The Macroeconomic Effects of Foreign Exchange Intervention

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Abstract

We estimate a panel structural vector autoregression identified with a high-frequency instrument for foreign exchange interventions in four major currencies over 30 years. An intervention shock of 1 billion U.S. dollar purchase of foreign currency increases domestic production by 0.1% after six months, and significantly above trend for two years. This is accompanied by a persistent depreciation of the domestic currency and a significant increase in exports. The multiplier of a 1 billion U.S. dollar intervention shock on GDP is about 0.5. We show that foreign exchange intervention can be as effective as conventional monetary policy.

JEL-Classification: F 31 (foreign exchange), F 38 (international financial policy), E 58 (central bank policies)

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1. Introduction

This paper presents the first empirical evidence that foreign exchange interventions (FXI), i.e. the buying or selling of foreign currency by central banks, have significant output effects. We compute an intervention-to-GDP multiplier of 0.5 and document that the effectiveness is comparable to that of conventional monetary policy. The evidence complements theoretical work showing that FXI may work and improve welfare in imperfect international markets (Gabaix and Maggiori, 2015; Fanelli and Straub, 2021; Itskhoki and Mukhin, 2023). It also complements long-standing practice of central banks based on firm believes about the merits of this policy (e.g., Neely, 2008), and mounting evidence on the effectiveness of other balance sheet policies like quantitative easing (e.g., Bhattarai and Neely, 2022).

Exchange rate policy has been a focus of international policy coordination and monetary systems at least since the Gold Standard. Today, the foreign exchange market is the largest financial market in the world, with a daily transaction volume of 7.5 trillion U.S. dollars, and foreign reserves are countries' largest external asset position, accounting for 20% of total external assets and 11% of GDP (Milesi-Ferretti, 2022). While some central banks, such as the Federal Reserve or the European Central Bank, have rarely used FXI during the last two decades, the interest in exchange rate policy has regained momentum recently due to rising geopolitical tensions. FXI are frequently used by many other advanced economies, such as Japan or Switzerland, and they are in the regular toolkit of monetary authorities in emerging and developing economies (Frankel, 2019; Adler et al., 2025).

FXI intend to stabilize foreign exchange markets and to influence the level of the exchange rate. However, this is often not the final objective. FXI aim at supporting the real economy, i.e. to stabilize economic activity. What is missing so far, complementing the theoretical foundations and practiced policy, is empirical evidence about the effects of FXI on the real economy.

Previous studies have analyzed the impact of FXI on exchange rates. For a long time, even this effect seemed to be debatable (Sarno and Taylor, 2001). However, during the last years the assessment of FXI has become more favorable (e.g., IMF, 2022). Recent theoretical and empirical analysis supports the effectiveness of FXI at managing exchange rates, further substantiating the long-standing use by central banks. This motivates to go one step further, i.e., to extend the analysis of FXI from the impact on the exchange rate (and financial markets in general) to potential effects on the real economy.

In this paper, we use a panel structural vector autoregression (SVAR) to analyze the macroeconomic effects of FXI. We focus on the most important and major traded freely floating currencies in the world, the Japanese yen, U.S. dollar, Euro, and British pound. These currencies account for 74% of all daily transactions in the global FX market. We find that surprise purchases of foreign currency lead to a significant increase in domestic output, together with a significant depreciation of the domestic currency. The effects are persistent and are accompanied by further changes in the macroeconomy, such as increasing (net) exports and a slight increase in domestic inflation. We obtain an intervention-to-GDP multiplier of 0.5, comparable to the size of fiscal multipliers, and show in a common framework that FXI is similarly effective as standard monetary policy. Overall, this set of macroeconomic results is new in the literature and economically important for policy makers.

The major challenge in examining the impact of FXI, even more so at the macro level, is identification because FXI tend to be directed against a prevailing exchange rate trend, the so-called "leaning against the wind." This dominating intervention policy leads to the well documented fact that – at the monthly level – FXI in the form of purchasing foreign currency is related to an appreciation of the domestic currency; thus, FXI seems to be ineffective. This result has motivated prior researchers to analyze FXI at a higher frequency, where interventions are shown to be effective. However, for the macro-analysis building on monthly or lower frequency data, the identification of exogenous FXI remains a challenge.

We address the challenge by building an instrument for FXI based on daily intervention data. This follows other macro studies that exploit high-frequency data to construct instruments for structural shocks (e.g., Nakamura and Steinsson, 2018; Känzig, 2021). We take five steps, of which three follow the procedure in Menkhoff et al. (2021) and two others are new to deal with monthly data (steps three and five). First, we restrict the sample to countries with a floating exchange rate regime that publish daily FXI data and sterilize FXI. In this regime, FXI occur infrequently and are largely idiosyncratic events, so that they are much more difficult to forecast than FXI in (narrow) band regimes (Ilzetzki et al., 2019). Second, we use only the intervention on the first day of an intervention sequence. Interventions typically occur in sequences, where the first day has a higher intervention volume than later intervention days and captures an exogenous event, free from concrete anticipation (Fischer and Zurlinden, 1999). Third, we consider – whenever possible – only intervention starts at the beginning of a month to reduce the probability of endogenous FXI reactions to exchange rate changes during earlier days of the month. Fourth, we code an indicator of the intervention direction on the first day of a sequence instead of using the actual volume to rule out that the traders executing the intervention directive react to daily market conditions by adjusting the volume. Finally, we aggregate the daily indicator to a monthly frequency. These steps deliver a monthly instrument for FXI in four major freely floating currencies based on daily data that measures the direction of an intervention sequence start happening at the beginning of the month.

We use the instrument in a panel SVAR with monthly data since the 1990s to identify latent structural FXI shocks and to trace their dynamic impact on the real economy, using the methodology of Stock and Watson (2012) and Mertens and Ravn (2013). An important advantage of this approach is that our instrument is treated only as a noisy measure of true FXI shocks, which may capture further elements, particularly the communication of authorities. This reduces a potential attenuation bias relative to approaches that treat FXI measures as a one-to-one mapping to the latent structural shock.

We find economically and statistically significant effects of FXI shocks on the real economy. A surprise purchase of foreign currencies of 1 billion U.S. dollars induces a hump-shaped rise in industrial production, which increases by 0.1% above trend at peak and returns to trend after about two years. Variance decompositions show that FXI shocks explain about 2-4% of the unexpected variation in output at different horizons. Historical decompositions detect prolonged periods in the 1990s and 2000s where FXI shocks changed the level of production below or above the level where it would have been without the interventions. A back-of-the-envelope calculation for quarterly data implies that an intervention shock of 1 billion U.S. dollars increases nominal GDP by 0.5 billion U.S. dollars on average, indicating an intervention-to-GDP multiplier of 0.5, at the lower bound of the range of fiscal multipliers and largely in line with the output effects of completely different exchange rate shocks (Fukui et al., 2025).[1] Finally, we show that the macroeconomic effects of FXI are similar to those of standard monetary policy shocks.

Our findings suggest that the transmission of the FXI shocks runs through the external value of the domestic currency, which depreciates significantly for many months following an

[1] Fukui et al. (2025, p.14) report that a depreciation of the nominal effective exchange rate of 0.9% results in a 0.4% increase in GDP after four years. We find that a 1 billion U.S. dollar FXI shock leads to a depreciation of about 0.2% at peek and an increase in production by 0.1%.

expansionary shock. The impact is strong enough to also influence the (trade weighted) effective exchange rate, so that the intervention in one market is not compensated in other FX markets. Consistently, we find that real exports increase significantly and persistently. Real imports increase as well, but less and insignificantly, such that net exports are above trend for half a year. The currency depreciation and the increase in output also lead to a tentative, but also insignificant decline in the unemployment rate and a small increase in inflation, which becomes significant after half a year.

These results are derived from a specific sample, i.e. four advanced economies with floating exchange rates. We discuss the generalizability of results in Section 4, but mention already here that FXI behavior is different in countries with fixed exchange rates. Moreover, the impact of FXI may differ in emerging economies because of thinner financial markets and less trade invoicing in domestic currency. Regarding our group of countries, Japan dominates the sample, but we find the same qualitative pattern of results if we analyze Japan, the United States and the United Kingdom (joint with the Euro Area) separately.

Literature. Research on FXI focuses on either institutional foundations, theoretical reasoning or empirical evidence. Papers on institutional foundations often survey authorities and show their appreciation for FXI (e.g., Neely, 2008). Early theoretical research explored various channels by which FXI may impact exchange rates, surveyed by Sarno and Taylor (2001). In particular, the portfolio balance channel has been elaborated also in recent research (Frankel and Dominguez, 1992; Gabaix and Maggiori, 2015; Maggiori, 2022). Further theoretical work analyzes optimal FXI policy responding to capital flows (due to shifting demand in asset holding) in a small open economy (e.g., Cavallino, 2019; Fanelli and Straub, 2021; Hassan et al., 2023; Itskhoki and Mukhin, 2023).

The bulk of research, however, centers around the empirical examination of interventions. Sarno and Taylor (2001) do not draw a firm conclusion regarding effectiveness, but much research has developed since then which tentatively supports the case of FXI. We select a few representing strands of literature during the last two decades. One strand uses high-frequency data to isolate the effect of FXI (e.g., Dominguez, 2003). Another strand applies an event-study approach with daily data (e.g., Fatum and Hutchison, 2003; Fratzscher et al., 2019). A third strand uses country-specific circumstances for identification (e.g., Kuersteiner et al., 2018). A fourth strand creates counterfactuals to assess FXI impact (e.g., Chamon et al., 2017). All these approaches show some effectiveness of FXI in limiting exchange rate volatility and influencing the exchange rate level.

These analyses capture days or weeks but not the macroeconomic horizon of months and quarters ahead. Work in this direction typically introduces instruments to address endogeneity of FXI and applies VAR-approaches to show longer-term effects of FXI on the exchange rate, such as Blanchard et al. (2015). Still, there are two limitations, i.e., these articles exclusively focus on effects on the exchange rate and rely on instruments that are debatable. The first issue has been addressed by Jin et al. (2021) who consider in a reduced form approach a set of macro variables that may be affected by FXI, although not output. The second issue has been addressed by Menkhoff et al. (2021) who use a daily instrument in a Proxy-SVAR model. They analyze the impact of FXI on financial markets at a daily frequency and find – among others – that stock prices of larger (i.e., more export oriented) firms gain from FXI depreciating the domestic currency.

While our study is related to Menkhoff et al. (2021) by relying on the same kind of methodological approach and countries, we differ in several important ways: most crucial, our focus is on the real economy, which implies working with respective variables in the SVAR model, such as output and exports. In contrast, the other paper is limited to financial variables, such as interest rates and stock prices. Moreover, the monthly data need some adjustment to obtain a suitable instrument. Because of the lower frequency, we lose observations relative to Menkhoff et al. (2021) which we address by using a panel approach.

In sum, none of the earlier studies examines the causal impact of FXI on the macroeconomy, in particular on output – this is our contribution.

2. Empirical framework

2.1 The panel SVAR model

The reduced-form representation of the panel SVAR for the monthly frequency is

$$\mathbf{y_{it}} = \mathbf{C_i} + \sum_{\mathbf{l=1}}^{\mathbf{p}} A_l y_{it-l} + \mathbf{Dx_{it}} + \mathbf{u_{it}} \tag{1}$$

with $i = 1,\dots,N$ countries and sample length $t = 1,\dots,T$. The vector $\mathrm{y_{it}}$ contains $k = 1,\dots,K$ endogenous country-specific variables. C_i includes country-specific fixed effects. The matrices A_l contain the autoregressive part of the model and D captures parameters on contemporaneous exogenous variables. The vector $u_{it} = \left(u_{1,it},\dots,u_{K,it}\right)'$ contains the reduced-form errors, which are zero-mean white noise with covariance matrix $E(u_{it}u'_{it}) = \Sigma$.

The panel contains four countries: Japan, the United States, the Euro Area, and the United Kingdom. The countries are selected because they have the most important freely floating currencies in the world and because their data on FXI at a daily frequency are publicly available. The baseline specification contains four endogenous variables. First, we use the level of the intervention volume of purchases and sales of foreign currencies, computed as the cumulative sum of daily interventions. We use this variable as a policy indicator to determine the sign and size of latent FXI shocks. The variable is scaled in billion U.S. dollars. Second, we add the log of the nominal bilateral exchange rate, which we generally define as foreign currency to domestic currency. We use the bilateral rate against the main intervention currency based on the sample mean of all interventions per country. Thus, the model contains the USD/JPY, EUR/USD, USD/EUR, and JPY/GBP exchange rates. Third, we use the short-term interest rate differential to the respective foreign country to control for monetary policy. Fourth, we include the log of real industrial production as the main outcome variable for determining whether FXI shocks have real macroeconomic effects (more details on data in the Appendix). In the second step of the analysis, we extend the y_{it}vector to obtain a broader picture of the effects of FXI on the real economy.

In all models, we control for seasonality, FXI of foreign countries, monetary policy surprises, and address potential structural breaks (e.g. in industrial production) by including monthly dummies, the cumulative intervention volume of the respective foreign country, monetary policy surprise series, and a linear-quadratic trend in the vector x_{it}. We estimate the model in levels and set $p = 12$, in line with the monthly frequency, even though information criteria indicate an optimal lag length of 3. Using a different lag length, omitting the trend entirely, including a linear trend only, normalizing the intervention volume by GDP, and controlling for uncertainty yields similar results (Section 4).

We use the reduced-form errors of Equation (1) to recover the structural shock of interest. Specifically, we assume that the errors are linearly driven by an FXI shock ϵ_{it}^{p}, and by other structural shocks $\epsilon_{\mathrm{it}}^{*}$ irrelevant for our analysis. We can write the linear combination as

$$\boldsymbol{u}_{it} = \boldsymbol{B}\boldsymbol{\epsilon}_{it} = \boldsymbol{b}^{p}\boldsymbol{\epsilon}_{it}^{p} + \boldsymbol{B}^{*}\boldsymbol{\epsilon}_{it}^{*}. \tag{2}$$

The B matrix contains the contemporaneous impact of the structural shocks on the endogenous variables in y_{it}. The structural shocks ϵ_{it} are assumed to have a diagonal covariance matrix with unit variance. To identify the impulse vector b^p and recover the intervention shocks ϵ_{it}^p, we construct an external instrument s_{it} and use the identification approach of Stock and Watson (2012) and Mertens and Ravn (2013).

The central step of determining b^p is the estimation of the relative impulse vector $\tilde{b}^p$, denoting the relative impact of exogenous changes in the policy indicator on all other variables $K-1$: $\tilde{b}^p = b^p/b_1^p = \left(1, b_2^p/b_1^p, \dots, , b_k^p/b_1^p\right)'$. For simplicity, we order the policy variable first, but it can be arranged in any order. We construct an external instrument s_{it} correlated with the policy shock of interest

$$\boldsymbol{E}\left(\boldsymbol{s}_{it}\boldsymbol{\epsilon}_{it}^{p}\right) \neq \mathbf{0}, \tag{3}$$

but uncorrelated with all other structural shocks

$$\boldsymbol{E}\left(\boldsymbol{s}_{it}\boldsymbol{\epsilon}_{it}^{*}\right) = \mathbf{0}. \tag{4}$$

Then, the instrument s_{it} and the residuals $\hat{u}_{k,it}$ from Equation (1) are used to estimate

$$\widehat{\boldsymbol{u}}_{k,it} = \boldsymbol{\alpha}_k + \boldsymbol{\beta}_k \boldsymbol{s}_{it} + \boldsymbol{\nu}_{k,it} \;. \tag{5}$$

We use the estimated $\hat{\beta}_k$ coefficients of Equation (5) to compute $\tilde{b}^p$ as $\left(1, \hat{\beta}_2/\hat{\beta}_1, \dots, \hat{\beta}_k/\hat{\beta}_1\right)'$. Finally, we combine the estimated $\tilde{b}^p$ with the covariance restrictions $\Sigma = BB'$ to get the absolute impulse vector b^p. In the baseline, we assume homogenous coefficients across countries (apart of constants) given the limited number of non-zero instrument observations. The results hold when using a mean group estimator (Section 4).

2.2 Data

We use monthly data because this is the highest frequency at which information about the real economy is available, such as industrial production or exports and imports. The sample starts vary across countries as we make sure to cover only periods of freely floating exchange rate regimes. Thus, the sample is 1991M4-2022M12 for Japan and the United States because intervention data for Japan start in April 1991. The samples for the Euro Area and the United Kingdom start in 1999M1 and 1992M10, respectively. Details on the data, sources, and definitions are in the Appendix. The results are similar if we extend the Euro sample backward, using German macro data and Bundesbank interventions (Section 4).

The Bank of Japan intervened in 72 out of 381 months of the sample, as summarized in Table 1. Its intervention behavior is characterized by primarily purchases of the U.S. dollar. On average, the absolute volume is 12.4 billion U.S. dollars per intervention month. In comparison to Japan, the sample contains fewer and smaller interventions for the United States, the Euro Area, and the United Kingdom. Together, these three countries intervened 27 times in the sample. The Bank of Japan and the Federal Reserve Bank adjusted their intervention strategies after the mid-1990s regarding the length of intervention sequences and volumes (see Appendix A and Section 5). Interventions are mostly clustered in the 1990s and fewer in the 2000s to 2020s. The FXI covered here are sterilized, i.e. central banks offset the effect on the monetary base by opposing transactions such as open market operations (Menkhoff et al., 2021; Fatum et al., 2024).

< Table 1 >

2.3 Instrument

The main challenge we face is the endogenous character of FXI. Central banks often intervene in the FX market by responding to exchange rate movements. We address the challenge by constructing an instrumental variable for FXI based on daily data for the intervention direction, volume, and currency of central banks. The instrument should be a good proxy for the full setup of FXI policy but should develop its impact only via this FXI policy on the variables of interest, such as output and the exchange rate. We proceed in the following five steps to ensure that the instrument is exogenous to other structural shocks:

1. We use only data from countries with freely floating exchange rates to focus on FXI-events that are difficult to forecast by market participants, and thus largely surprising to them. These are the four countries of the sample. Here, central banks do not follow a pre-announced rule regarding FXI and they do not announce their FXIs prior to intervention. Moreover, their decision-making process leading to FXI typically involves different institutions. For example, in Japan the Ministry of Finance is the principal and the central bank is the agent. Decisions thus take some time and do not react on short-term events, so that neither the exact FXI timing nor their amount can be expected with certainty. This can be also recognized from central bank statements at times of FXI that rather focus on exchange rate level concerns than on shorter-term volatility concerns (see Appendix B).
2. We select only intervention days that are the start of an FXI sequence. Central banks mostly intervene in sequences that stretch over days or weeks, usually intervening consistently in one direction within sequences. However, the information contained at the various days is different. The first day of a sequence has the highest information content, reflecting the decision-making process when the central bank implements the time-consuming policy decision to intervene. Because of this process the first intervention day is also largely exogenous. Continued FXI at a following day, by contrast, may indicate that the exchange rate is developing not as intended, so that the FXI becomes endogenous.[2] The particular importance and information content of the first day of FXI has been substantiated by high-frequency research which shows that the first FXI-volume in a sequence is typically twice

[2] One-day interventions, such as in March 2011 or, more recently, in September 2022, are treated analogously to the first day of a sequence, as these days are similarly free from anticipation, irrespective of the number of following intervention days.

as large as later FXI-volume and it has a much larger impact than other interventions of a sequence (e.g., Fischer and Zurlinden, 1999). We define a sequence start when there were no FXI during the prior five days, in line with previous research (e.g., Fatum and Hutchison, 2003; Fratzscher et al., 2019). The definition has proved to be robust to some variation, such as requiring a ten-day interval between sequences.

3. We focus on sequence starts at the beginning of the month. Thereby, we address the consequence of working with monthly macro data, including exchange rate changes during a full month. Otherwise, we could have situations in which the intervention is placed towards the end of a month, thus being unable to influence the exchange rate during the full month. Accordingly, we prefer to consider FXI during the beginning of a month. However, this requirement depends on data availability. As we have most interventions, and consequently sequence starts, for Japan, we consider here only starts within the first week of a month. We have fewer starts for the U.S. so that we here consider the first two weeks. As we have only a hand full of interventions for the Euro Area and the United Kingdom, we consider any FXI.
4. To further reduce the risk of reverse causality, we use a categorical variable for the direction of the intervention on the first day of a sequence. This transformation reduces the risk that the intervention volume on the first day of the sequence is based on the size of exchange rate movements on that day. We define the variable to have values [-1, -0.5, 0, 0.5, 1]. We code a 1 (in absolute value) if the intervention volume on the first day is above the country's average daily volume, and a 0.5 (in absolute value) if it is below that threshold but unequal zero. If there is no start of the sequence, we code a 0. Thereby, we retain some information about the intensity of the intervention as the intervention volume may matter for its effectiveness (e.g., Fratzscher et al., 2019).

To see whether the intervention surprises work, we estimate an event study panel regression to analyze the impact of the daily intervention indicator (start of new sequences at the beginning of the month) on daily exchange rate changes.[3] Table 2 suggests that nominal exchange rates move significantly in the intended direction on the days when FXI sequences start. The point estimate on the intervention indicator is 0.9-1.0, depending on the specification, and statistically significant across all specifications and according to four different types of standard errors that range between 0.3-0.5. A start of a new purchase sequence of domestic currency leads to an appreciation of the domestic currency of about 1% on the same day on average.

