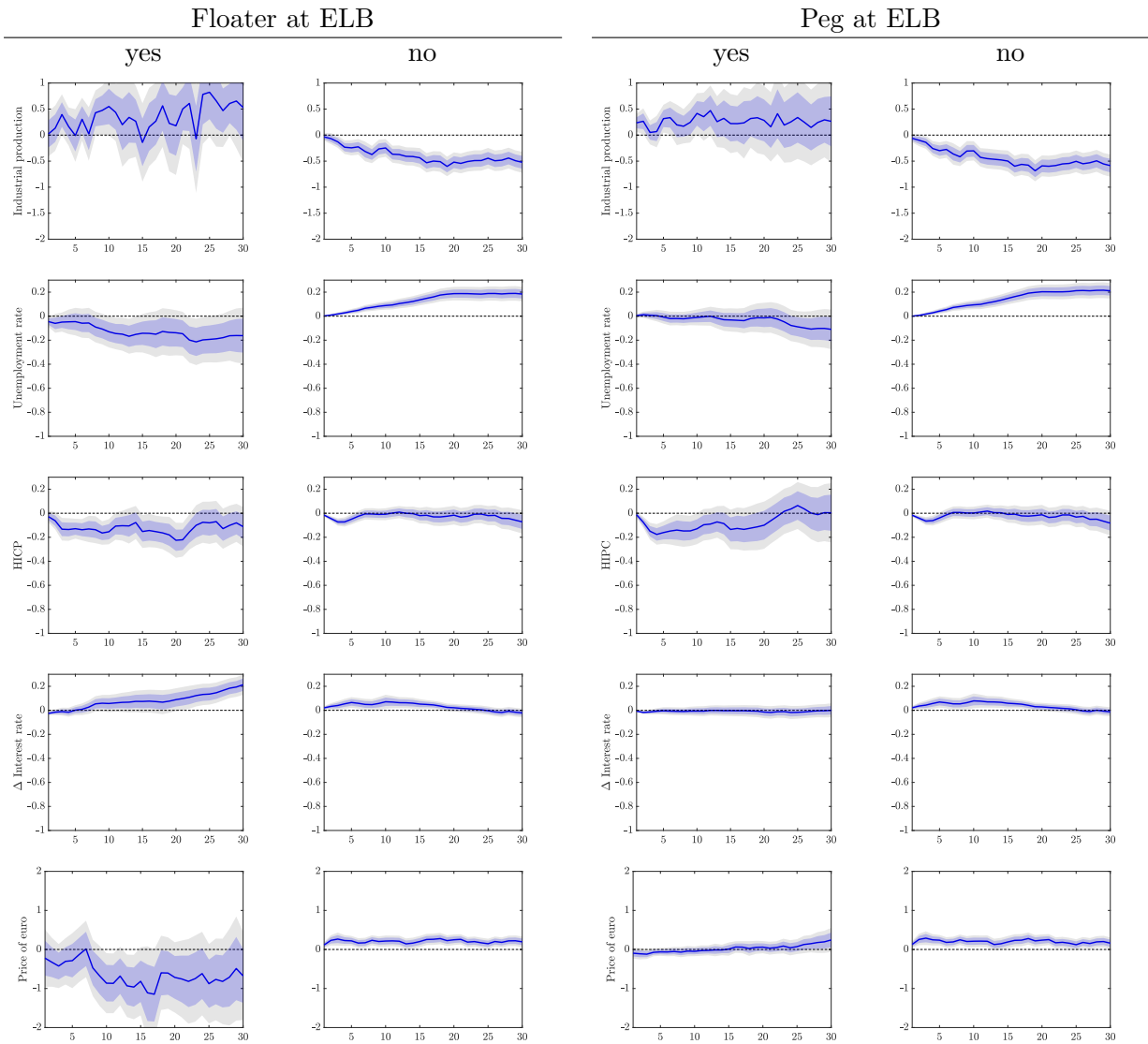


Figure 16: Spillover effect of euro area credit shock. broad definition of float Baseline: float narrowly defined (category 3 in table 1 above). Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.

