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## The Dynamic Impact of FX Interventions on Financial Markets

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## **WEB-APPENDIX**

### **The dynamic impact of FX interventions on financial markets**

by Lukas Menkhoff, Malte Rieth and Tobias Stöhr

**Appendix A. Identification via timing restriction (detailed version of Section 4.2)**

**Appendix B. Robustness checks (detailed version of Section 4.4)**

**Appendix C. Further sensitivity analyses (detailed version of Section 4.5)**

**Appendix D. Evidence for the US, Euro Area and UK (detailed version of Section 5)**

## **Appendix A. Identification via timing restriction (detailed version of Section 4.2)**

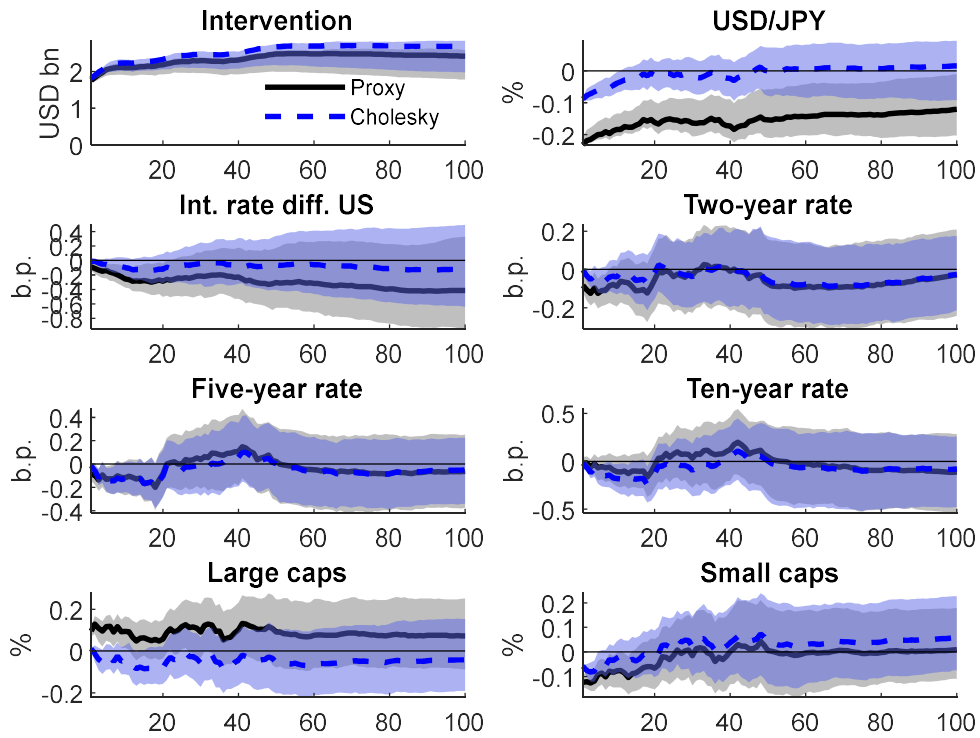
Figure A1 presents the estimates from a Cholesky ordering of the variables, and our modeling approach (from Section 3.3). It shows that the Proxy-SVAR leads to larger impacts of FX intervention shocks. Regarding the exchange rate, the effect is twice as large and lasts for 100 days, whereas for the recursive model it is indistinguishable from zero after only 10 days. Interest rates show the same pattern as before, but effects are even smaller and consistently insignificant under the timing restriction. Regarding stock prices, there is no longer an effect on large firms and only a short-lived effect (5 days) on small firms' stock prices. Thus, it may be reassuring that a different method leads to the same qualitative findings but if one is convinced by the superiority of the Proxy-SVAR, this method is crucial to obtain relatively large and persistent effects on exchange rates and stock prices.

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**Table A1.** As discussed in Section 3.3, Table A1 reports the results of the test on invertibility, following Stock and Watson (2018). Results indicate that there is no statistically significant evidence against the hypothesis of invertibility.