< Table 2 >

5. Then, we aggregate the daily indicator variable that records the direction of intervention starts happening at the beginning of the month to a monthly level, consistent with the macroeconomic data in the SVAR.

In sum, these five steps deliver 28 months with non-zero instrument observation in total, recording the start of a sequence mostly with purchases of foreign currencies. Half of them constitute coordinated FXI. We test the strength of the instrument by computing the F-statistic for the null hypothesis $\beta_1 = 0$ using Equation (5). For the baseline specification, the F-statistic

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[3] We estimate the following regression model. $\Delta \ln FX_{it} = \alpha_i + \beta\, Int_{it} + \gamma\, X_{it} + \eta_{it}$, with $i = 1, \ldots, N$ countries and sample length $t = 1, \ldots, T$. α_i are country-specific fixed effects and X_{it} contains additional controls, being either day-of-the-week dummies or one lag of the endogenous variable. η_{it} is the error term. $\Delta \ln FX_{it}$ is the log change in the nominal bilateral exchange rates against the main intervention currency based on the sample mean of all interventions per country, quoted indirectly with the domestic currency as the base currency. Int_{it} is the intervention indicator that contains 30 starts of intervention sequences. We provide a table of changes in exchange rate levels on the days FXI sequences start in Appendix D.

is 33.1. For the extended models, the F-statistics vary between 31.2 to 34.3 Thus, the instrument is strong, exceeding the threshold value of 10 (Stock et al., 2002). Further, we compute the reliability measure of the instrument of Mertens and Ravn (2013), which is 0.55. This measure is the R-squared of a regression of the structural FXI shock on the non-zero instrument observations. Thus, the instrument contains valuable information to identify the structural shocks, but measurement errors are likely.

We also assess the quality of the instrument by testing whether lags of the endogenous variables predict it. Neither variable Granger-causes the instrument (see Appendix D). Following the literature on monetary policy surprises, particularly by Bauer and Swanson (2023), we conduct another test on instrument predictability. We regress the instrument on a set of lagged macroeconomic variables, whose deviations from short-term trend could predict the direction of future interventions. The variables are ingredients of standard exchange rate models and central bank intervention reaction functions, namely actual and forecasted exchange rates, interest rates, output, trade and oil prices. Table 3 suggests no concerning prediction of the instrument by these macroeconomic variables. The R-squared is only 3-4%, depending on the specification. However, a few point estimates (for interest rates and imports) are statistically significant.[4] We interpret this as type I error but nevertheless estimate the baseline model using orthogonalized FXI shocks, which hardly change the responses (Figure J8 in Appendix J).[5]

[4] We regress the monthly instrument on nine one-period lagged macroeconomic variables, measured as differences to their three-, six-, and twelve-month moving averages, with each model specification consistently using one of these time horizons. The regression model follows Bauer and Swanson (2023) and is specified as: $Int_{it} = \alpha_i + \beta X_{it-1} + \gamma Z_{it} + \eta_{it}$, with $i = 1, \ldots, N$ countries and sample length $t = 1, \ldots, T$. Int_{it} is the intervention indicator, α_i are country-specific fixed effects, and X_{it-1} contains the macroeconomic variables, which are known prior to the FXI. Z_{it} contains monthly dummies. η_{it} is the error term.

[5] Orthogonalized FXI shocks are conceptually based on Bauer and Swanson (2023, 2023a). We use the residuals from Table 3 regressions.

Further tests yield no statistically significant evidence against the null hypothesis of invertibility of the SVAR model (see Appendix E). Section 4 shows that the results are robust to using local projections and to alternative definitions of the instrument, such as weighting it, excluding unilateral interventions, or different coding of the indicator variable. Finally, if our instrument did contain some remaining endogeneity despite the five identification steps, our estimates would present a lower bound of the effectiveness of FXI.

< Table 3 >

3. Results

3.1 Baseline model

Figure 1 reports the results for the baseline model showing the responses of the endogenous variables to an intervention shock over a horizon of 24 months with their 68% and 95% confidence bands. We use a fixed-design wild bootstrap procedure based on 1,000 bootstrap replications. This bootstrapping procedure handles the generated regressor problem by including both stages of estimation within each replication (see Mertens and Ravn, 2013). The results are robust to using a block bootstrap (Section 4). The block bootstrap is not ideal for our sample with few non-zero instrument observations which can lead to bootstrap blocks without non-zero instrument observations.

< Figure 1 >

The upper left panel shows the policy indicator used to scale the sign and size of the shock. We consider a shock of 1 billion U.S. dollar surprising purchase of foreign currencies by central banks. The typical intervention reaches a maximum level of about 2 billion U.S. dollars and converges back to its initial level. This large and persistent intervention shock causes an immediate increase in industrial production by 0.07%. Output increases further in a hump-shaped manner, reaching its maximum of 0.10% after six months. Overall, the impact is statistically significant for about one year.

Further consequences of the intervention shock inform about the transmission of the shock. The purchase of foreign currency depreciates the domestic currency against its reference currency significantly. The impact effect is 0.11%. The exchange rate depreciates further for another six months, in line with the increasing intervention volume. Thereafter, the exchange rate converges to the level where it started. The exchange rate effect is statistically significant for the full horizon of 24 months.

Lastly, we estimate a slight decline in the interest rate differential. It drops by up to 0.01 percentage points. The decline in the three-month rate possibly mirrors expectations about future monetary easing, in line with a signaling channel of FXI. The effect is small, however.

The estimated contemporaneous impact on the exchange rate of 0.11% is largely in line with the literature. A meta-study estimate on 67 FXI observations in free floating exchange rate regimes shows a 0.4% depreciation caused by 1 billion U.S. dollar purchase; these studies analyze usually all FXI, so that our restriction to the first FXI in intervention sequences (measuring a much higher impact) leads to a qualitatively similar result (Arango-Lozano et al., 2024). While there is no other paper, according to our knowledge, examining the same panel, we can compare our results to other studies examining FXI of Japan because these observations dominate our sample. Menkhoff et al. (2021) report a devaluation of the Japanese Yen of 0.2%

in response to a surprising purchase of 1.7 billion U.S. dollars, an implied effectiveness similar to our findings. They also show that their result fits well to other studies, such as Chen et al. (2012), although these later studies report findings on horizons of days or weeks only.

3.2 Economy-wide effects

We extend the baseline model by adding one fifth variable to the y_{it} vector at a time to obtain a broader picture of the macroeconomic effects of FXI.[6] Specifically, we estimate nine extensions. We collect the responses of the additional variables in Figure 2 and the responses of the baseline variables in the augmented models in Appendix F. The results for the baseline variables remain qualitatively unchanged.

< Figure 2 >

We start with the results on further exchange rates. The effect on the bilateral exchange rate largely translates into the nominal effective exchange rate, although to a somewhat smaller extent as not all other exchange rates react as strongly as the one with FXI. Moreover, the intervention also impacts the real bilateral exchange rate almost as strong as the nominal one, in line with the expectation that financial prices react faster and stronger than goods prices. Due to the impact of FXI on the nominal effective exchange rate and on the real bilateral exchange rate, it follows that there is also an impact on the combination of these two effects, i.e. on the real effective exchange rate. However, reflecting the smaller effects of the two elements (i.e.

[6] We add, one at a time, the log of the nominal effective exchange rate, the log of the real bilateral exchange rate, the log of the real effective exchange rate, the inflation differential to foreign country in percentage points, the log of real exports and the log of real imports, real net exports to monthly real GDP in percent, the unemployment rate in percent, and the ten-year rate on government bonds in percent. All variables enter in levels.

nominal effective and real bilateral), the combination of the two leads to an effect which is borderline significant. Still, overall, the domestic exchange rate depreciates in all forms of measures.

The somewhat smaller effect on the real relative to nominal exchange rates goes along with a small, but only partially significant, increase in domestic inflation relative to foreign inflation. Both higher output and the declining nominal exchange rate, leading to an increase in import prices, contribute to the rise in the general price level (see also Jin et al., 2021). The small size of this effect indicates a marginal pressure on prices and thus no risk for an inflation target.[7] The changes in the exchange rates also influence trade flows, as a depreciation stimulates exports, which is a stylized fact in international economics. The increase in real exports is about 0.2% at impact and converges back to its initial level after 10 months. Real imports slightly increase at first and over time by up to 0.1%, but remain insignificant for most of the period. Because of the change in real exports and real imports, real net exports also increase and seem to be one main explanation for the increase in output.

Further, we find a tentative decrease in the unemployment rate, but the intervention shock of 1 billion U.S. dollars just leads to a decrease of about 0.003 percentage points and the impact is estimated imprecisely. Thus, the FXI shock increases industrial production but this does not fully feed through to the economy-wide labor market. Finally, the ten-year interest rate does not respond significantly, possibly reflecting the each other offsetting decline in the short-term rate and the increase in inflation.

Overall, the consideration of these further macro variables contributes to a fuller picture what FXI do to the economy. Interventions do not only impact the exchange rate, but this effect

[7] When we use the measure of core inflation instead of consumer price inflation, which is more relevant to monetary policy, there is no significant effect of FXI on inflation. The reason could be that depreciation directly increases import prices, in particular those on energy commodities that are excluded from the measure of core inflation.

is strong enough in our sample to create sizable effects in parts of the real economy, in particular regarding output and trade.

3.3 Variance and historical decomposition

To quantify the average economic importance of the results, we compute the h-step ahead forecast error variance decomposition. This procedure quantifies how much the estimated intervention shocks contribute to variation in the forecast errors of the endogenous variables. Table 4 documents the results for the baseline specification at horizons up to 24 months. Generally, higher percentage shares indicate that the intervention shocks are more relevant for understanding unexpected variation in the respective variable.

< Table 4 >

The shocks explain a large fraction of the cumulative total intervention volume, which contains all interventions and not only the first day of a sequence. The explanatory power in the first month is 89% and decreases to 77% over longer horizons. For the nominal bilateral exchange rate, the intervention shocks explain 5% of the variability. The share is roughly halved for the short-term interest rate, as expected given the small response (see Figure 1). The explanatory power for industrial production, with up to 4%, indicates that FXI have a relevant effect on the real economy without dominating their development.

Next, we show results of a historical decomposition of the nominal bilateral exchange rate, industrial production, and real exports to assess the economic importance of past intervention shocks on historically observed fluctuations in these variables. We focus on Japan as we have most interventions here. There are two noteworthy intervention sequences. In

2003/2004, the Bank of Japan intervened with purchases of 315 billion U.S. dollars. In times of a stagnant economy, it aimed for depreciating the Japanese yen, probably to stimulate the domestic economy. Figure 3 shows that these interventions indeed curbed the appreciation of the domestic currency as the difference between the fitted data and the counterfactual shows. Consistently, real exports and industrial production are persistently above the level where they would have been without the interventions. We find similar results for the 2011 intervention, where the G7 countries coordinately intervened in response to a strong appreciation of the yen after the Tohoku earthquake (see Ito and Yabu, 2007, for more details on Japanese FXI policy).

< Figure 3 >

3.4 Comparison to monetary and fiscal policy

To put the efficacy of FXI into perspective, we compare the effects to those of standard monetary policy and fiscal policy interventions. For the comparison to standard monetary policy, we construct a level playing field. We slightly modify the baseline model into a common panel Proxy-SVAR framework for the estimation of FXI shocks and monetary policy shocks. More specifically, the y_{it} vector now contains six endogenous variables: the cumulative intervention volume and the one-year interest rate on government bonds as policy indicators for each shock, the log of nominal effective exchange rate, core inflation, log of economic activity, and the log of stock prices.[8] The monetary policy surprises are excluded from the exogenous

[8] Given the limited variation in manufacturing in the UK, we use the monthly GDP indicator to better capture output variation. The comparison of the two policy types is imperfect because the underlying structures in these panel estimations are not the same: FXI occur mainly in Japan, while monetary policy shocks are more equally distributed.

variables x_{it} and instead used as external instrument to identify latent monetary policy shocks. We incorporate inflation as a major objective of monetary policy and stock market prices as another forward-looking financial variable. Monetary policy is principally less bilaterally oriented than FXI, so we do not consider bilateral exchange rates or interest rate differentials. As external instruments, we use monetary surprises, such as provided by Bauer and Swanson (2023; 2023a) for the United States (more details in Appendix G). The F-statistic for the first stage is 46.2.

Figure 4 left column shows the responses to a one standard deviation FXI shock.[9] The results are qualitatively like those of the baseline model but quantitatively larger due to the higher FXI volume of 4 billion U.S. dollars. The right column shows the responses to a one standard deviation expansionary monetary policy shock that is about 0.15% at impact. It lowers the one-year rate by up to 0.21% points for one year. Then, the rate returns to trend. The exchange rate depreciates, while output, stock prices and inflation go up. The intervention volume does not respond upon impact, suggesting that the external instruments for the two types of shocks are orthogonal.

Comparing the size of the responses across shocks suggests that typical FXI shocks are as effective as typical standard monetary policy shocks. Output increases slightly more following FXI shocks, while inflation is somewhat more responsive to monetary policy shocks. Additional analyses indicate that the transmission mechanisms of both policies differ. While FXIs depreciating the exchange rate mainly work through immediate export stimulus and delayed import increase, monetary policy stimulates primarily domestic demand, thus also imports, whereas exports react delayed (see Appendix G).

[9] Using one standard deviation shocks here allows for a comparison of typical FXI shocks and typical monetary policy shocks.

< Figure 4 >

A similar comparison of FXI to the efficacy of fiscal interventions is not possible due to a lack of monthly fiscal data. Instead, we conduct a back-of-the envelope calculation. A standard metric to evaluate the effectiveness of fiscal policy is the fiscal multiplier. It measures the increase in GDP in U.S. dollars for each additional U.S. dollar of fiscal spending (or reductions in tax revenues). Similarly, we compute an FXI multiplier that measures the increase in GDP in U.S. dollars for each additional U.S. dollar of intervention volume. First, we compute the average of the impulse response of industrial production for the first quarter from the baseline model (see Figure 1), which is 0.07%. Second, we compute the elasticity of GDP to industrial production in the sample by estimating a linear panel regression model (details in Appendix H). We obtain an elasticity of 0.36. Third, we multiply the percentage change in GDP induced by the surprise intervention with the average nominal GDP in the sample. Finally, we divide the change in GDP by the intervention volume of 1 billion. We obtain an FXI multiplier of 0.5. Thus, a surprising purchase of foreign currencies worth 1 billion U.S. dollars delivers an additional 0.5 billion U.S. dollars in nominal GDP within the first quarter. The literature on fiscal multipliers reports results in a wide range of roughly 0-3 (e.g., Ramey, 2011; Auerbach and Gorodnichenko, 2012). The FXI multiplier of 0.5 lies toward the lower bound of this range.

4. Generalizability

The findings in this paper are based on a sample of four countries and we discuss to which degree these findings may be generalized. We consider five issues in this respect, i.e. the exchange rate regime, differences between advanced and emerging economies, possible asymmetries between intervention purchases and sales, the role of Japan in our sample, and implications for the use of FXI.

First, this study considers the FXI regarding four currencies that are all operating in a floating exchange rate regime. The study focuses by purpose on this regime to increase the likelihood that the selected FXI events are exogenous. By contrast, a regime with fixed exchange rates requires recurrent FXI to stabilize the exchange rate such that interventions are largely expected. Between fixed and floating exchange rates, there is a continuum of other regimes that operate with some flexibility. Taking the classification of Ilzetzki et al. (2019), there are 8 countries /currency areas with floating exchange rates, 84 with fixed exchange rates, and 64 with intermediate regimes, according to the latest available data from 2019. The floaters are economically large as the four cases covered here (the United States, Euro Area, Japan and the United Kingdom) make up for more than 50% of world GDP in 2022. Thus, our analysis and possible extensions to further countries are relevant for the world economy.

Second, we cover only advanced economies which typically differ from most emerging economies in some institutional aspects that may matter for FXI. Deeper financial markets in advanced economies ease substitution mechanisms regarding central banks purchases or sales of foreign currency and thus lower FXI effectiveness. However, advanced economies also tend to invoice their trade to a larger extent in domestic currency, which helps to avoid negative effects from the import side and still supports gains in real exports. On top of this, emerging economies rely more on commodity exports, markets that are often regulated via quotas or longer-term contracts. In sum, the intervention impact on exchange rates may be stronger in emerging economies, while the impact of an exchange rate change on output may be stronger in advanced economies.

Third, our analysis is by construction symmetric regarding purchases and sales of foreign currency. There is some evidence that FXI buying foreign currency may be more effective than selling it, possibly because this intervention direction can more easily be kept up. As we cover more often purchases, as is also the case in larger databases (e.g. Fratzscher et al., 2019; Adler et al., 2025), we may overestimate the general impact of FXI on the exchange rate and thus on the macroeconomy.

Fourth, while we consider four currencies in a panel approach to increase the number of observations, the empirical analysis is in fact dominated by Japan that has almost 60% of non-zero instrument observations according to our criteria. Thus, Figure 5 provides results when we split up the panel into Japan (with 16 non-zero instrument observations), the United States (7 observations) and the Euro Area together with the United Kingdom (jointly 5 observations), using the baseline SVAR specification. In all cases the direction of change is the same as in the panel approach. Foreign currency purchases lead to a domestic currency depreciation and an increase in output. However, the depreciation and the increase in production are only weakly statistically significant for some countries according to the one standard error bands. Not surprisingly, the significance and the size of the reactions for Japan are closest to the panel approach.

< Figure 5 >

Due to the loss of observations in the three models relative to the panel model, we also estimate a model with fewer lags. Appendix I shows results when the number of lags is reduced from 12 to 6 lags. The consequence of this modification is that the results become sharper, for example, the increase in output for Japan turns statistically significant. Overall, we conclude that the panel results are dominated by Japan, but that they also tend to hold for the United States and the group of Euro Area and the United Kingdom.

Finally, one may wonder whether the impact of FXI holds across space and time. The results are based on two further conditions that increase the likelihood that the identified FXI have an impact: first, we analyze specific FXI, i.e. the first day of a sequence, that usually have a higher impact than the average FXI. Second, intervention decisions are typically made by informed policy makers who can reasonably assess whether success will be likely. These two conditions potentially increase the impact of FXI impact, which would imply that our estimates are probably at the upper bound.

Overall, we do not claim that our results would apply to all kinds of FXI implemented anywhere at any time. At the other extreme, results are not specific to Japan only. The degree of generalizability seems to be in between these extremes: the findings apply to regimes with flexible exchange rates, i.e. definitely floating regimes, but definitely not to fixed exchange rates. They apply to advanced economies, possibly less to emerging markets. They apply better to countries that purchase foreign exchange than selling it. They cover the impact of selected FXI that are typical for informed policy making.

5. Sensitivity analysis

In this section, we summarize sixteen sensitivity analyses. They show that the main results do not change qualitatively; the details are in Appendix J. First, we change the lag length of the endogenous variables from 12 lags to a range of between 3 and 36 lags. Second, we show results with 24 lags and corresponding confidence bands. Third, we estimate the model with either a linear trend or without any trend component. Fourth, we normalize the intervention volume by monthly GDP to account for different sizes of the four economies considered (see Figure A2 in Appendix A for more details on intervention-to-monthly-GDP ratios). Fifth, we modify the external instrument by excluding either coordinated or unilateral interventions, expecting (due to results in the literature) and finding a greater impact of the former on the exchange rate. Sixth, we use weighting factors of 0.25, 0.75 or 1.00 (i.e., no weights) instead of 0.5 for the instrument, as the size of these weights is arbitrary to some extent. Seventh, we consider all sequence starts within a month and weight values inversely by the respective day; this includes all intervention starts and still gives more weight to FXI early during a month. Eighth, we use orthogonalized FXI shocks based on Bauer and Swanson (2023). Ninth, in cases where we consider FXI of one country in two different currencies, we focus only on the more important one (and neglect the other); this slightly reduces intervention sequences although not for the most important country, i.e. Japan. Tenth, we present baseline results using mean group estimation, a method that handles potential cross-country heterogeneity. Eleventh, we control for market expectations of future FXI by including exchange rate forecasts. Twelfth, we control for global uncertainty by adding an economic policy uncertainty index and the CBOE Volatility index to the model. Thirteenth, we expand the Euro Area sample by Bundesbank interventions. Fourteenth, we account for the structural break around 1995, when the Bank of Japan and the Federal Reserve Bank adjusted their intervention patterns. Fifteenth, we use a different bootstrap, i.e. the moving block bootstrap by Jentsch and Lunsford (2019). Sixteenth, we estimate a similar specification as in the Proxy-SVAR using instrumental variable local projections.

6. Conclusion

Foreign exchange interventions (FXI) are conducted for several reasons. Whether the objective is rather to counter a longer-term trend or short-term volatility, the intervention always intends to impact the exchange rate. While a large literature shows that this tentatively works, stabilizing the exchange rate is typically not the final but an intermediate target of policy makers. In the end, policy makers (as households and firms) care about the development of the real economy. However, there is no empirical evidence so far that FXI does impact output.

We aim at filling the gap. This requires overcoming an identification problem, which has been an obstacle in the literature, even more so at the low frequency of macro-oriented studies: FXI are a response to the state of the economy, including the exchange rate. We tackle the problem with an instrumental variable approach. We construct an instrument for latent intervention shocks exploiting institutional features of FXI in four advanced economies and publicly available high frequency data, leaning on Menkhoff et al. (2021).