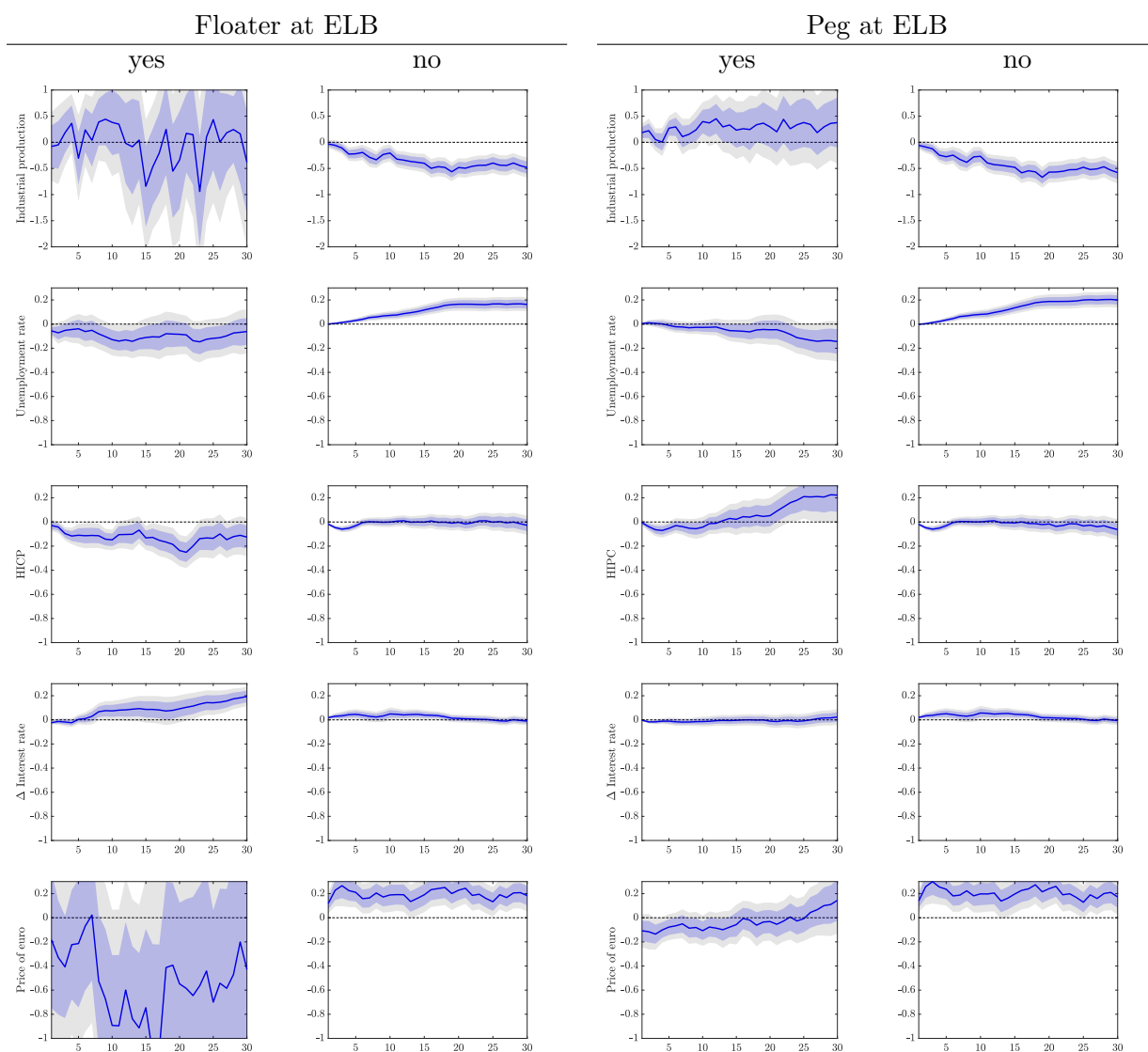


Figure 17: Spillover effect of euro area credit shock. narrow definition of float. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.

7 Conclusions

To be added.

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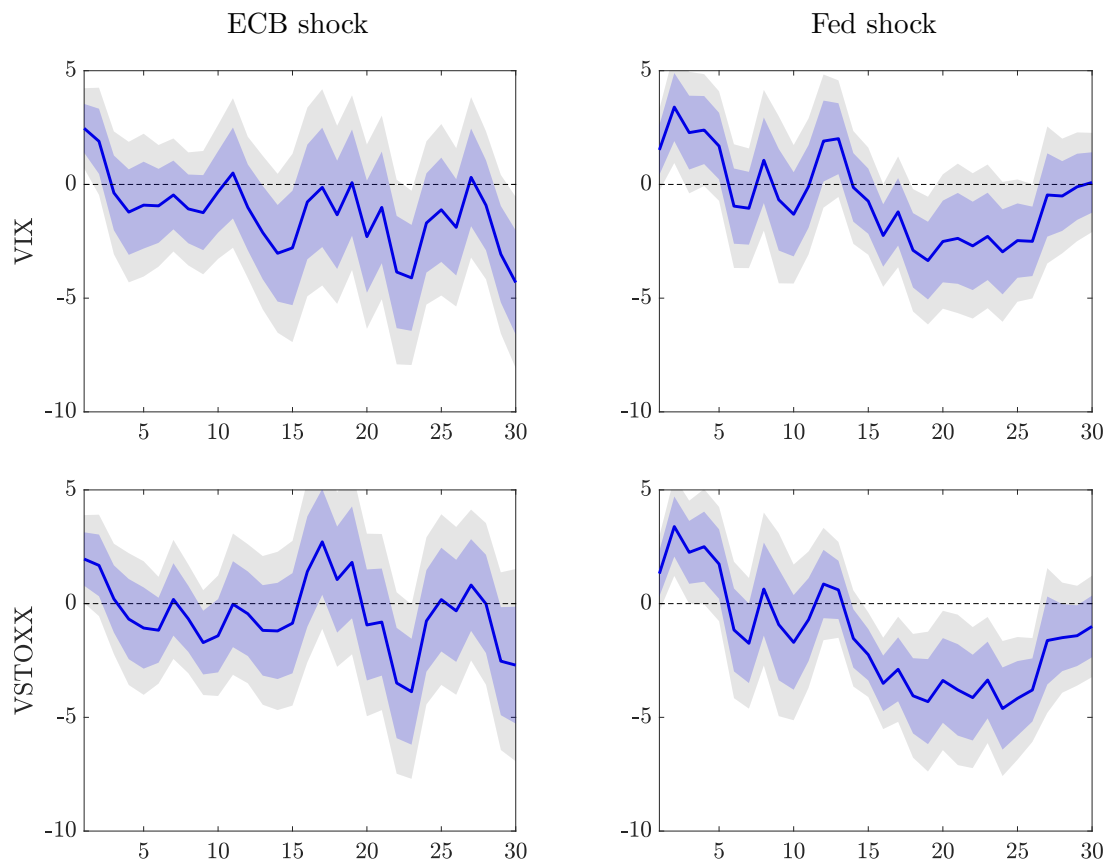