**Figure A1: Comparison of Proxy-SVAR and recursive identification**

The figure shows the responses of different asset prices to an intervention shock of one standard deviation over a horizon of 100 trading days based on a SVAR(50) identified with an external instrument (solid line) and based on a SVAR(50) identified recursively with the cumulated interventions ordered first (dashed line), along with their 90% confidence bands.



**Table A1: Test for invertibility of SVAR identified with external instrument**

The table shows  $p$ -values for a robust  $F$ -statistic testing the null hypothesis that the coefficients on 1 to 1-6 lags of the instrument are jointly equal to zero in each of the VAR equations of the extended model.

Lags	<i>Equation</i>							
	Inter- vention	USD/ JPY	Int. rate diff.	Two- year rate	Five- year rate	Ten- year rate	Large caps	Small caps
1	0.91	0.24	0.31	0.35	0.66	0.38	0.37	0.68
2	0.36	0.32	0.59	0.63	0.17	0.07	0.08	0.20
3	0.32	0.39	0.25	0.23	0.14	0.11	0.16	0.26
4	0.47	0.46	0.30	0.18	0.07	0.05	0.13	0.20
5	0.59	0.61	0.40	0.23	0.08	0.07	0.21	0.30
6	0.71	0.70	0.51	0.32	0.11	0.08	0.30	0.41

## Appendix B. Robustness checks (detailed version of Section 4.4)

In this appendix, we perform four analyses to see how the results are affected by our definition of the instrument. First, we use a policy reaction function approach to clean the instrument. Second, we redefine intervention sequences using a stricter criterion. Third, we exclude coordinated interventions. In all cases, we scale the policy shock to one standard deviation of the baseline model for comparability and focus on the bivariate model for brevity. Fourth, we perform a counterfactual placebo analysis by purposely applying a “useless” instrument variable in our Proxy-SVAR approach, i.e. the second day of an intervention episode (instead of the first day).

**Policy reaction function.** We argue that the first day of any intervention sequence is largely exogenous. This implies that - although market participants form expectations about future interventions - it is difficult to forecast these days. In order to capture this reasoning, we use the reaction function for Japanese FX interventions proposed by Ito and Yabu (2007). Assuming that interventions being explained by this approach can be expected, we take the (unexplained) residual as instrument in our Proxy-SVAR. These values deviate at most  $\pm 7\%$  from the values of the categorical variable (1, 0, -1) used in the baseline specification. Thus, it is not a surprise that the estimated intervention impact, shown by the solid line in [Figure B1](#), is graphically difficult to distinguish from the impact relying on our baseline instrument. We conclude that the exact intervention day is actually hard to anticipate.

**Longer intervention sequences.** Next, we evaluate whether our argumentation for instrument exogeneity based on the institutional design for intervention policy relates to the length of an intervention sequence. *Ex ante*, it is conceivable that our assumption is better suited for longer sequences with larger volumes than for shorter and smaller sequences, as the former might require more preparatory work and coordination between the Bank of Japan and the

Ministry of Finance. To test this hypothesis, we re-define intervention sequences as consisting of at least two intervention days within five trading days. We leave the definition of the start of a sequence unchanged such that there are no interventions in the preceding five trading days. The dotted line in Figure B1 shows that the estimated effect of intervention shocks based on the modified instrument is qualitatively the same as for the baseline definition of the instrument or the cleaned instrument. It remains statistically significant. However, the effect decreases substantially, both upon impact and thereafter. *Ex post*, we interpret the smaller estimate as reflecting selection bias in the redefinition of the instrument. Using only longer spells seems to imply focusing on sequences that are less successful initially and, therefore, are continued longer, such that the estimated impact based on this subset of non-censored instrument observations declines.

**Internationally coordinated interventions.** Finally, we assess how the baseline results change when excluding coordinated interventions. It is a stylized fact that these interventions have larger effects. For data availability reasons, we exclude days from the sample when US monetary authorities also intervened. There are seven such days in the sample. Indeed, the dashed line in Figure B1 shows that the estimated impact on the exchange rate decreases, but the depreciation remains statistically significant for 45 days.