We use the high frequency external instrument in a panel Proxy-SVAR with monthly data to identify latent structural FXI shocks and assess their dynamic effects at the macro level. We find that expansionary FXI shocks have a statistically significant, sizable, persistent, and robust positive impact on output, here proxied by industrial production. We also document a plausible transmission process, as the FXI shocks move exchange rates significantly and persistently in the intended direction. The shocks also induce a significant rise in exports, while imports increase later, insignificantly, and less strongly.

The size of FXI impact is considerable as a 1 billion U.S. dollar purchase of foreign currency depreciates domestic currency by 0.17% and increases industrial production by 0.10%. For comparison with monetary policy, we modify our baseline model and identify standard monetary policy shocks. We find that the impact of these on industrial production is quantitatively similar to the effects of FXI shocks, although the transmission mechanism differs. As an analogy to fiscal policy, we compute an FXI-to-GDP multiplier of 0.5, i.e. a surprise intervention of 1 U.S. dollar increases GDP by 0.5 U.S. dollars.

These results are new to the literature. They complement the evidence on the effectiveness of other central bank balance sheet policies (such as quantitative easing or credit easing), recent theoretical contributions hinting at the effectiveness of FXI in models with financial frictions, and the century old policy view that exchange rate policy is fundamental. However, our results do not motivate the use of FXI as an instrument of employment policy, as FXI cannot really counteract strong macroeconomic forces in the long run. FXI should be rather seen as one instrument in a more complex policy approach, encompassing the choice of the exchange rate regime, monetary and fiscal policy, and various instruments shaping capital flows. Still, our study emphasizes the potential of FXI being able to not only influence the exchange rate in the shorter-term but also to feed through to the real economy and impact output.

Appendix Detailed data sources and definitions

Variable	Description	Source
Intervention	Each country has predominantly intervened in two FX markets during the sample period. We include both currency pairs in the analysis: USD and DM/Euro for Japan, DM/Euro and Yen for the United States, USD and Yen for the Euro Area, and Euro and Yen for the UK. The currencies ordered first are those against which the respective country intervened with the highest absolute volume. We compute the intervention variable as follows: First, we convert FXI volumes, typically enominated in domestic currency, into USD for comparability. Second, we sum daily volumes within each month to obtain the total amount of foreign currencies bought or sold. Positive numbers indicate that the amount of purchases of foreign currencies exceeds the sales of foreign currencies in the respective month. Finally, we cumulate the monthly intervention data.	Data on FXIs are from the FRED, the ECB homepage, and the HM Treasury. The FRED provides data on Japanese and U.S. FXIs, including information on the intervention date, volume, currency pair, and which currency was bought or sold. The ECB offers details on past FXI on their homepage since 2020, including the date, volume, currency pair, the currency bought, and whether the ECB's intervention was unilateral or coordinated. Data on UK interventions after 1997 are obtained from reports, such as the Quarterly Bulletin.
Nom. bilat. exchange rate	The bilateral exchange rates are defined as foreign currency to domestic currency, with the foreign currency being the one that is bought or sold the most. Thus, we have the following four currency pairs: USD/JPY, EUR/USD, USD/EUR, and JPY/GBP. The series are seasonally adjusted and log-transformed.	Nominal spot exchange rate data are used from the FRED.
Interest rate differential	This variable is computed as the short-term interest rate differential between domestic and foreign countries, with country pairs matching those used for the bilateral exchange rate variable.	We use three-month interest rate data from the FRED. For Japan, we use rates on certificates of deposits, while for the others, we use interbank rates.

Industrial production	We use data on industrial production as a proxy for output. The series are seasonally adjusted and log-transformed. The values are given as indices with the base year 2015.	We use data on industrial production (manufacturing) from the OECD.
Ten-year rate	We use ten-year rates on governments bonds as a measure of long-term interest rates. Values are given in percent p.a.	Data are used from the OECD.
Nom. eff. exchange rate	The nominal effective exchange rate is a geometric trade-weighted average of foreign currencies to domestic currency, with the 2020 base period. The series are log-transformed.	Data are obtained from the Bank for International Settlements (BIS).
Real bilat. exchange rate	We adjust nominal bilateral exchange rates for prices of goods and services (consumer price index) between domestic and foreign countries. Consumer price indices include food and energy. The series are log-transformed.	Data for Japan, the United States, and the United Kingdom are from the OECD. Data for the Euro Area are from the FRED.
Real eff. exchange rate	The real effective exchange rate is a geometric trade-weighted average of foreign currencies against the domestic currency, with the 2020 base period. Exchange rates are price-adjusted. The series are log-transformed.	Data are obtained from the BIS.
Real exports	We use data on nominal exports of goods, adjusted for prices using either export price indices or consumer price indices. Real exports are computed as index values with the 2015 base period. The series are log-transformed.	Data are used from the FRED, US Census Bureau and the OECD.
Real imports	We use data on nominal imports of goods, which are price-adjusted using either import price indices or consumer price indices. Real	Data are used from the FRED, OECD, US Census Bureau and Eurostat.

	imports are expressed as index values relative to the 2015 base period. The series are log-transformed.	
Real net exports	We compute real net exports as a share to monthly real GDP by using the annual nominal GDP in local currency, divided by 12. Nominal GDP is deflated using either the GDP deflator or consumer price index with the base year 2015.	Data on real net exports are the same as for real exports and imports. Data on nominal GDP and deflators are obtained from the OCED and FRED.
Unemployment rate	Unemployment rates are computed as the percentage share of people being unemployed to total labor force. The series are seasonally adjusted.	Unemployment data are obtained from the OECD.
Inflation	We take the difference in annual growth rates of consumer price indices between domestic and foreign countries, with the country pairs matching those used for the bilateral exchange rate variable.	Data are used from the OECD and FRED.
Core CPI	We use consumer prices excluding food and energy, expressed as an index with the base year 2015. The series are seasonally adjusted and log-transformed.	Data are used from the OECD and FRED.
Economic activity	We use data on either industrial production or monthly GDP as proxies for output. The series are seasonally adjusted and log-transformed. The values are expressed as indices relative to the 2015 base period.	We use data on industrial production (manufacturing) from the OECD. For the United Kingdom, we use monthly GDP, as the Office for National Statistics publishes monthly GDP estimates on its webpage.
One-year rate	We use interest rates on government bonds at one-year constant maturity. Values are given in percent per annum.	Data for Japan are used from the Ministry of Finance, data for the United States from FRED, data for the Euro Area from Eurostat, and data for the United Kingdom from the Bank of England.

Stock prices	We use stock prices for the Nikkei225, S&P 500, Stoxx 50, and FTSE 100 indices. Data are log-transformed.	Data for Japan are from FRED, data for the other countries are provided by Macrobond.
Nominal GDP	For comparing the intervention shock to fiscal policy, we use data on quarterly nominal GDP expressed as index values relative to the base year 2015 and in billion U.S. dollars. Both series are seasonally adjusted.	Data are used from the FRED.

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Table 1: Summary statistics of FXI and start of sequences by country

	Japan	United States	Euro Area	United Kingdom
Number of interventions				
Number of interventions	72	22	3	2
Purchases of foreign currencies	57	6	0	1
Sales of foreign currencies	15	16	3	1
In billion U.S. dollars				
Average absolute intervention	12.43	0.86	3.28	0.11
Average purchase	13.93	0.42	0.00	0.08
Average sale	-6.73	-1.02	-3.28	-0.15
Median intervention	4.95	-0.53	-2.76	-0.04
Maximum purchase	103.53	1.34	0.00	0.07
Maximum sale	-43.31	-2.60	-6.08	-0.15
In percent				
Average absolute volume to monthly GDP	3.92	0.13	0.47	0.07
Start of sequence				
Starts	16	7	3	2
Purchases of foreign currencies	14	0	0	1
Sales of foreign currencies	2	7	3	1
Coordinated interventions	3	7	2	2
Unilateral interventions	13	0	1	0

Notes. This table presents summary statistics on FXI conducted by the Bank of Japan, the Federal Reserve Bank, the European Central Bank, and the Bank of England. The sample is 1991M4-2022M12 for Japan and the United States. For the Euro Area and the United Kingdom, the sample starts in 1999M1 and 1992M10, respectively, covering only periods of freely floating exchange rate regimes. Numbers are on a monthly basis. The first block of rows provides information on the number of months when central banks intervened in the FX market at least once. The bottom block of rows provides details on the starts of FXI sequences used as an instrument to identify latent structural FXI shocks in the panel Proxy-SVAR. Sequence starts are further classified into purchases and sales of foreign currencies, and into coordinated and unilaterally conducted FXIs.

Table 2: Results from event study panel regression

Specification	(1)	(2)	(3)
Daily Intervention Indicator ($\hat{\beta}$)	-0.91	-0.90	-0.97
Conventional SE	*(0.50)*	*(0.50)*	*(0.51)*
Huber-White SE	*(0.36)*	*(0.36)*	*(0.36)*
Clustered SE[a]	*(0.40)*	*(0.40)*	*(0.43)*
Bootstrapped SE[b]	*(0.32)*	*(0.33)*	*(0.32)*

Notes. This table shows estimates from three different event study panel regressions using daily data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. Estimates are presented as percentages (%). The model is estimated in first log differences, with country-specific fixed effects. Specification (1) is estimated without any controls, specification (2) controls for seasonality, and specification (3) includes one lag of the endogenous variable in X_{it}. Different types of standard errors are provided in parentheses.

[a] Standard errors are clustered at the country level.

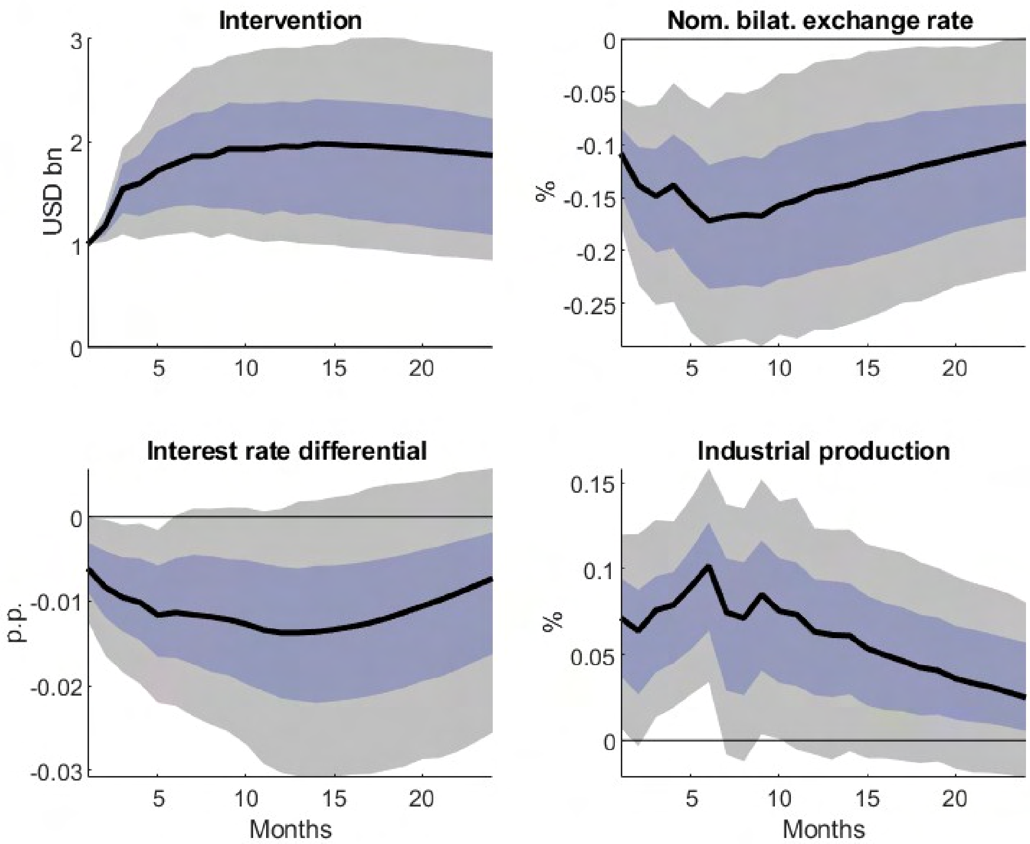
[b] Standard errors are computed using the fixed design wild bootstrap.

Table 3: Regression results on instrument predictability

Specification	(1)	(2)	(3)
Nom. bilat. exchange rate ($\hat{\beta}_1$)	0.31	0.40	0.49
Conventional SE	*(0.63)*	*(0.39)*	*(0.33)*
Huber-White SE	*(0.64)*	*(0.39)*	*(0.30)*
Real bilat. exchange rate ($\hat{\beta}_2$)	0.19	-0.10	-0.28
Conventional SE	*(0.62)*	*(0.39)*	*(0.33)*
Huber-White SE	*(0.54)*	*(0.36)*	*(0.27)*
Nom. bilat. exchange rate forecast ($\hat{\beta}_3$)	-0.19	-0.11	-0.07
Conventional SE	*(0.28)*	*(0.18)*	*(0.12)*
Huber-White SE	*(0.21)*	*(0.15)*	*(0.12)*
Nom. eff. exchange rate forecast ($\hat{\beta}_4$)	-0.18	-0.03	0.11
Conventional SE	*(0.33)*	*(0.21)*	*(0.13)*
Huber-White SE	*(0.40)*	*(0.26)*	*(0.16)*
Short-term interest rate ($\hat{\beta}_5$)	-0.03	-0.02**	-0.02**
Conventional SE	*(0.02)*	*(0.01)*	*(0.01)*
Huber-White SE	*(0.02)*	*(0.01)*	*(0.01)*
Industrial production ($\hat{\beta}_6$)	0.00	0.11	-0.01
Conventional SE	*(0.26)*	*(0.19)*	*(0.13)*
Huber-White SE	*(0.21)*	*(0.16)*	*(0.10)*
Real import ($\hat{\beta}_7$)	0.30**	0.21**	0.17**
Conventional SE	*(0.15)*	*(0.10)*	*(0.08)*
Huber-White SE	*(0.15)*	*(0.08)*	*(0.07)*
Real export ($\hat{\beta}_8$)	-0.21	-0.19	-0.12
Conventional SE	*(0.17)*	*(0.12)*	*(0.09)*
Huber-White SE	*(0.21)*	*(0.13)*	*(0.08)*
WTI crude oil ($\hat{\beta}_9$)	0.06	0.07	0.05
Conventional SE	*(0.11)*	*(0.08)*	*(0.07)*
Huber-White SE	*(0.11)*	*(0.09)*	*(0.08)*
Brent crude oil ($\hat{\beta}_{10}$)	-0.07	-0.08	-0.04
Conventional SE	*(0.12)*	*(0.08)*	*(0.07)*
Huber-White SE	*(0.12)*	*(0.10)*	*(0.09)*
R-squared	*0.03*	*0.03*	*0.04*

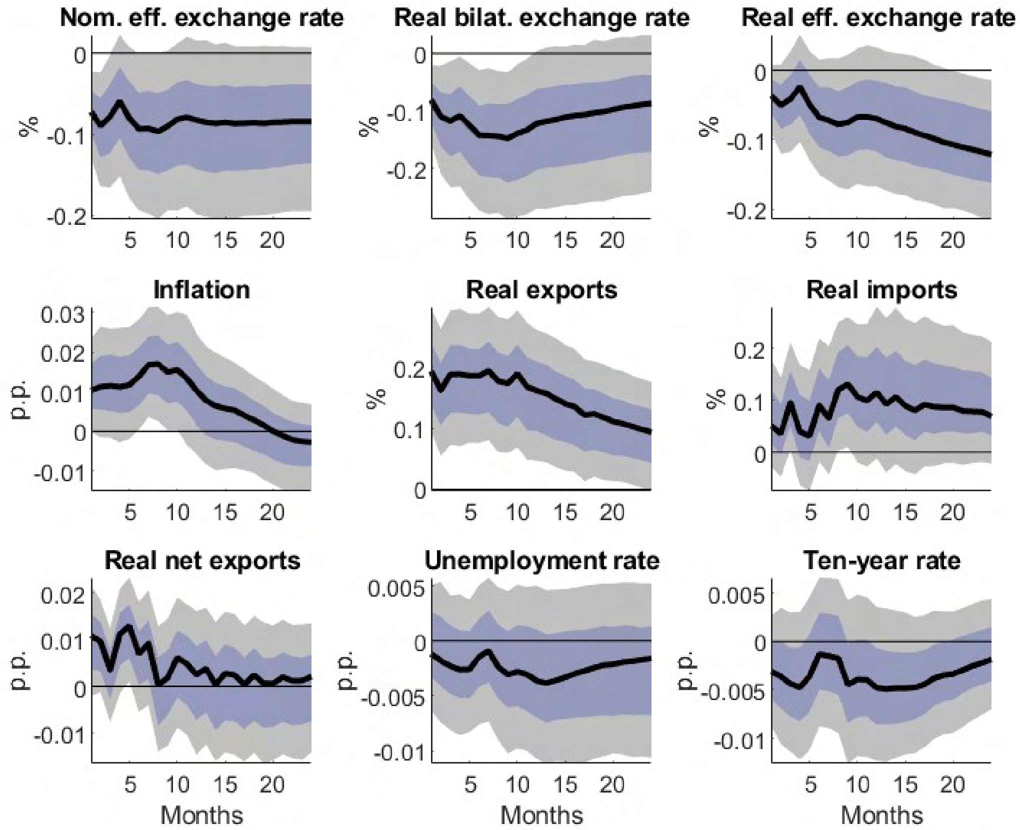
Notes. This table shows estimates from three different panel regressions using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. Following Bauer and Swanson (2023), we regress the instrument on nine macroeconomic variables, measured as the difference to their three-, six-, and twelve-month moving average. Specification (1) uses three-month moving averages, specification (2) uses six-month moving averages, and specification (3) uses twelve-month moving averages. Different types of standard errors are provided in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Figure 1: Baseline model



Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure 2: Economy-wide effects



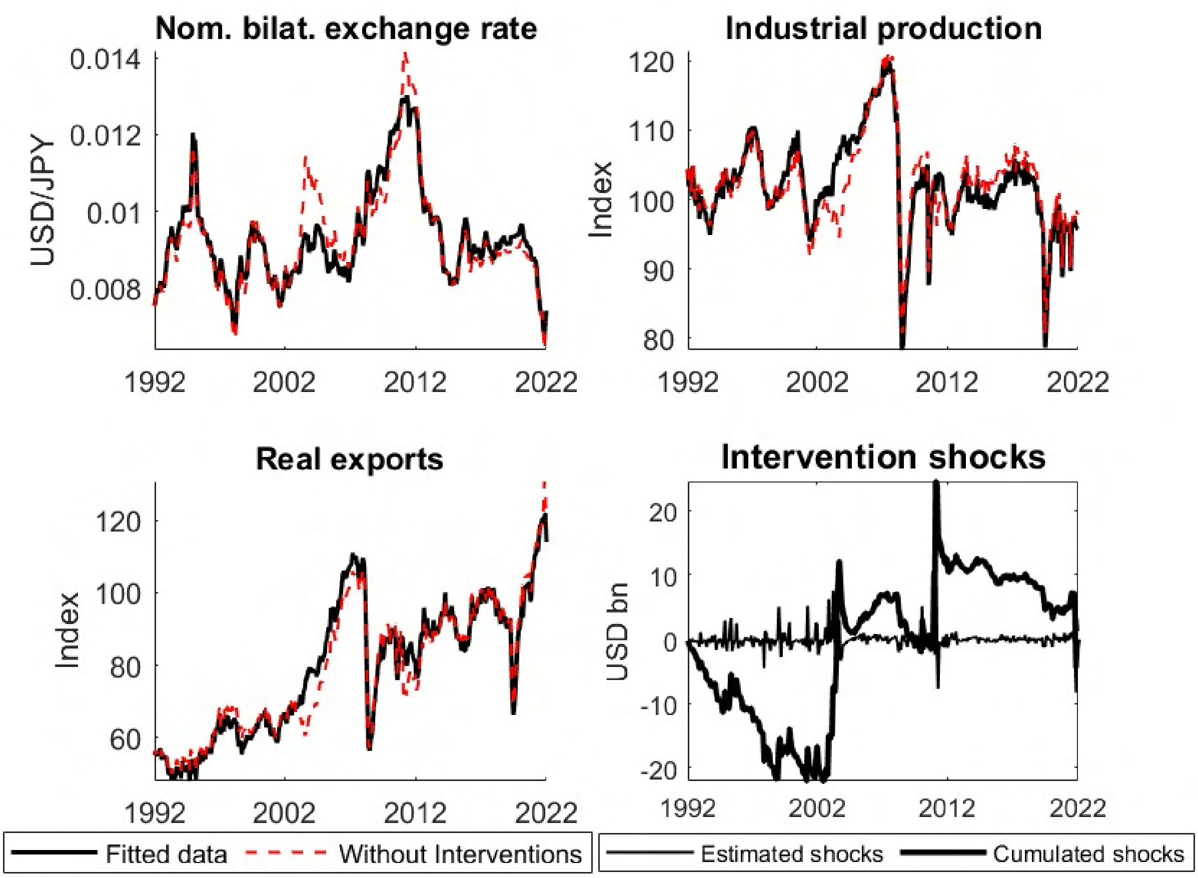
Notes. This figure shows the impulse response functions of nine additional macro-variables to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. The baseline Proxy-SVAR is augmented with one additional variable at a time. Responses of the baseline variables in the augmented models are collected in Appendix F. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Table 4: Forecast error variance decomposition

Horizon	Intervention	Nom. bilat. exchange rate	Interest rate differential	Industrial production
1	89.8	3.6	1.9	2.2
6	87.0	4.1	2.4	3.5
12	83.1	5.1	2.3	4.1
24	77.6	5.2	2.3	4.2

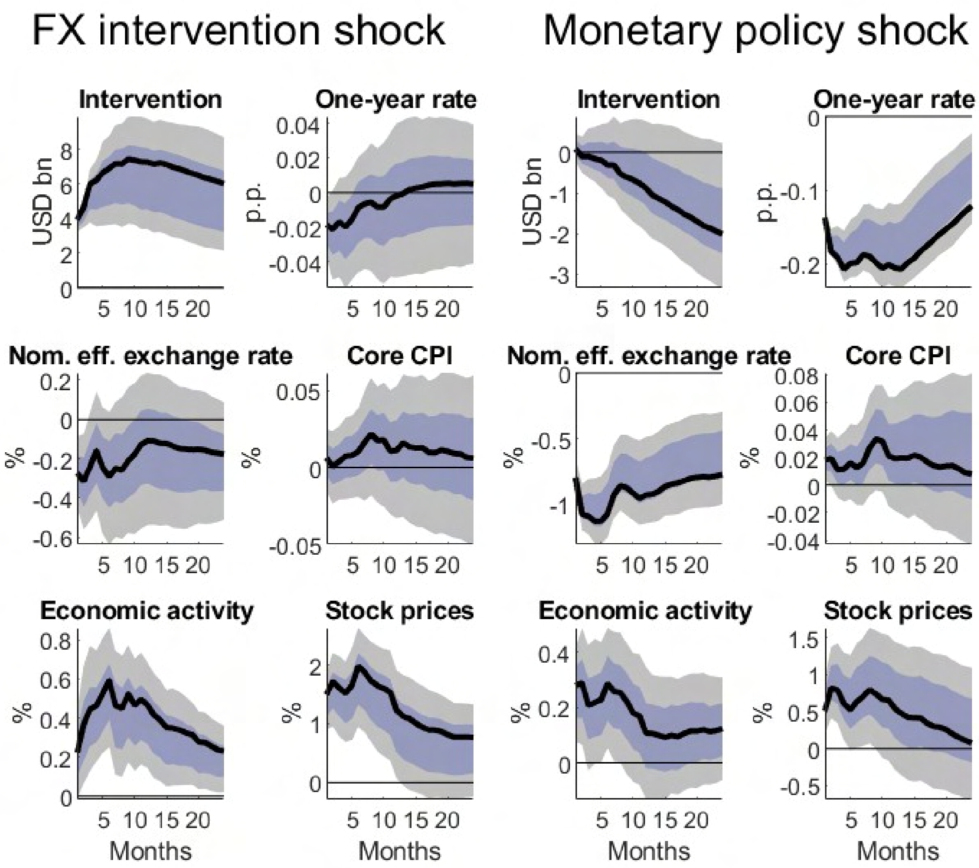
Notes. This table documents the results for the forecast error variance decomposition of the baseline specification estimated in Section 3.1. Numbers (in percent) indicate the contribution of the estimated intervention shocks to variations in the forecast error of each endogenous variable at horizons up to 24 months after the shock.