Figure A.18: Euro area adjustment to euro area monetary policy shock. Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Decline of exchange rate reflects appreciation.

A Additional results

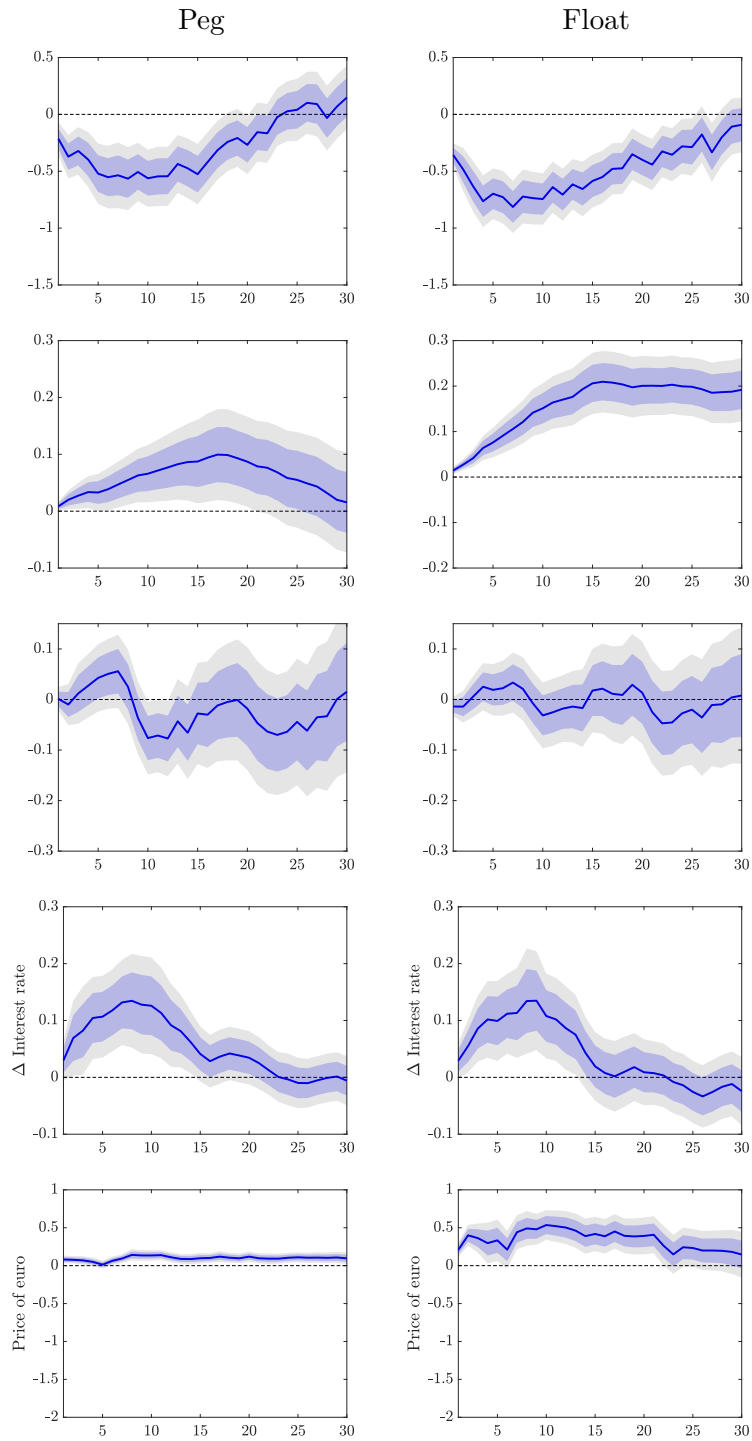


Figure A.19: Spillover effect of euro area monetary policy shock. Baseline: float broadly defined (category 3 and 2 in table 1 above). Solid line indicates point estimate, shaded areas correspond to 68 and 90 percent confidence bounds. Horizontal axis measures time in months. Vertical axis measure deviation in percent/percentage points.