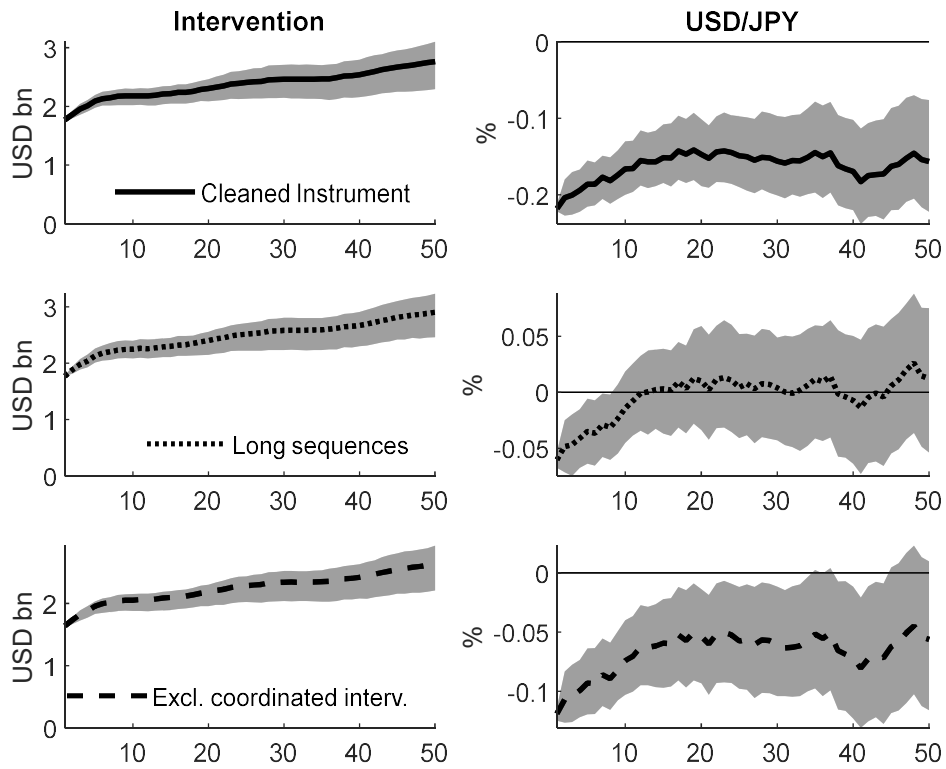
**Placebo test.** To see which conditions would invalidate our approach, we use an alternative and *ex ante* conceivably useless instrument. Specifically, we employ the second day of the intervention sequences that we identify for the baseline results as instrument for intervention shocks, instead of the first day of these sequences. As we argued before, the decision to continue a sequence is more likely to depend on current market conditions which reflect the success of the initial intervention. Hence, we expect the results to be affected by endogeneity. Figure B2 shows that this is indeed the case. An intervention shock of the same sign as in the baseline model now leads to an appreciation of the currency, instead of a

depreciation, and significant increases in interest rates of different maturities. This placebo test suggests that our identification strategy actually works for latent intervention shocks and that our results are not by chance.