Figure 3: Historical decomposition



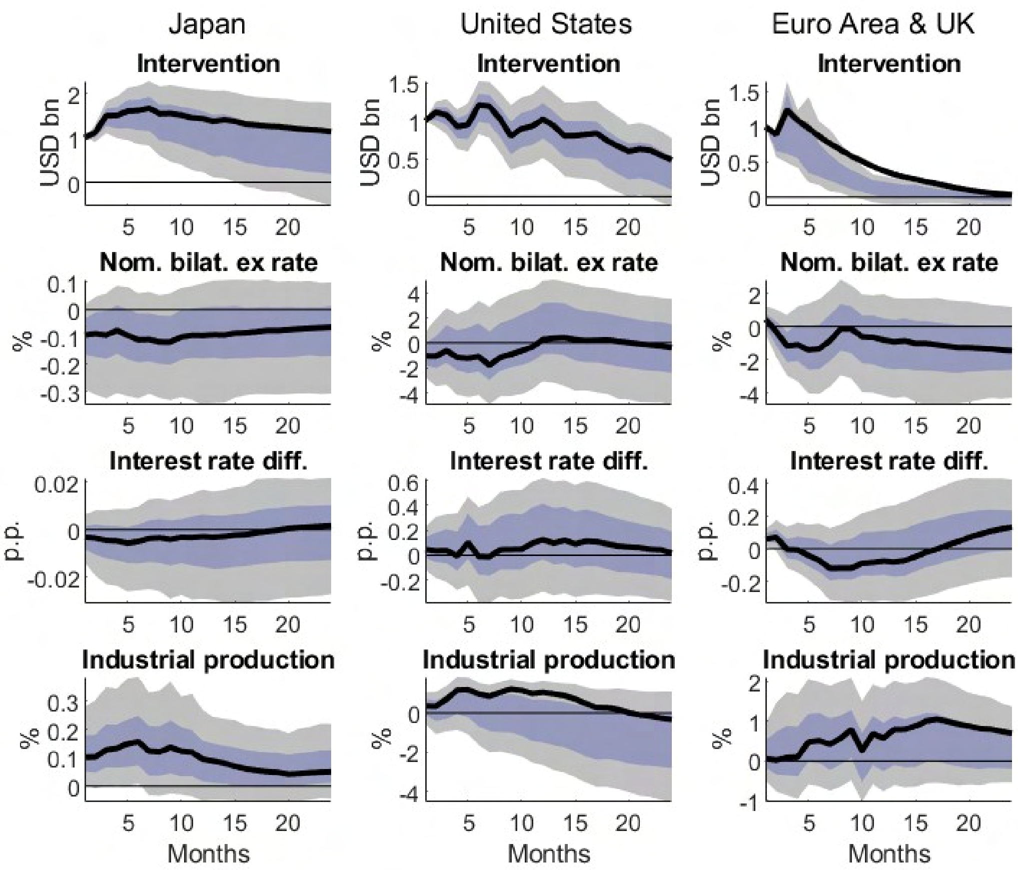
Notes. The upper panels and the bottom left panel show the historical decomposition of the nominal bilateral exchange rate, industrial production, and real exports for Japan for the 1992M4-2022M12 period. Solid lines show the fitted data, and dashed lines show the counterfactual. The bottom right panel shows the estimated structural intervention shocks used for historical decomposition. Thin lines show estimated structural intervention shocks, and thick lines show their cumulated version.

Figure 4: Comparison to conventional monetary policy



Notes. This figure shows the impulse response functions to a one standard deviation FXI shock (left panel) and an expansionary monetary policy shock (right panel) in a common panel Proxy-SVAR framework. Results are shown over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. To identifying latent structural FXI shocks, the intervention variable is instrumented using a series that contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention. In the monetary policy framework, the one-year interest rate on government bonds is instrumented using monetary policy surprises, such as those provided by Bauer and Swanson (2023) for the United States (see Appendix G for more details). 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure 5: Country-specific results



Notes. This figure shows the country-specific impulse responses of the baseline variables to an FXI shock of 1 billion U.S. dollars over a 24-month horizon, when we split up the panel into Japan, the United States, and the Euro area together with the United Kingdom. The (panel) Proxy-SVARs are estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data since the 1990s. For Japan, the United States, and the Euro area together with the United Kingdom, the instruments contain 16, 7, and 5 sequence starts, respectively. The instruments are categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Online Appendices

to accompany

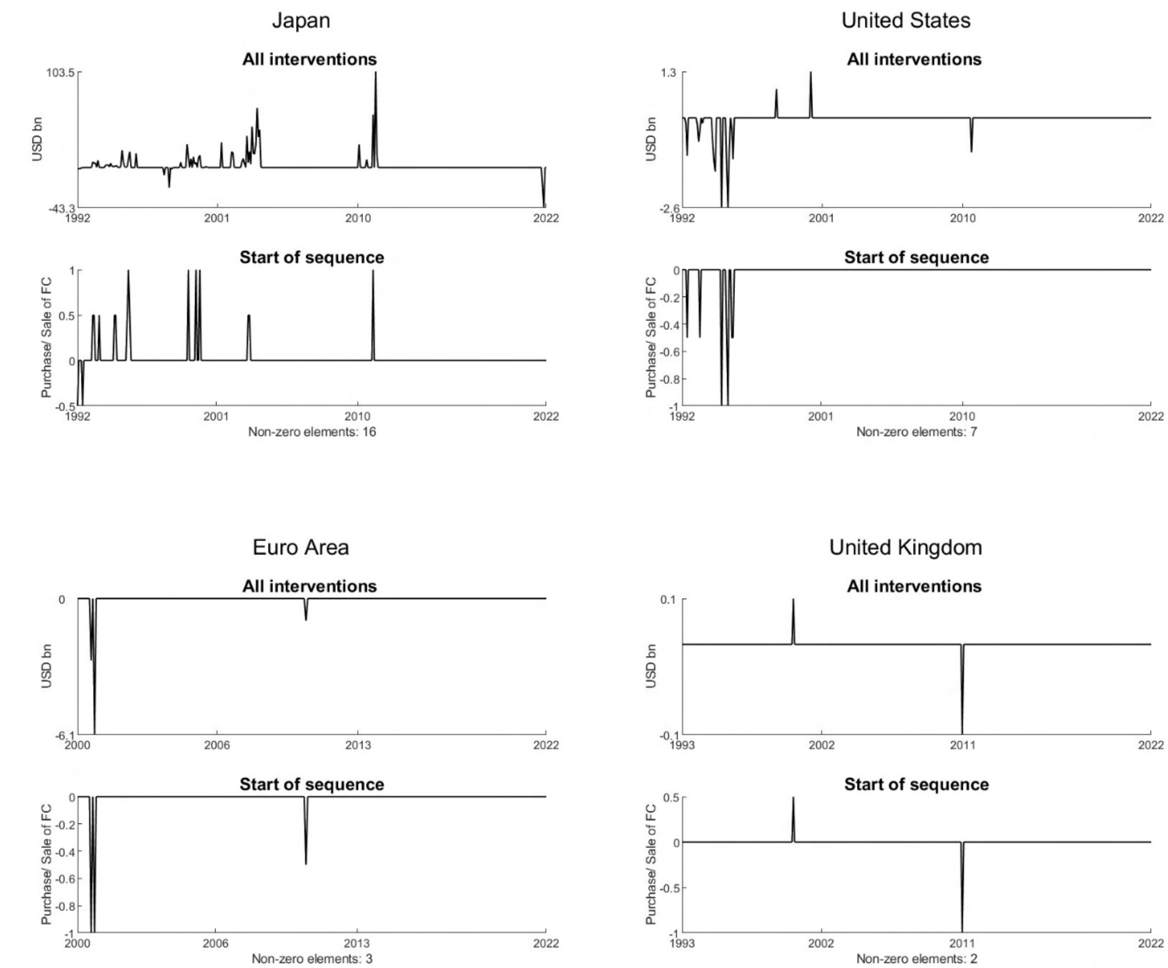
"The Macroeconomic Effects of Foreign Exchange Intervention"

Lukas Menkhoff, Karoline Offen, and Malte Rieth

Appendix A Interventions and instrument

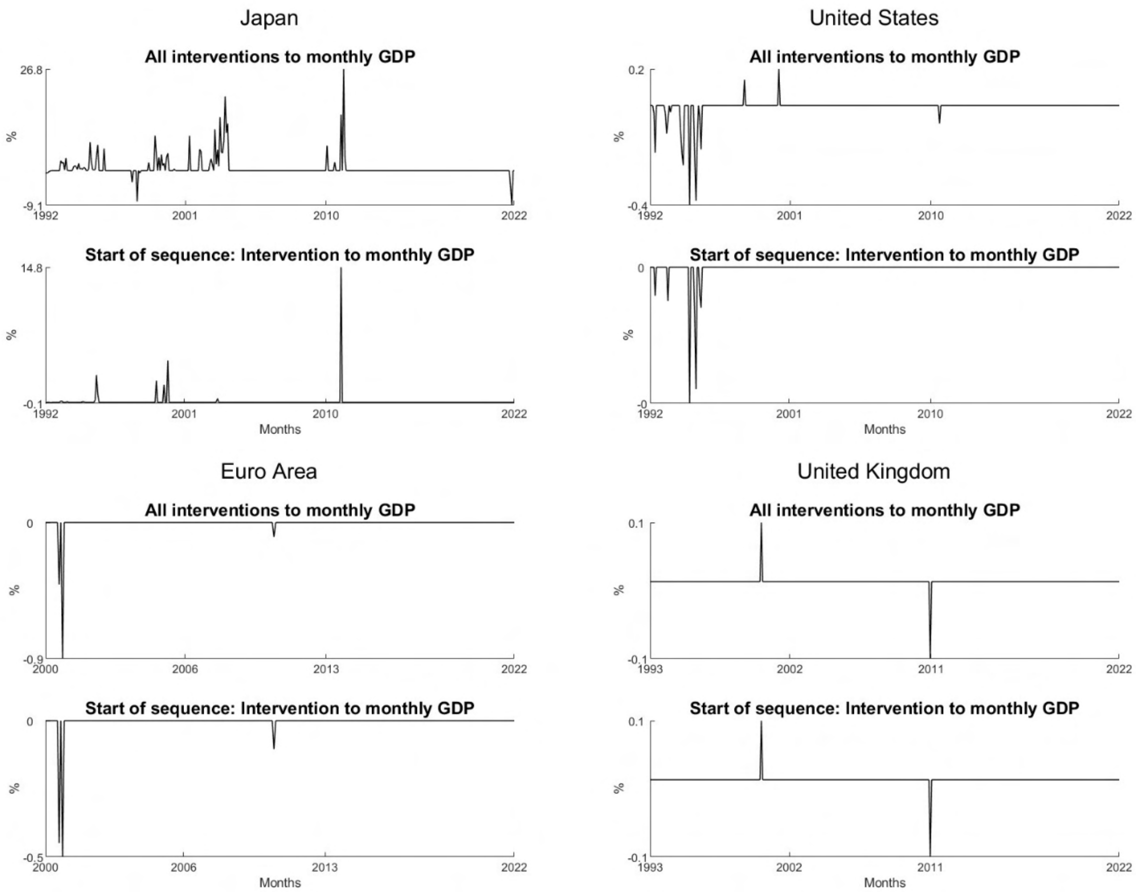
In Figure A1, we show absolute FX intervention volumes and sequence starts as a categorical variable, which we use as an external instrument to identify latent structural shocks. In Figure A2, we plot the FX intervention volumes (shown in the upper subpanels in Figure A1) and volume of sequence starts (same events as in the bottom subpanels in Figure A1) as percentage shares of monthly GDP.

Figure A1: Absolute intervention volumes and instrument



Notes. This figure shows the actual FXIs conducted by the Bank of Japan (upper left), the Federal Reserve Bank (upper right), the European Central Bank (bottom left), and the Bank of England (bottom right). The periods shown are the same as used for model identification, while the sample used for estimating the panel Proxy-SVAR is 1991M4-2022M12 for Japan and the United States, and for the Euro Area and the United Kingdom, the sample starts in 1999M1 and 1992M10, respectively, covering only periods of freely floating exchange rate regimes. Each panel contains two subpanels. The upper subpanels show monthly intervention volume. The bottom subpanels indicate the start of intervention sequences, directions, and intensity used as an external instrument to identify latent structural FXI shocks.

Figure A2: Intervention volumes as a ratio to monthly GDP



Notes. This figure shows the actual FXI to monthly GDP conducted by the Bank of Japan (upper left), the Federal Reserve Bank (upper right), the European Central Bank (bottom left), and the Bank of England (bottom right). The periods shown are the same as used for model identification, while the sample used for estimating the panel Proxy-SVAR is 1991M4-2022M12 for Japan and the United States, and for the Euro Area and the United Kingdom, the sample starts in 1999M1 and 1992M10, respectively, covering only periods of freely floating exchange rate regimes. Each panel contains two subpanels. The upper subpanels show ratios of monthly intervention volumes to monthly GDP. The bottom subpanels show the ratio of volume to monthly GDP at the start of intervention sequences. All numbers are in percent (%).

Appendix B **Statements about FX interventions**

Country	Type of publication	Notes	Statement
Japan	A speech given by Yutaka Yamaguchi, Deputy Governor of the BoJ (July 13th 1999)	Role of the BoJ in international finance (institutional framework)	Finally, I would like to briefly describe the **role of the Bank of Japan** in international finance. In the new Bank of Japan Law, effective **since April last year**, provisions that allow the Bank to conduct activities related to international finance based on its judgments have been stipulated reflecting the globalization of finance. The Bank performs many functions: e.g., **intervening** in foreign exchange markets **as an agent of the Finance Minister**, providing services to foreign central banks and international organizations wishing to invest in yen. In addition, the Bank is actively engaged in activities related to international finance through channels other than the BIS, including the G7, G10, IMF, etc. In the remaining minutes I would like to take up, from this broad spectrum, a few issues that are related to the role of our Bank with respect to international financial crises.
Japan	Statement by the governor (September 25th, 1999)	Several FXI sequences in 1999. Statement does not refer to one specific sequence	The Bank of Japan has provided ample liquidity in the context of the zero interest rate policy. The Bank is **concerned** about the negative impact of the recent rapid **yen appreciation on economic activity and prices**. This view is shared with the government. The Bank is prepared to use the flexibility it has in the context of the present monetary policy stance to respond appropriately and timely to developments in the economy as well as financial markets, including the foreign exchange market. We are exploring how we could improve money market operations so as to assure the further permeation of liquidity in the context of the zero interest rate policy.
Japan	Statement by the governor (October 19th 1999)	Might refer to FXI in November/ December 1999	Let me next explain the Bank's new measures decided at the Monetary Policy Meeting on October 13. The following two factors were **taken into account**. First, **the effects of the yen's recent appreciation on the economy**. The **15 percent appreciation against the US dollar** between July and September of this year was quite rapid. At this juncture, let me explain our

			thinking regarding the relationship between monetary policy and the exchange rate since it seems we have not been able to make it completely clear so far. In examining this issue, two important points should be borne in mind. First, the **Bank should act appropriately and timely by paying due attention to developments in the economy as well as financial markets, including the foreign exchange market, since the exchange rate has various effects on economic activity and prices**. Second, it is not appropriate for the Bank of Japan to conduct monetary policy with the objective of guiding the exchange rate to a specific level.
Japan	Remarks given by Kazuo Ueda, Member of the Policy Board of the BoJ (October 20th, 1999)	General remark on (un-) sterilized FXI	Just a few words on central bank **purchase of foreign exchanges**. Sorry to come back to the Japanese example so often, but I just wanted to note that the **BOJ cannot do this because it is prohibited from buying dollars in an attempt to influence the exchange rate**. The MOF can, of course, do it, and we are in no way against their doing it at appropriate timing. There remains the question of whether intervention should be sterilized or not. As many have pointed out in this conference, sterilized and unsterilized interventions are theoretically equivalent under zero interest rates unless one wants to rely on probably non-rational market expectation that the two are different.
Japan	Speech given by Nobuyuki Nakahara, Member of the Policy Board of the BoJ (November 1st, 1999)	General comment on FXI	I would like to touch last upon the September 21 meeting. At the time of this meeting, the **yen**--which had broken through 110 yen and was **appreciating**--was a focal point. However, many members of the Policy Board appeared to be surprisingly complacent about the impact of the rapid rise in the yen. I have spent most of my career in the oil industry, which is extremely sensitive to fluctuations in foreign exchange rates. My experience there has taught me that the difference in the effect on businesses with the yen staying at 120 yen to the dollar and breaking a resistance level at 108 yen is significant. Therefore, it was my opinion that **preemptive action should be taken**. I also believed market **intervention should be unsterilized**, if the markets were expected to react favorably to such a decision. At the September 21 meeting, as the minutes show, members generally

			shared the view that "a little **more time** was needed to **judge the degree of the downside risk to the economy arising from the recent appreciation** of the yen." My understanding is that most members were inclined to take a wait-and-see stance. I warned them that financial markets, not only the foreign exchange market, but also the Tokyo and New York stock markets, were at an extremely critical juncture, thus, grave consequences might ensue if appropriate action was not taken.
Japan	Statement by the governor Hayami (December 1st, 1999)	Referring to FXI sequences in 1999	The Bank of Japan **supports the recent action by the Ministry of Finance in the foreign exchange market** and strongly hopes that market stability is restored as soon as possible. The **Bank is prepared to promptly provide sufficient funds in order to maintain the stability** of the short-term money market, taking account of the government's yen funding of foreign exchange intervention and any disruptive impact of excessive movements in the foreign exchange market on domestic financial transactions. The Bank has been flexibly providing ample funds to the short-term money market taking account of factors including yen liquidity arising from foreign exchange intervention, and, under this operational framework, today continued to supply substantial amount of liquidity.
Japan	Remarks by Sakuya Fujiwara, Deputy Governor of the BoJ, to the Yomiuri Int'l Economic Society in Tokyo on Dec. 7, 1999	General comment on (un-) sterilized FXI	Some **have suggested further monetary easing through unsterilized yen-selling foreign exchange intervention**. If 'sterilized intervention' means 'the Bank absorbing all yen funds provided by individual yen-selling intervention through daily money market operations,' then the Bank **is not implementing such operations**. Under the zero interest rate policy, the Bank has been flexibly providing ample funds to the short-term money market in an amount more than necessary for financial institutions, taking account of factors including yen liquidity arising from foreign exchange intervention. On December 1, Governor Hayami issued a statement referring to this point and clarified once again the relationship between the Bank's money market operations and foreign exchange intervention.

Japan	Based on a speech given by Kazuo Ueda, Member of the Policy Board (September 29th 2001)	Institutional framework	Let me make some comments on operations involving foreign exchange. First, in Japan the responsibility for operations in the **foreign exchange market to stabilize exchange rates is assigned by law to the Ministry of Finance**, and not to the BOJ. Second, there **is a view that the effect of interventions on the foreign exchange rate is reduced if they are sterilized**. It is, however, almost meaningless to discuss the distinction between sterilized and unsterilized interventions under a zero interest rate. This is because the difference between the two only amounts to whether to conduct the BOJ's operation in short-term government securities and allow an increase in the monetary base: base money and short-term securities are almost perfect substitutes for each other as discussed earlier. Finally, for the same reason, the Ministry of Finance is in a position to carry out a non-traditional monetary policy operation under a zero interest rate. That is, it can buy foreign exchange by issuing treasury bills. The operation is almost the same as the BOJ buying of foreign exchange by expansion of the monetary base.
Japan	Summary of a speech given by Teizo Taya, Member of the Policy Board (January 29th 2004)		In spite of upward revisions in the outlook for growth, higher stock prices, and a weaker U.S. dollar, long-term interest rates have stabilized at a low level. This is not only the result of speculation that monetary easing is likely to remain for the long term; it is also related to the influx of funds from overseas financial authorities' U.S. dollar-purchasing interventions that have continued since 2002. Speculation that an accommodative monetary policy may last into the long term is due not only to established factors, which remain important, such as the rapid growth in U.S. productivity and the slack that exists in both labor holdings and production capacity, but may also be attributed to the continuing tendency for the core consumer price index (CPI) to grow at a slower rate than previously. Turning to the weakness of the U.S. dollar, this may be partly explained in terms of adjustment pressure, springing from the large U.S. current account deficit, working itself out via the exchange rate. The exchange rate has come under pressure because adjustments on the income side have proved elusive in both the United States and its main trading partners.

			For the United States, it is currently difficult to impose policies to curb domestic demand, just as various reasons of their own have made it difficult for the main trading partners of the United States to stimulate demand domestically. Faced with a weak dollar and appreciation in their own currencies, a situation has evolved in which financial authorities **mainly in Japan and other East Asian economies have been constantly engaged in dollar-purchasing interventions**. Reflecting these interventions by overseas financial authorities, the amount of assets held in the United States by foreign authorities is thought to have increased by as much as US$200 billion in 2003. Even the increase alone may be thought a significant amount when set against the U.S. current account deficit in 2003, said to have reached some US$550 billion. However, while the growth prospects of U.S. trading partners have been gradually improving, the pace of U.S. economic expansion in 2004 is thought to have slowed in comparison with the second half of 2003. In these circumstances, we might reasonably expect that the effect on the trade balance of the devalued dollar, cheaper since 2002, will shortly start to be felt. The related questions of what will happen to the U.S. current account deficit and whether or not the trend of dollar weakness will continue are highly significant for the world economy. On the other hand, should there for some reason be a rise in long-term interest rates in the United States, there is a danger that this would have an extremely heavy impact not only on the U.S. economy but all over the world. Attention should not be restricted to the dollar's weakness, but should be paid to this point as well.
Japan	Summary of a speech given by Toshikatsu Fukuma, Member of the Policy Board (March	General remark on FXI	The second reason was to secure enough leeway in the target range for current accounts at the Bank to ensure that the surge in the issuance of financing bills (FBs) accompanying **the increase in foreign exchange intervention did not disturb the Bank's market operations and so impede the Bank's efficient communication with the market**. As Chart 17 indicates, the amounts outstanding of FBs and treasury bills (TBs) in the money market are increasing rapidly. However, although it might take some time, newly issued FBs and TBs are likely to be absorbed smoothly in the market and the yields on

	25th , 2004)		FBs and TBs should be consistent with other relevant market interest rates. From the viewpoint of the asset-liability management (ALM) of private banks, it is desirable that the terms of financing on funds raised for investment in FBs and TBs should be as close as possible to the maturity of the securities purchased, namely three months, six months and one year. However, with the zero interest rate prevailing in the money market, and the removal in April 2002 of blanket deposit insurance for all bank liabilities sparking concerns about credit risk at individual banks, raising funds with relatively long maturities of three-months to one-year from the markets is difficult for private banks, who are therefore dependent upon the Bank's market operations for such financing. In fact, as Chart 18 shows, the bid-to-cover ratio for the Bank's longer term funds-supplying operations has remained at a high level, and this seems to have been caused in part by the high level of FB issuances. Liquidity demand in the money markets should be monitored closely, with a view to securing market stability.
Japan	Speech given by Toshihiko Fukui, Governor of the BoJ (October 13th 2004)	Comment on absence of FXI for months	You may perhaps remember the concerns voiced in the market some twelve months ago. There **were worries** that the U.S. dollar might fall sharply, were it not for continued and heavy currency market interventions by Asian monetary authorities. That has not been the case so far. In the case of the yen, even in the **absence of official interventions in the foreign exchange market since mid-March**, the dollar has held up well against the yen. This suggests that private capital flows are now playing a more important role in determining market dynamics. I might even say that we should be proud of ourselves in allowing the international financial markets to develop into such a resilient system.
Japan	Statement by the governor (August 12th, 2010)	Might refer to upcoming FXI sequence starting on September 15th, 2010	There are **substantial fluctuations in the foreign exchange** and stock markets mainly against the backdrop of growing uncertainty about the outlook for the U.S. economy. The Bank of Japan **will carefully monitor** such **developments** and their effects on Japan's economy.

Japan	Statement by the governor (September 15th, 2010)	Referring to FXI on September 15th, 2010	There has been **growing uncertainty** about the future, especially for the U.S. economy, and **foreign exchange and stock markets** have been unstable. In these circumstances, the **downside risks to Japan's economy warrant attention**. The Bank of Japan strongly expects that the **action taken by the Ministry of Finance in the foreign exchange market will contribute to a stable foreign exchange rate formation**. The Bank will, while pursuing strong monetary easing, continue to provide ample liquidity to the financial markets.
Japan	Statement by the governor (Mar.18th, 2011)	Referring to FXI on March 18th, 2011	The Bank of Japan strongly expects that Japan's concerted action with G7 member countries in the foreign exchange market **will contribute to the stable formation of foreign exchange rates**.
Japan	Statement by the governor (August 4th, 2011)	Referring to FXI on August 4th, 2011	The Bank of Japan strongly expects that the action taken by the Ministry of Finance in the foreign exchange market will contribute to **stable price formation in the market**.
Japan	Speech by Governor Shirakawa in Osaka (Outlook and Challenges for Japan's Econ.) (Oct. 31st, 2011)	Referring to FXI on October 31st, 2011	As illustrated, it can be said that the recent appreciation of the yen is one example of the spillover effect of the sovereign debt problem in Europe into Japan through the increasing risk aversion by global investors. In this regard, the Ministry of Finance intervened to the foreign exchange market today. The Bank strongly expects that such an action will contribute to **the stable price formation in the market**.
Japan	Reuters	Anticipation of FXI on	TOKYO, June 10 (Reuters) - Japan's government and central bank **said on Friday they were concerned by recent sharp falls in the yen** in a rare joint statement,

		September 22nd 2022	the strongest warning to date that Tokyo **could intervene** to support the currency as it plumbs 20-year lows. The statement underscores growing concern among policymakers over the damage that sharp yen depreciation could inflict on Japan's fragile economy by hurting business activity and consumers. https://www.reuters.com/markets/currencies/japan-edges-closer-intervention-yen-after-rare-govt-cbank-joint-statement-2022-06-10/
Japan	Reuters	Referring to FXI in (summer) 2024	LONDON/TOKYO, July 24 (Reuters) - Japanese official buying to defend the yen is fast becoming a standard feature of the FX landscape in 2024, but authorities in Tokyo have switched up their methods, making it **even trickier for investors to second-guess** when and how they might step in. The novel intervention tactics may have wrongfooted traders enough to help Japan's financial authorities turn the tide on their currency, which hit its weakest against the dollar since 1986 just four weeks ago. https://www.reuters.com/markets/currencies/investors-foxed-by-japans-revamped-fx-intervention-blueprint-2024-07-24/
United States	Quarterly report on FX operations (Q2 1998)	FXI on 17th June, 1998	We welcome Prime Minister Hashimoto's announcement of steps to **stimulate the Japanese economy**. In the context of **Japan's plans to strengthen its economy**, the U.S. monetary authorities operated in the exchange market this morning in cooperation with the monetary authorities of Japan.
United States	Quarterly report on FX operations (Q3 2000)	FXI on September 22nd, 2000	Market **nervousness** over additional bouts of **volatility increased** as the euro reached new historic lows against the major currencies, raising market perceptions of the possibility of official intervention in support of the euro. One-month option implied volatility for the euro-yen exchange pair jumped 1.5 percentage points in the first week of September to 18.2 percent, its highest level since April 2000. Option implied volatility for the euro-dollar exchange pair also increased, with the one month tenor reaching 14.4 percent on September 8. As the operation began, the U.S. Department of Treasury issued the following statement: "At the

			initiative of the European Central Bank, the monetary authorities of the United States and Japan joined with the European Central Bank in concerted intervention in exchange markets, because of their shared concern about the **potential implications of recent movements in the Euro for the world economy**."
United States	Quarterly report on FX operations (Q1 2011)	FXI on March 11th, 2011	As we have long stated, **excess volatility and disorderly movements in exchange rates** have **adverse implications for economic and financial stability**. We will monitor exchange markets closely and will cooperate as appropriate.
Euro Area	Annual Report 2000	September 22nd; November 3rd, 6th, and 9th 2000	The concern about the potential implications of developments in the euro exchange rate for the world economy, as shared by our partners in the G7, ultimately prompted interventions in the foreign exchange markets, together with its G7 partners on the initiative of the ECB in Sep. and then unilaterally by the Eurosystem in Nov. At the end of last year the euro started to recover. Over the summer of 2000, the level of the exchange rate of the euro had moved further out of line with the sound fundamentals of the euro area, thereby also raising concerns **about potential implications for the world economy**. The depreciation of the euro was addressed at the level of the G7 on 22 September 2000, on the initiative of the ECB, in the form of a concerted intervention in the foreign exchange market together with the monetary authorities of the United States, Japan, the United Kingdom and Canada. The ECB, consistent with its concerns about the **risks for price stability in the euro area stemming from the depreciation of the exchange rate of the euro**, decided to intervene again in foreign exchange markets in early November.
Euro Area	Annual Report 2011	FXI on March 18th 2011	In 2011 the Eurosystem undertook one intervention in the foreign exchange markets. In response to the movements in the exchange rate of the yen associated with the natural disaster in Japan, and at the request of the Japanese authorities, the authorities of the United States, the United Kingdom and Canada, as well as

			the ECB, joined Japan, on 18 March, in a concerted intervention in foreign exchange markets.
United States	Quarterly Bulletin (November 2000)	FXI on September 22nd 2000	On 22 September, the G7 countries intervened in the foreign exchange markets, buying euros. The G7 summarised its activities in the following statement: 'At the initiative of the European Central Bank, the monetary authorities of the United States, Japan, the United Kingdom, and Canada, joined with the European Central Bank on Friday 22nd September in co-ordinated intervention in exchange markets, because of the **shared concern** of Finance Ministers and Governors about the potential implications **of the recent movements in the euro for the world economy**. In light of recent developments, we will continue to monitor developments closely and to co-operate in exchange markets as appropriate'.
United States	Quarterly Bulletin Q2 2011	March 18th 2011	On 18 March 2011, G7 Finance Ministers and Central Bank Governors announced that, in **response to the appreciation of the yen** following the earthquake and tsunami in Japan, and at the request of the Japanese authorities, the authorities of Canada, the United Kingdom, the United States, and the European Central Bank would join with Japan in **concerted intervention in foreign exchange markets**. On 18 March 2011, the Bank, under instruction from HM Treasury, and using the United Kingdom's official foreign exchange reserves, sold yen and purchased sterling in the foreign exchange market to give effect to the G7 Finance Ministers' communiqué.

Notes. This table collects selected passages from statements, speeches, press releases, or reports on FXI by the Bank of Japan, the Federal Reserve Bank, the European Central Bank, and the Bank of England. Historical press releases on FXI from the FED go back to 1996. Most of the selected passages have been published ex-post. A few statements provide vague indications regarding future FXI, with details such as timing and volume remaining unknown.

Appendix C Exchange rate changes on days of sequence starts

Date of intervention	USD/JPY	EUR/USD	USD/EUR	JPY/GBP
12.07.1991		0.32		
04.03.1992	-0.97			
01.04.1992	-1.18			
07.08.1992	0.20	-0.60		
02.04.1993	-0.09			
05.05.1993	0.05			
08.06.1993		-0.39		
07.09.1993	0.48			
06.09.1994	0.22			
03.10.1994	-0.45			
02.11.1994		-0.19		
02.03.1995		-0.3		
03.04.1995		-0.61		
07.07.1995	-1.85	0.33		
02.08.1995	-2.67	0.17		
06.09.1995	-1.04			
05.07.1999	-0.33			
04.01.2000	-1.36			
03.04.2000	-2.01			
22.09.2000			2.71	3.34
03.11.2000			0.23	
05.06.2003	0.84			
03.07.2003	0.33			
18.03.2011			0.85	3.28
04.08.2011	-2.75			

Notes. This table shows the first differences of exchange rate levels on the days FXI sequences start for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. We use nominal bilateral rates against the main intervention currency based on the sample mean of all interventions per country and quote them indirectly, with the domestic currency as the base currency. The first column lists the dates when FXI sequences start, providing information on the direction and intensity of intervention based on the intervention volume on the respective days. All numbers are reported as percentages (%), with positive (negative) numbers indicating currency appreciation (depreciation) relative to the previous day.

Appendix D Test of instrument quality

Variable	F-statistic	p-value
Intervention	1.0	0.43
Nom. bilat. exchange rate	1.5	0.11
Interest rate differential	1.1	0.39
Industrial production	1.1	0.38

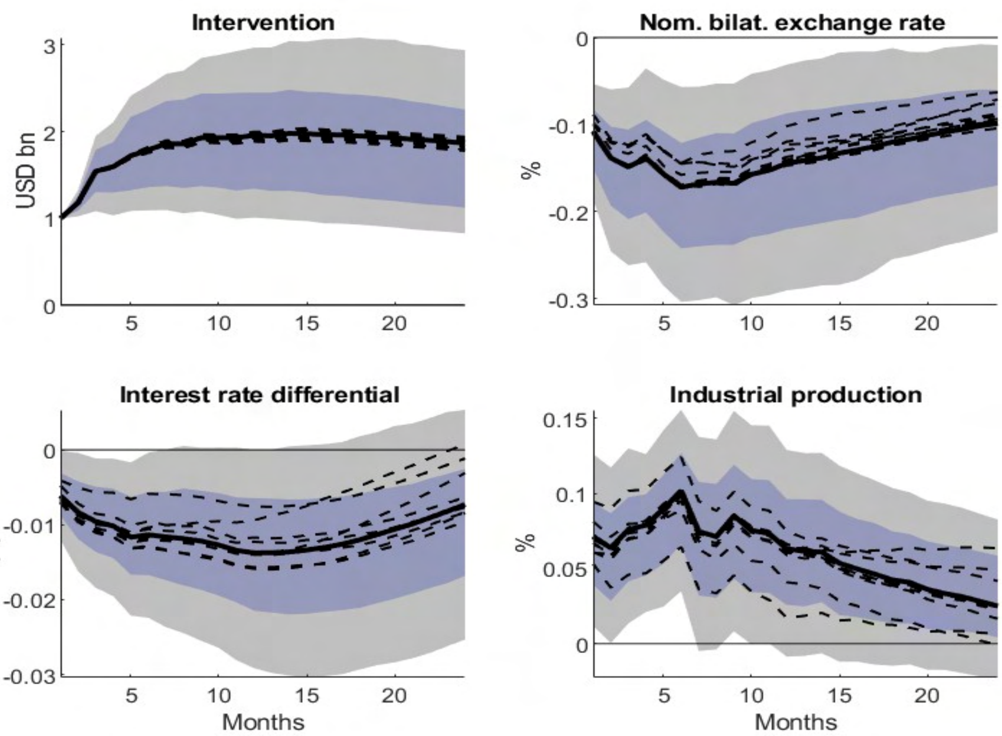
Notes. This table presents results from the Granger-causality test on the predictability of the external instrument. We test the null hypothesis that the lags of the endogenous variables of the baseline specification are jointly equal to zero by regressing the instrument on the autoregressive part of the reduced-form model. F-tests are computed using Huber-White heteroscedastic-robust standard errors. The p-values suggest non-predictability of the instrument.

Appendix E Test for VAR invertibility

Variable	F-statistic	p-value
Intervention	1.2	0.31
Nom. bilat. exchange rate	1.4	0.15
Interest rate differential	1.4	0.17
Industrial production	1.1	0.32

Notes. This table presents results from the invertibility test of Stock and Watson (2018). We estimate the baseline specification, including 12 lags of the instrument in each VAR equation, and test the null hypothesis that the coefficients on the 12 lags of the instrument are jointly equal to zero. F-tests are computed using Huber-White heteroscedastic-robust standard errors. The p-values suggest no statistically significant evidence against the null hypothesis of invertibility of the SVAR model.

Appendix F Impulse responses of baseline model with further variables



Notes. This figure shows the impulse response functions of the baseline variables in the augmented models, presented in Section 3.2, to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The solid line refers to the baseline specification in Section 3.1 and the dashed lines to the augmented models. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications on the baseline specification.

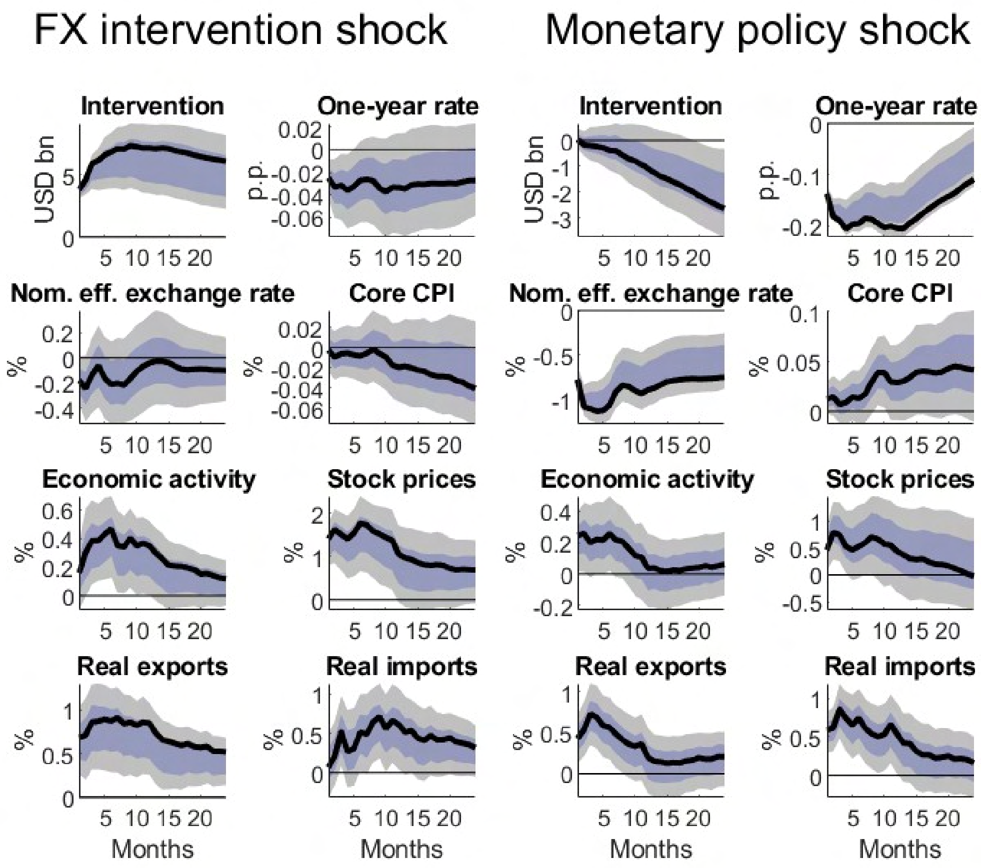
Appendix G Details on monetary policy surprises

This section provides details on the model presented in Section 3.4. We start by summarizing the four monetary policy shock series used as external instruments. These series are available either publicly or upon request. They are computed for Japan, the U.S., the Euro Area, and the UK by Kubota and Shintani (2022), Bauer and Swanson (2023), Boge et al. (2024), and Cesa-Bianchi et al. (2020), respectively. The reason why we use these four series is twofold. First, they cover a recent and extensive period, and second, they have also been used in related research, such as by Choi et al. (2024). Starting with the data for the Euro Area, Boge et al. (2024) compute monetary policy surprises for Germany between 1975 to 2021, covering periods of monetary policy conducted under the Bundesbank and the ECB. The authors follow a three-step process to build a high-frequency pure monetary policy shock. First, they compute daily changes in the financial market interest rates around meeting days. Then, they use the poor man's sign restriction identification approach from Jarociński and Karadi (2020) to disentangle pure monetary policy shocks from contemporaneous information shocks. This is achieved by examining co-movements of interest rates and stock prices on meeting days. Finally, Boge et al. only consider meeting days when interest rates and stock prices co-move negatively, ensuring pure monetary policy surprises, and regress changes in financial market rates on changes in the policy rate. We use the fitted values of the policy rate as our instrument for the Euro Area in Section 3.4. Kubota and Shintani (2022) construct monetary policy surprises for Japan using changes in three-month Euroyen futures and ten-year government bond futures prices around monetary policy announcements for the 1992 to 2020 period. They compute changes over a 30-minute window around the announcements to isolate the news from monetary policy announcements from other related news that could also affect the term structure of interest rates (see e.g. Cesa-Bianchi et al., 2020). However, Kubota and Shintani

(2022) do not decompose the monetary policy surprises into pure and information shocks but instead build on the method by Gürkaynak et al. (2005), which decomposes monetary policy surprises into target and path factors. The target factor is associated with changes in current short-term rates, while the path factor primarily affects the expected path of future rates. Similarly, Cesa-Bianchi et al. (2020) closely follow Gürkaynak et al. (2005) to construct monetary policy surprises for the UK for the 1997 to 2015 period. They compute the change in the price of three-month Sterling futures contracts in a 30-minute window around monetary policy announcements. We use the monthly aggregated version of these surprises as our instrument in Section 3.4. Bekaert et al. (2023) conclude that one should be careful when interpreting the results for Japan in line with, e.g. the U.S., due to the missing decomposition of monetary policy shocks from information shocks. A similar critique applies to the UK. Data on monetary policy surprises for the U.S. are used from Bauer and Swanson (2023), who go one step further by orthogonalizing the monetary policy surprises to macro and financial variables that precede the announcements. Thus, they account for the "FED response to news" channel of Bauer and Swanson (2023, 2023a). Specifically, they compute the change in the first four quarterly Eurodollar futures contracts in a 30-minute window around FOMC meetings and announcements, then regress macro and financial variables on the pure monetary policy shocks. We use the residuals obtained from this regression as the orthogonalized monetary policy surprises for the instrument in Section 3.4. Their series covers the 1988 to 2019 period, but we use data from 1991 onward when our sample starts.

Note that we estimate the reduced-form VAR using a longer sample period than for model identification to better estimate the lag coefficients and reduced form residuals (Cesa-Bianchi et al., 2020).

Figure G1: Comparison to conventional monetary policy



Notes. This figure shows the impulse response functions to a one standard deviation FXI shock (left panel) and an expansionary monetary policy shock (right panel) in a common panel Proxy-SVAR framework. Results are shown over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. Identifying latent structural FXI shocks, the intervention variable is instrumented using a series that contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention. In the monetary policy framework, the one-year interest rate on government bonds is instrumented using monetary policy surprises, such as those provided by Bauer and Swanson (2023) for the United States. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Appendix H Elasticity of GDP to industrial production

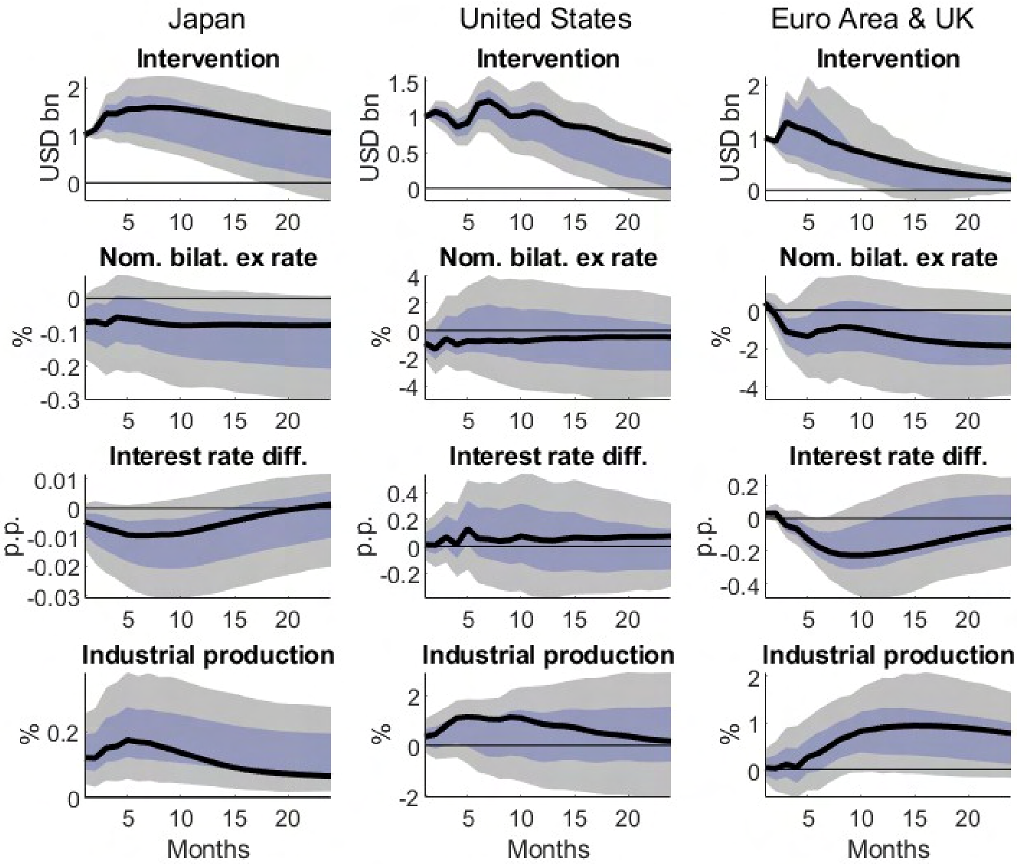
Specification	(1)	(2)
Industrial production ($\hat{\beta}$)	0.35***	0.36***
Conventional SE	*(0.02)*	*(0.02)*
Huber-White SE	*(0.05)*	*(0.05)*
Clustered SE[a]	*(0.12)*	*(0.10)*
Bootstrapped SE[b]	*(0.07)*	*(0.07)*
GDP deflator ($\hat{\gamma}$)	0.01	0.02
Conventional SE	*(0.09)*	*(0.09)*
Huber-White SE	*(0.40)*	*(0.40)*
Clustered SE[a]	*(0.32)*	*(0.32)*
Bootstrapped SE[b]	*(0.34)*	*(0.33)*
R-squared	*0.51*	*0.51*

Notes. This table reports estimates from the linear panel regression model using quarterly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. We estimate $\Delta \ln GDP_{it} = \alpha_i + \beta \, \Delta \ln industrial\ production_{it} + \gamma \, \Delta \ln GDP\ deflator_{it} + \delta \, X_{it} + \eta_{it}$, for $i = 1, \ldots, N$ countries and sample length $t = 1, \ldots T$. α_i are country-specific fixed effects and the matrix X_{it} contains further controls, depending on the estimated specification. Specification (1) is estimated without any further controls in the X_{it} vector. In specification (2), we control for seasonality. We control for price changes because GDP is given in nominal terms. The $\hat{\beta}$ coefficient indicates the elasticity of GDP to changes in industrial production. Different types of standard errors are provided in parentheses. *** p<0.01, ** p<0.05, * p<0.1

[a] Standard errors are clustered at the country level.

[b] Standard errors are computed using the fixed design wild bootstrap.

Appendix I Additional country-specific results



Notes. This figure shows the country-specific impulse responses of the baseline variables to an FXI shock of 1 billion U.S. dollars over a 24-month horizon, when we split up the panel into Japan, the United States, and the Euro area together with the United Kingdom. The (panel) Proxy-SVARs are estimated in log levels, with 6 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data since the 1990s. For Japan, the United States, and the Euro area together with the United Kingdom, the instruments contain 16, 7, and 5 sequence starts, respectively. The instruments are categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Appendix J Sensitivity analysis (detailed version of Section 5)

This appendix summarizes the results from a sensitivity analysis, addressing sixteen potential concerns. Overall, the results demonstrate that the baseline model is robust. (i) In detail, we estimate the panel Proxy-SVAR with different lag lengths varying between 3 and 36 lags. Figure J1 shows that the model is robust. (ii) In Figure J2 we show results of the baseline specification estimated with 24 lags and the corresponding 68% and 95% confidence bands. Further, we report results with either a linear trend or without a trend component. (iii) Figure J3 shows robust results to both specifications. (iv) Figure J4 shows robust results to normalizing the cumulative intervention volumes by monthly GDP, which is the policy variable. We aim to account for different sizes of the economies in our panel.

(v) Next, we report robust results with modified instruments. First, we either leave coordinated or unilateral interventions out (Figure J5). Results from unilateral interventions are largely driven by Japan, as the Bank of Japan primarily intervened unilaterally, whereas the Federal Reserve Bank and the Bank of England only intervened in collaboration with other central banks during the sample period. The results align with expectations that joint interventions are more effective not only in altering the exchange rate level but also in boosting output in the domestic country (following a devaluation of the domestic currency). (vi) Second, we modify the instrument by changing the weighting factor to either 0.25, 0.75, or 1 (no weighting). Results are shown in Figure J6. (vii) Third, we modify the instrument by computing the weighted sum of all sequence starts which happen within a month (Figure J7). We use the weighting factor from an inverse (quadratic) function, with days at the start of the month weighted more than those at the end.

(viii) Then, we test the robustness of the results to using orthogonalized FXI shocks. We use the residuals from each regression specification in Table 3 as instruments. Figure J8 shows robust results.

(iv) We slightly modify the considered cases of FXI in our analysis. So far, we include all FXI of any of the four countries or currency areas and measure their impact on the main exchange rate. Take, for example, Japan: most Japanese FXI are in U.S. dollar, but some are also conducted in the Euro (or Deutsche Mark). In order to get as large numbers and volume of FXI as possible, we also include the Euro-interventions in our study and assume that they also impact the exchange rate towards the U.S. dollar, even though probably to a smaller extent. This assumption seems appropriate as an example demonstrates: if the Bank of Japan purchases U.S. dollar to depreciate its domestic currency, this depreciation feeds, possibly not fully, through all other exchange rates too, otherwise the cross-rates would change. But why should the cross-rate, here the USD-Euro exchange rate, change proportionately to a USD-Yen intervention – instead, the Euro-Yen exchange rate will adjust. This mechanism also applies then to FXI in Euro by the Bank of Japan that will not only impact the Euro-Yen exchange rate but also the USD-Yen exchange rate, but not the USD-Euro relation. Still, if we neglect all FXI in so-to-say "second" currencies, we lose observations but the qualitative results remain unchanged as Figure J9 shows.

(x) Then, we test the robustness of the assumption on homogeneous slopes. Our analysis is based on results from pooled panel estimation, which relies on the assumption of homogenous slopes across countries included in the panel. One way to test if this homogeneity assumption is valid is to use the mean group estimator (Pesaran and Smith, 1995). We compute impulse responses and bootstrapped confidence bands for each country separately and then calculate weighted averages using weighting factors based on countries' share of non-zero elements in the instrument (see Figure J10).

(xi) As another test for the robustness of our model, we include exchange rate forecasts as a measure of market expectations of FXI. We either include nominal bilateral exchange rate forecasts vis-à-vis the U.S. dollar, nominal effective exchange rates or both variables at once. Figure J11 shows robust results when including forecasted exchange rates as exogenous variables.

(xii) Figure J12 shows that the model is robust while controlling for uncertainty. We estimate the model with the economic policy uncertainty (EPU) index and the CBOE volatility index (VIX) as exogenous variables. First, we estimate the model with each index separately, and then with both indices together.

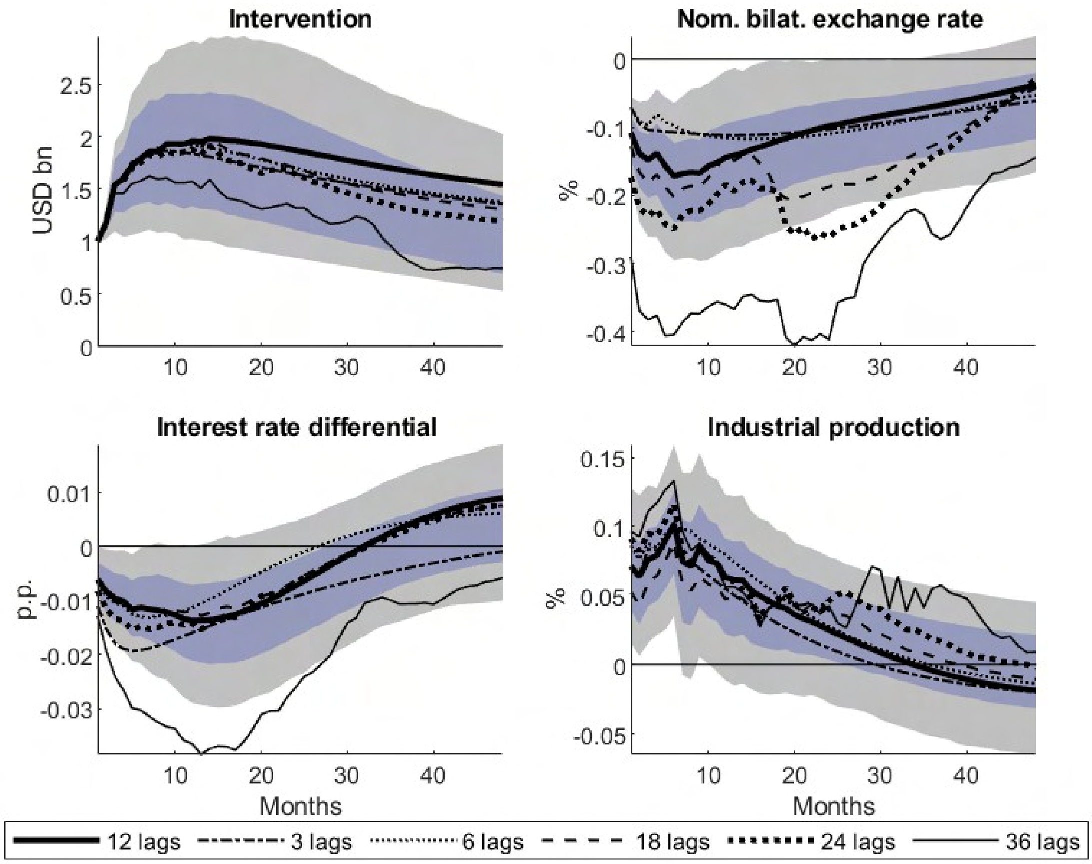
(xiii) Next, we extend the series of Euro interventions by Bundesbank interventions, such that this new Euro Area sample starts already in 1991M4. Prior to 1999, we use data for Germany to backward-iterate series for the Euro Area. As the number of interventions for the Euro Area increases, and consequently the number of sequence-starts, we can here consider starts only within the first two weeks. The number of non-zero elements in the instrument increases from 28 to 30, with four related to Bundesbank interventions and one to a Euro intervention. The results remain robust with the inclusion of Bundesbank interventions, as shown in Figure J13.

(xiv) Figure J14 shows robust results while accounting for the structural break around 1995, when the Bank of Japan and the Federal Reserve Bank adjusted their intervention patterns regarding the length of intervention sequences and volumes. We set the instrument observations for Japan and the United States before 1995 to zero, leaving the estimation period unchanged. The number of non-zero elements in the instrument decreases from 28 to 18.

(xv) Then, we use the residual-based moving block bootstrap by Jentsch and Lunsford (2019) as an alternative to the residual-based wild bootstrap. Following Kim et al. (2023), we set the block length to one, even if the rule of thumb proposed by Jentsch and Lunsford (2019) suggest a block length of $5.03T^{0.25}$. We do so because the moving block bootstrap picks observations at the beginning and end of the sample with lower probability, which impacts our results as many interventions – and thus non-zero elements in the instrument – are at the beginning of the sample periods. We compute 68% confidence bands as the moving block bootstrap produces much wider bands than the wild bootstrap. Results are shown in Figure J15.

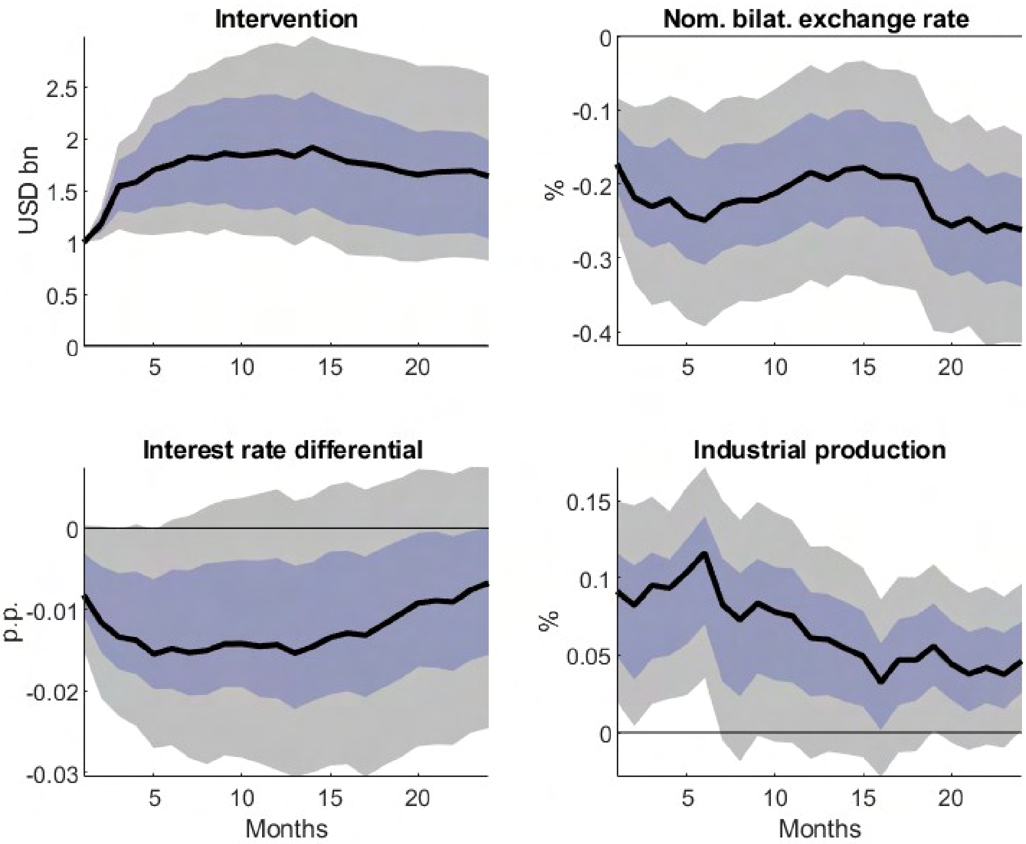
(xvi) Finally, following the literature around Stock and Watson (2018), we estimate the model using local projections – IV (LP–IV) and compare the impulse responses to those from the SVAR. With this, we extend the results from the invertibility test based on Stock and Watson (2018), which we conducted and summarized in Appendix E. Invertibility is a commonly made assumption when using a Proxy–SVAR, which is not required for the LP–IV method. To make results as comparable as possible, we use single-equation specification similar to those in the SVAR model for the second-stage regression. Figure J16 shows that the results hold.

Figure J1: Robustness to using different numbers of lags



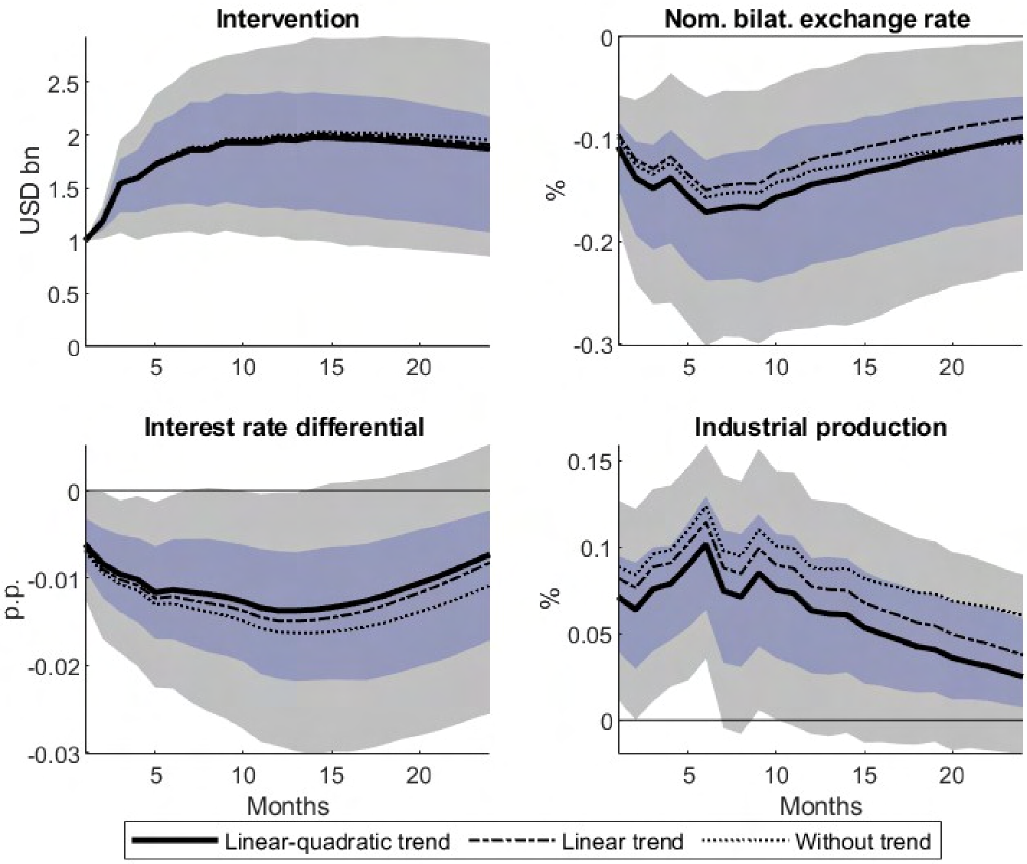
Notes. This figure shows several impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 48-month horizon. The panel Proxy-SVAR is estimated in log levels, with different lag lengths varying between 3 and 36, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J2: Robustness to using 24 lags and confidence bands



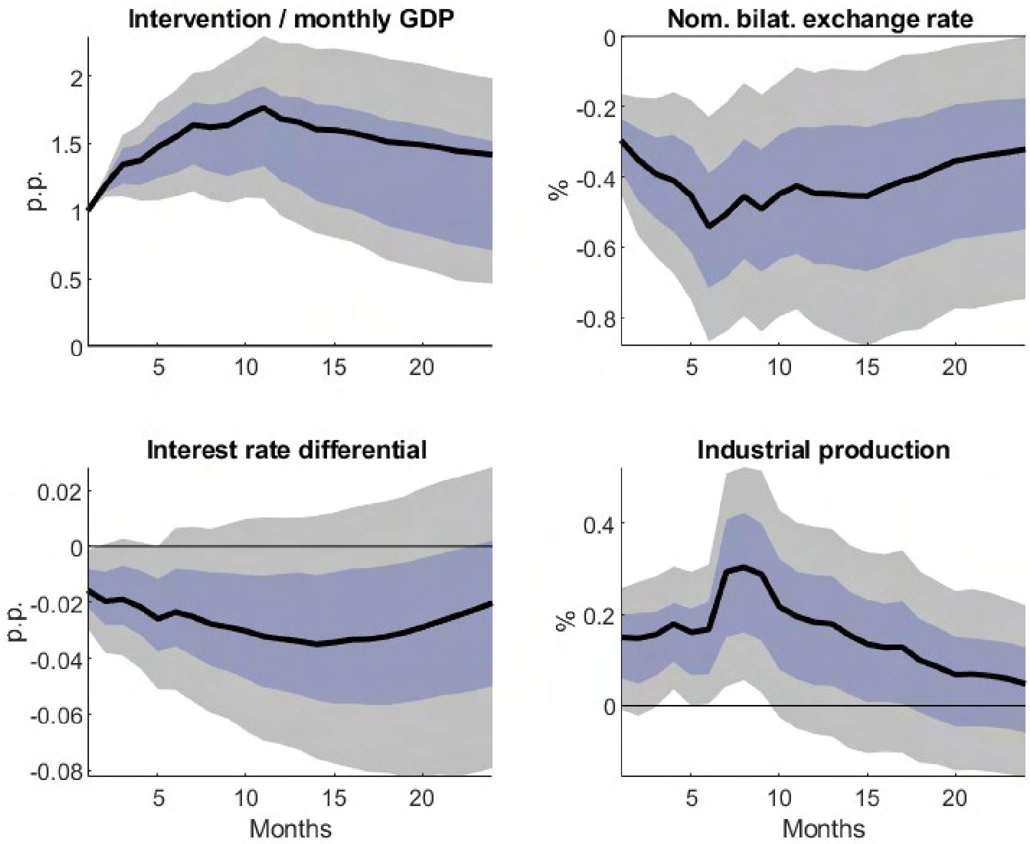
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 24 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J3: Robustness to linear trend and no trend



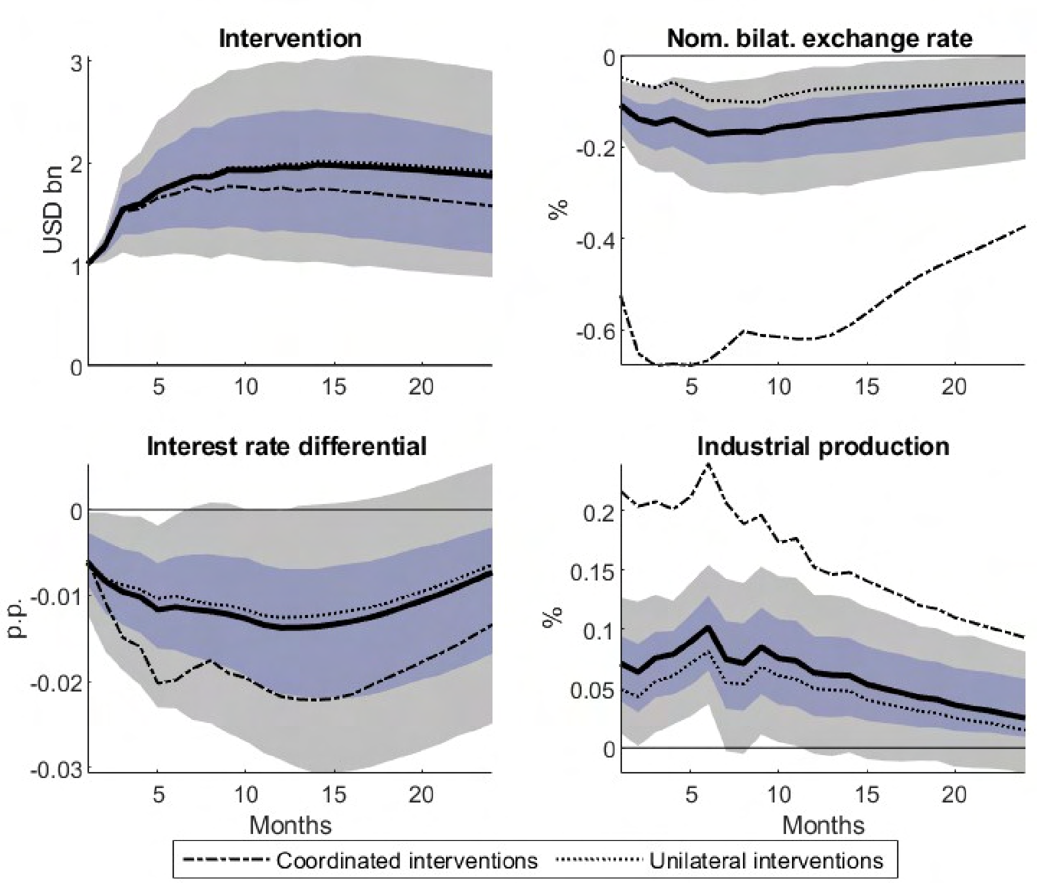
Notes. This figure shows several impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. Solid lines show responses of the baseline model as in Section 3.1. The dashed-dotted and dotted lines show responses with a linear and without trend, respectively. In its baseline version, the panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, and monetary policy surprises, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J4: Robustness to normalizing the intervention volume by GDP



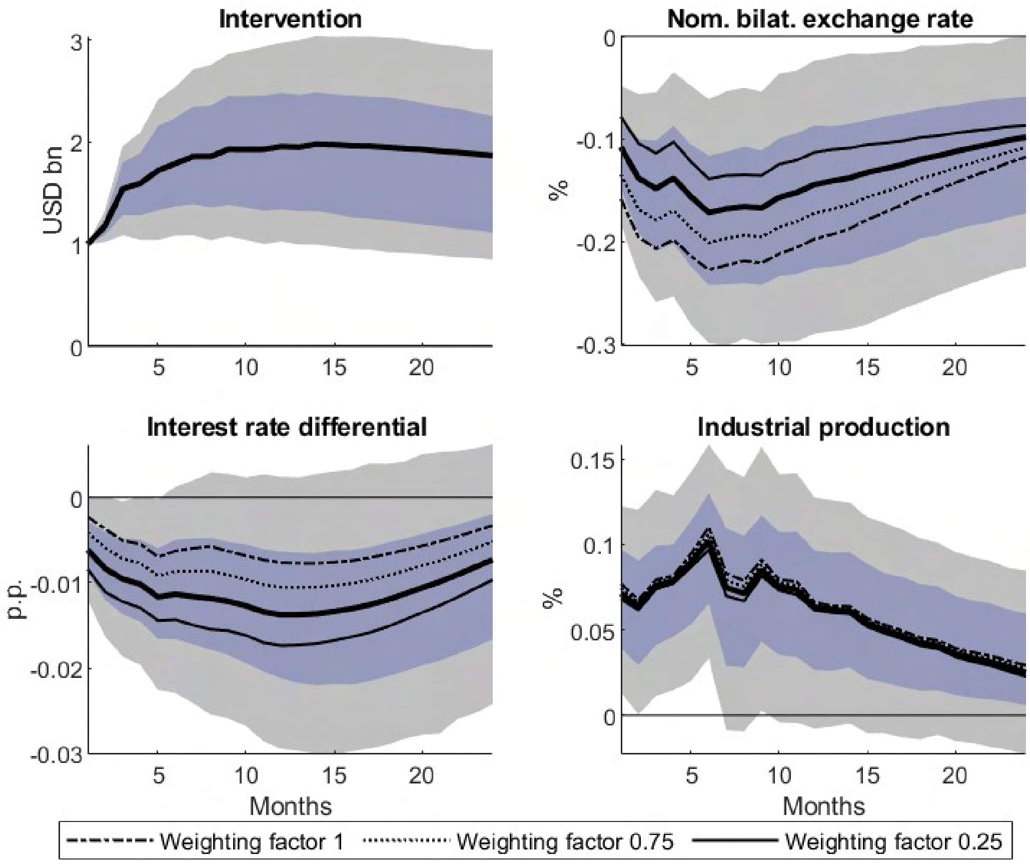
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 p.p. intervention volume relative to monthly GDP over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the policy variable. The cumulative intervention volumes are normalized by monthly GDP to account for the different sizes of the economies. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J5: Robustness to modifying the instrument I



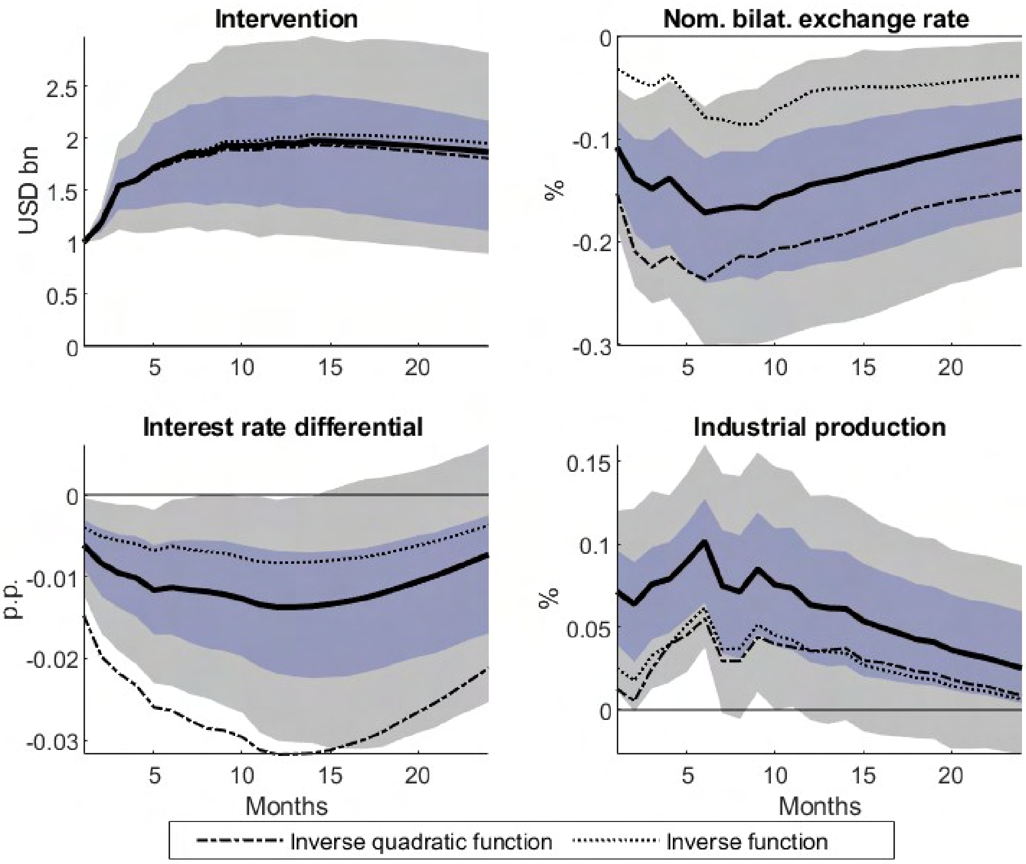
Notes. This figure shows several impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The intervention variable is instrumented using three different versions of the instrument. In its baseline version, the instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention (solid lines). Dashed-dotted and dotted lines show responses only considering either coordinated or unilateral starts of intervention sequences, respectively. Each instrument contains 14 starts of sequences. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J6: Robustness to modifying the instrument II



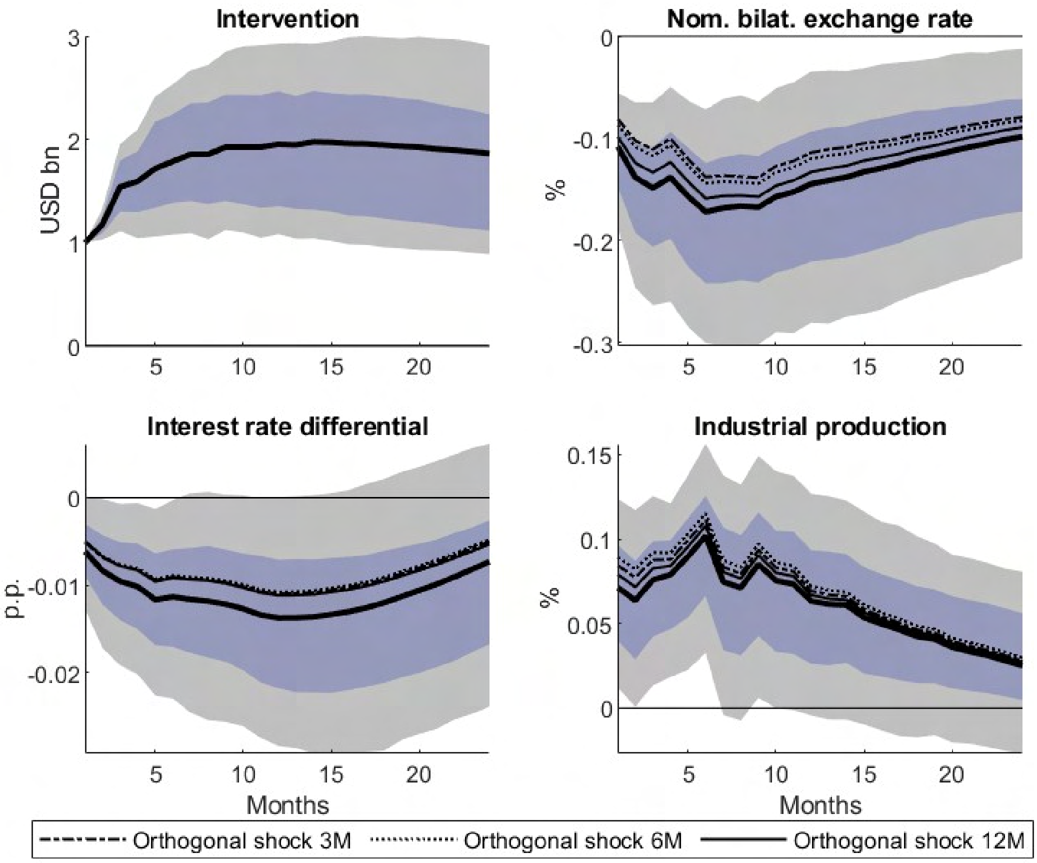
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The intervention variable is instrumented using four different versions of the instrument. In its baseline version, the instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention (thick solid line). In its modified versions, a weighting factor of either 1 (dashed-dotted line), 0.75 (dotted line), or 0.25 (solid line) is used. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J7: Robustness to modifying the instrument III



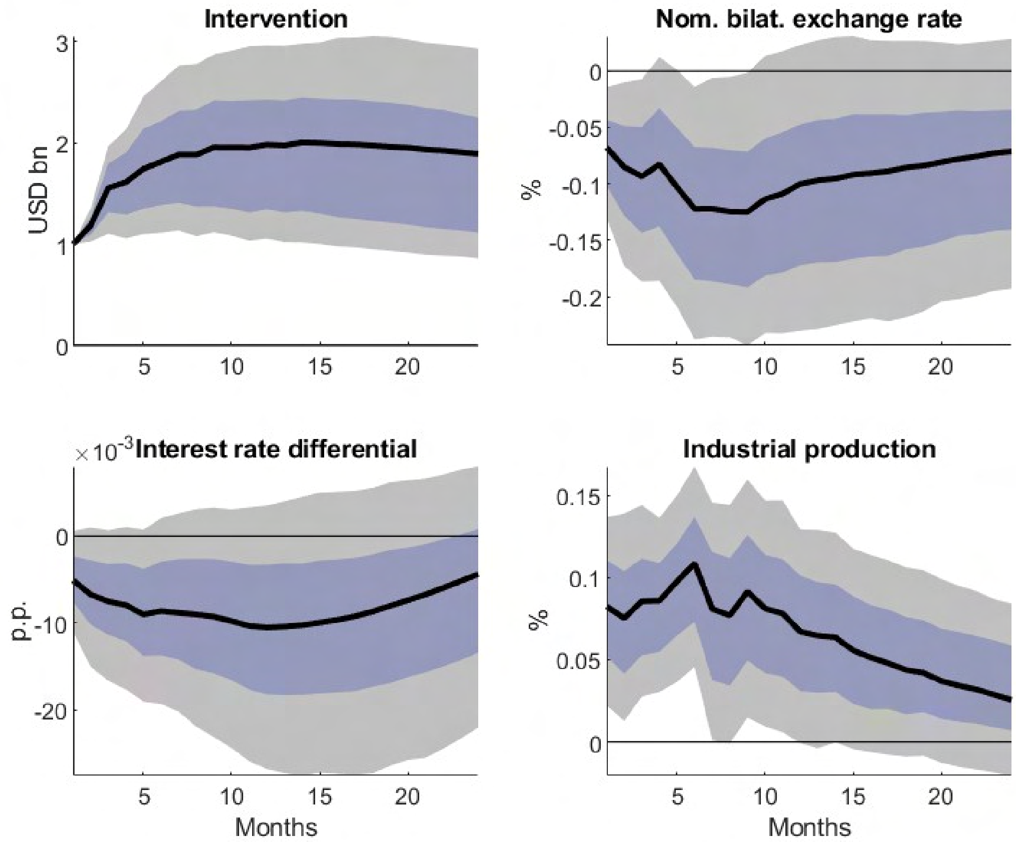
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The intervention variable is instrumented using three different versions of the instrument. In its baseline version, the instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention (thick solid line). In its modified versions, we consider all sequence starts within a month and weight values either inversely quadratic (dashed-dotted line) or inversely (dotted line). 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J8: Orthogonalized FXI shocks



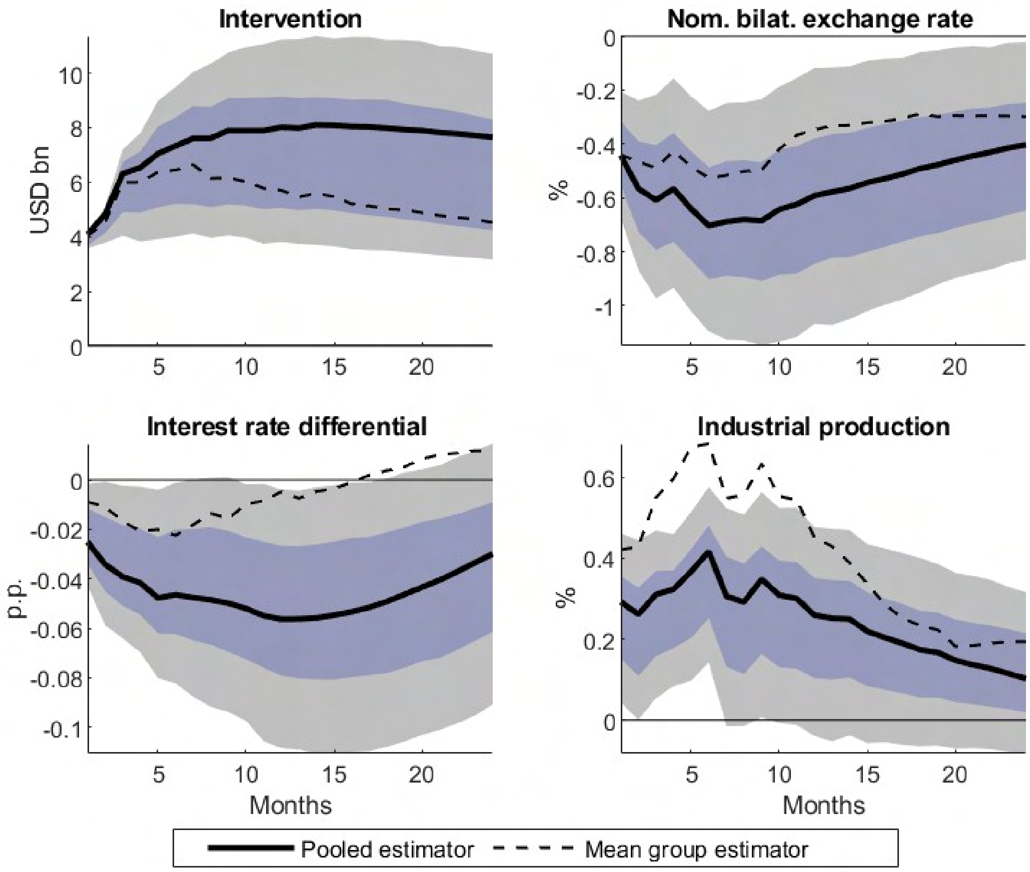
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The intervention variable is instrumented using three different versions of the instrument. In its baseline version, the instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention (thick solid line). In its modified versions, we use three different orthogonalized instruments, with each being the residuals from instrument projection onto nine macroeconomic variables that are measured as the difference from their three- (dashed-dotted line), six- (dotted line), and twelve-month (solid line) moving averages. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J9: Robustness to considering only the main intervention currency



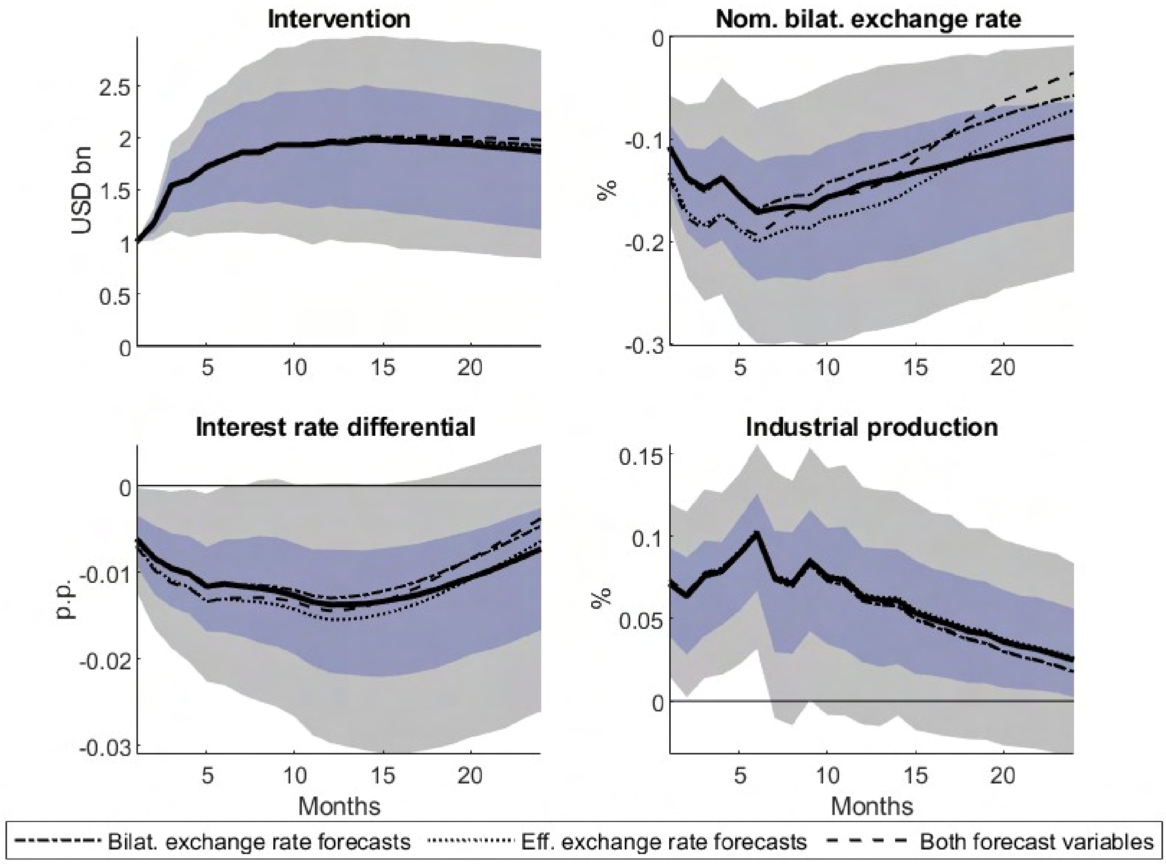
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 23 starts of intervention sequences in the main currency as categorical variables, indicating the intensity and direction of intervention used for instrumenting the policy variable. The intervention variable includes only purchases and sales of the main intervention currency as defined in the Appendix. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J10: Robustness to the assumption of homogeneous slopes



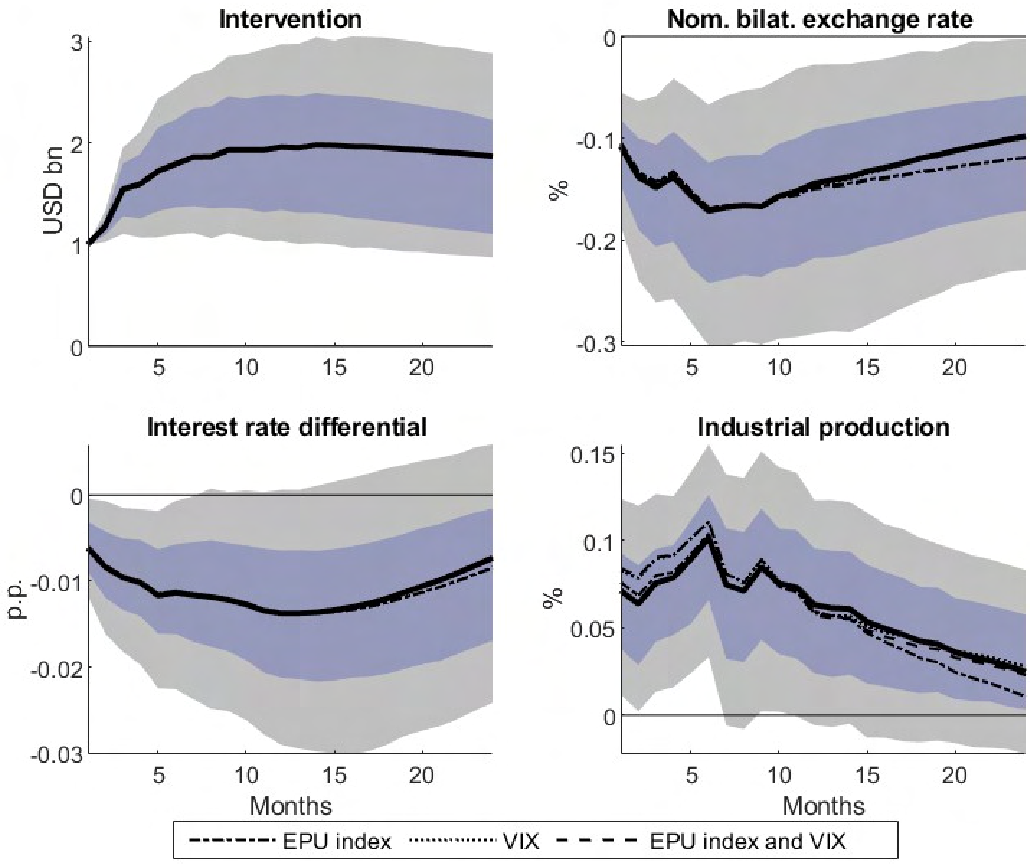
Notes. This figure shows the impulse response functions of the baseline model to a one standard deviation FXI shock of roughly 4 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. The figure reports results with pooled panel estimation (solid line) and mean group estimation (dashed line). 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications on pooled responses.

Figure J11: Robustness to forecasted exchange rates



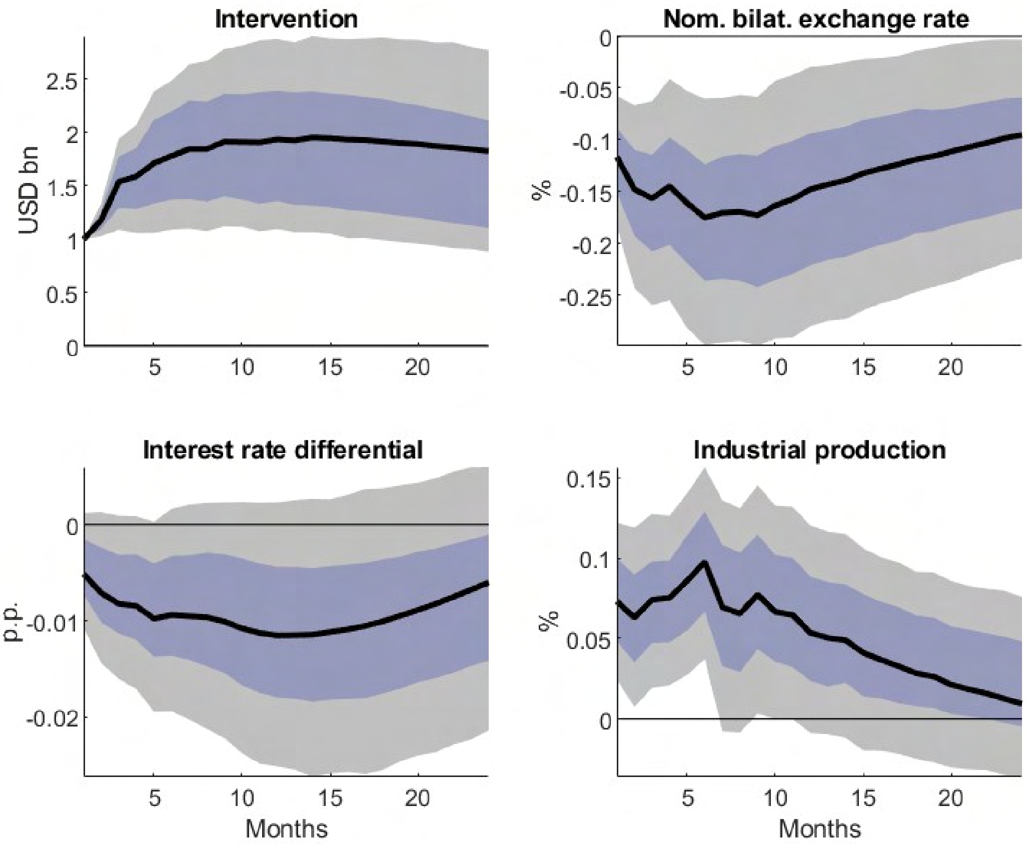
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. Solid lines show responses of the baseline model as in Section 3.1. The dashed-dotted, the dotted, and the dashed lines show responses with the inclusion of either nominal bilateral exchange rate forecasts vis-à-vis the U.S. dollar, nominal effective exchange rate forecasts, or both variables at once as exogenous, respectively. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J12: Robustness to uncertainty indices



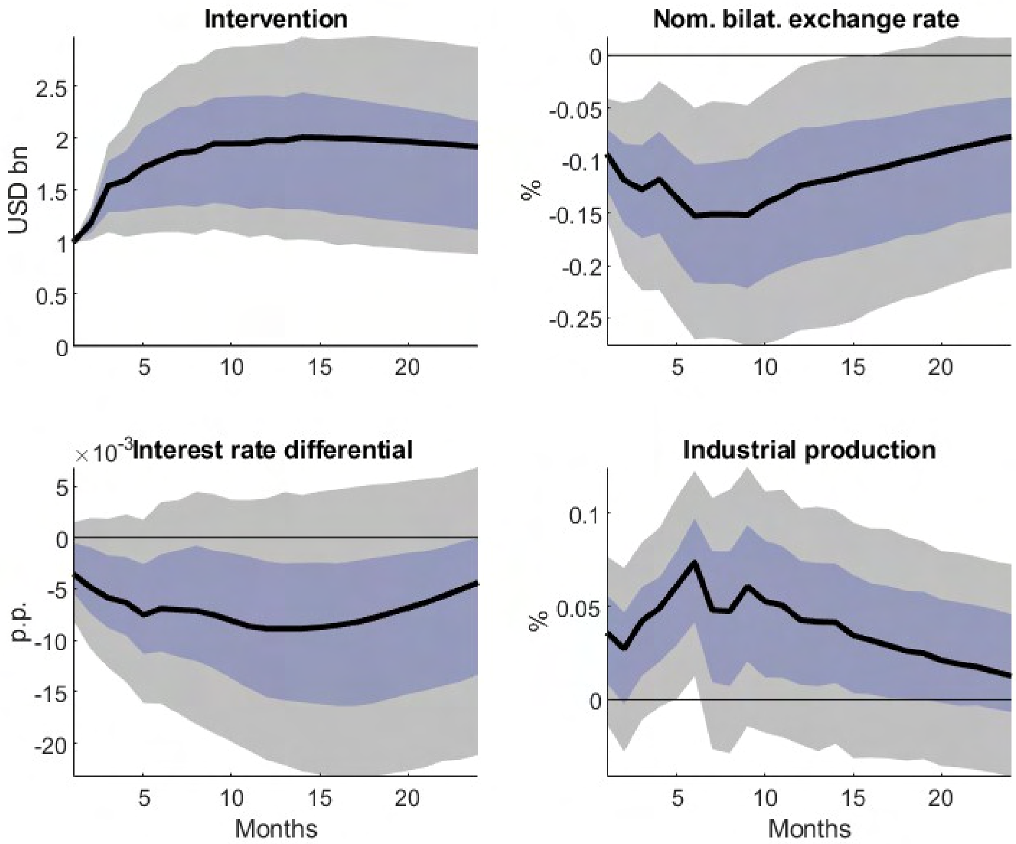
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. Solid lines show responses of the baseline model as in Section 3.1. The dashed-dotted and dotted lines show responses with the economic policy uncertainty (EPU) index and the CBOE index as exogenous variables, respectively. The dashed lines show responses, including both indices as exogenous. In its baseline version, the panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J13: Extending Euro Area series with Bundesbank interventions



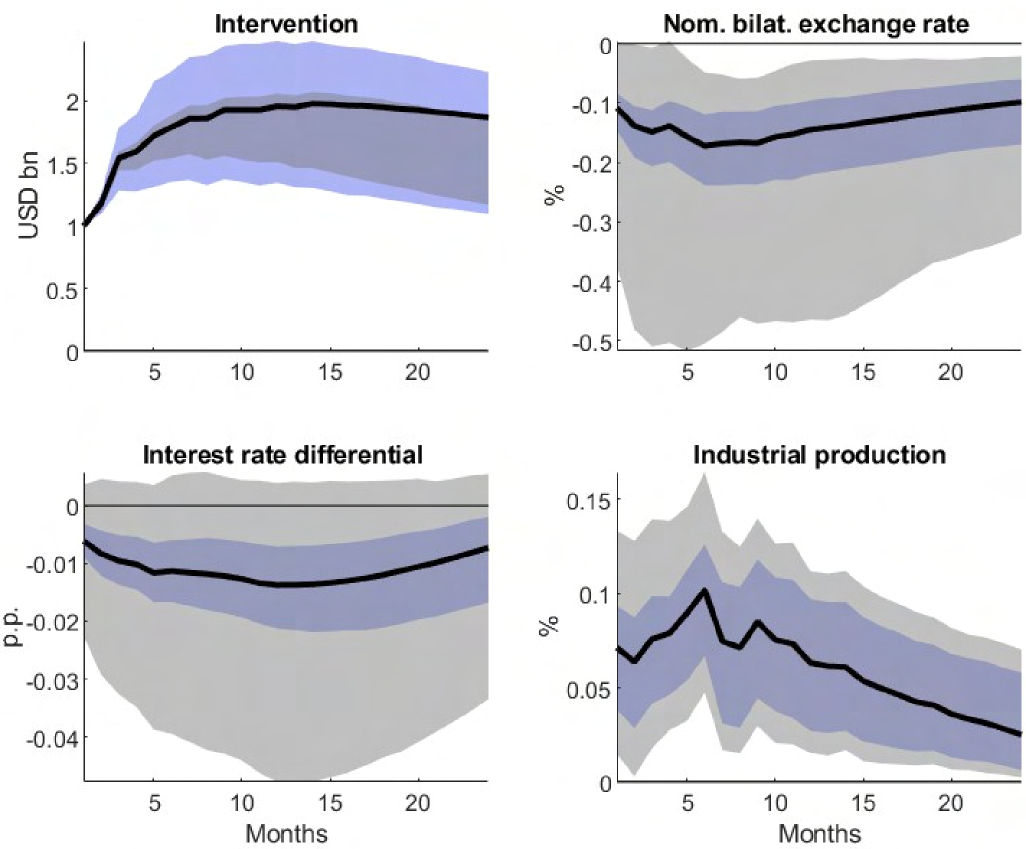
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The Euro Area sample is expanded with Bundesbank interventions; thus, it starts in 1991M4. The instrument contains 30 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J14: Accounting for the institutional break in the mid-1990



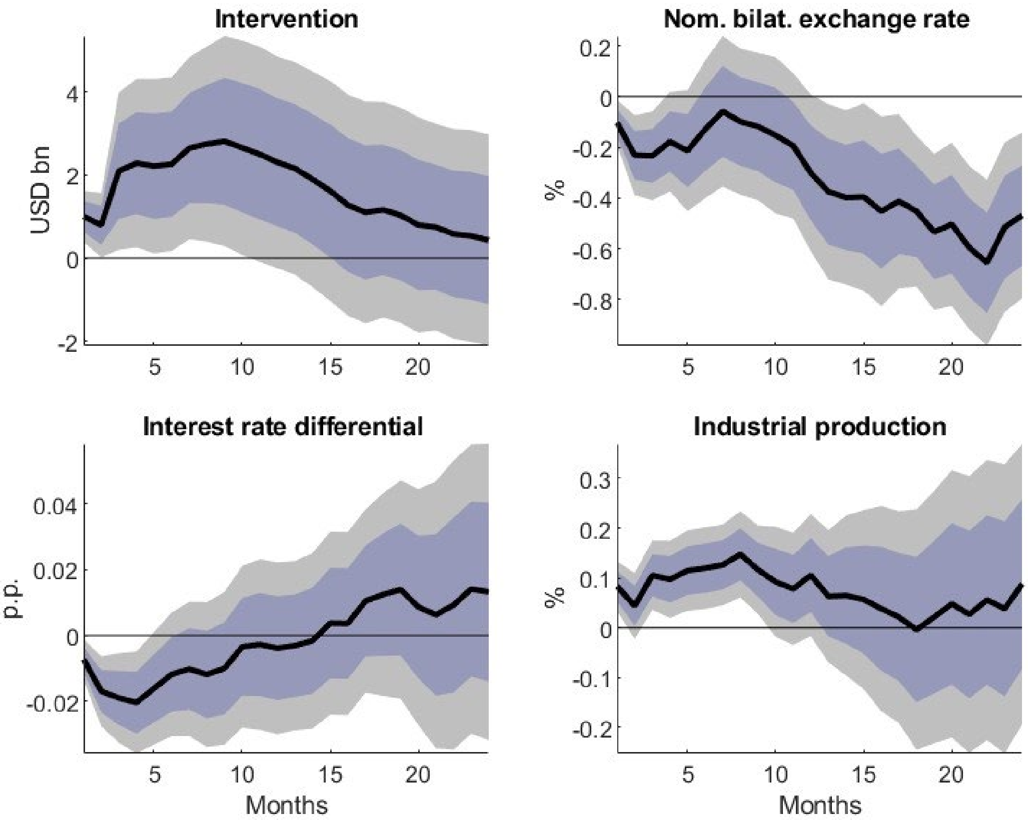
Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon accounting for the institutional break in Japan and the United States around 1995. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 18 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% (dark grey) and 95% (light grey) confidence bands are computed using residual-based wild bootstrap with 1,000 replications.

Figure J15: Robustness to alternative bootstrap procedure



Notes. This figure shows the impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. The panel Proxy-SVAR is estimated in log levels, with 12 lags, controlling for seasonality, the FXI of the foreign country, monetary policy surprises, and potential structural breaks, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention used for instrumenting the intervention variable. 68% confidence bands are computed using residual-based wild bootstrap (dark grey) and residual-based moving block bootstrap (light grey), each with 1,000 replications.

Figure J16: Robustness to using local projections



Notes. This figure shows impulse response functions of the baseline model to an FXI shock of 1 billion U.S. dollars over a 24-month horizon. Responses are computed using instrumental variable local projections, using monthly data for Japan, the United States, the Euro Area, and the United Kingdom since the 1990s. The instrument contains 28 starts of intervention sequences as categorical variables indicating the intensity and direction of intervention. In the first stage, we regress the cumulative intervention volume, which is the policy variable, on the instrument, using only the non-zero instrument observation periods. The regression model is $cum\,volume_{it} = \alpha_i + \gamma\, Instrument_{it} + \delta\, Z_{it} + u_{it}$, with $i = 1, \ldots, N$ countries and $t \in \{1, \ldots T \mid Instrument_{it} \neq 0\}$ periods. α_i are country-specific fixed effects and Z_{it} contains the FXI of the foreign country, monetary policy surprises, and exchange rate forecasts. The predicted values are assigned to the periods in which the instrument is non-zero. For the remaining periods, we set the value to zero. The second stage regression is: $y_{it+h} = \alpha_i + \beta_h \widehat{cum\,volume}_{it} + \varphi X_{it} + \eta_{it}$, for horizons $h = 1, \ldots, H$. $X_{i,t}$ contains all variables that are on the right-hand side of the VAR, as well as exchange rate forecasts and 12 lags of the shock. 68% (dark grey) and 90% (light grey) confidence bands are computed using Huber-White standard errors.

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