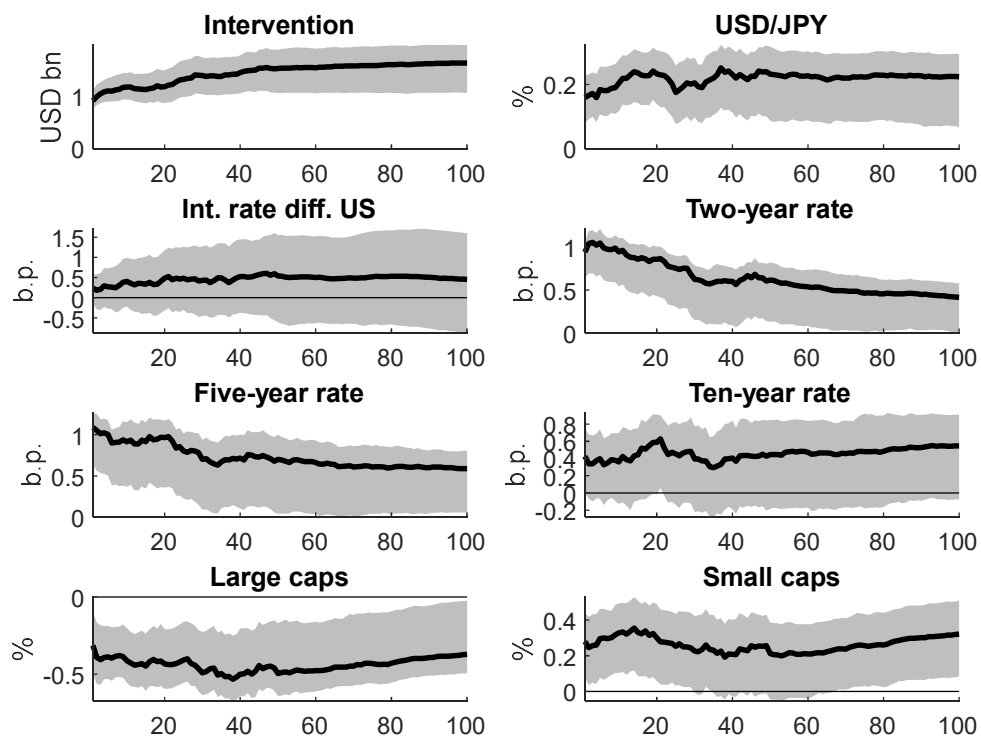
**Figure B1: Impulse responses for modified instruments**

The figure shows the responses of the endogenous variables to an intervention shock of one standard deviation in the baseline model for 50 trading days based on a SVAR(50) identified with modified external instruments, along with 90% confidence bands using 200 bootstrap replications. The solid line refers to an instrument cleaned through a policy function approach, the dotted line to longer intervention sequences including at least one additional intervention in the five days following the initial intervention, and the dashed line to an instrument that excludes coordinated interventions.



**Figure B2: Placebo test using second day of intervention sequence**

The figure shows the responses of different asset prices to an intervention shock of one standard deviation over a horizon of 100 trading days, along with their 90% confidence bands from 200 bootstrap replications, based on a SVAR(50) identified with an external instrument. The instrument is the second day of an intervention sequence.



## **Appendix C. Further sensitivity analyses (detailed version of Section 4.5)**

In this appendix, we summarize the results from an extensive sensitivity analysis. They demonstrate that our main results are robust and tend to provide a conservative, that is, lower bound estimate of the effect of FX interventions. In detail, we exclude either the weekday or month dummies from the set of exogenous variables, or include either a linear trend or year dummies. The differences are so small that they are invisible graphically, so we do not report them in a separate figure in the Appendix. Furthermore, we use the following different numbers of lags of the endogenous variables: 10, 20, 30, 40, 60, and 70. Outcomes presented in [Figure C1](#) show that there are no major qualitative modifications to the benchmark results.

Next, we consider alternative definitions of our instrument. On the one hand, we change the definition of an intervention sequence by shortening the time-window before the start of a new sequence without interventions from 5 days in the baseline specification to 4, 3, 2, 1, and 0 days, respectively. This increases the number of non-zero observation of the proxy up to 325 actual intervention days. But the corresponding [Figure C2](#) shows that the impact decreases in the size of the disconnection window since the risk of defining continuation days of an earlier sequence as a new sequence increases. On the other hand, we use the actual intervention size, instead of a categorical variable indicating the direction of the intervention, which we winsorize at the 10% level to remove outliers. The estimated impact decreases slightly in absolute size but remains significant for about 100 trading days (see [Figure C3](#)).

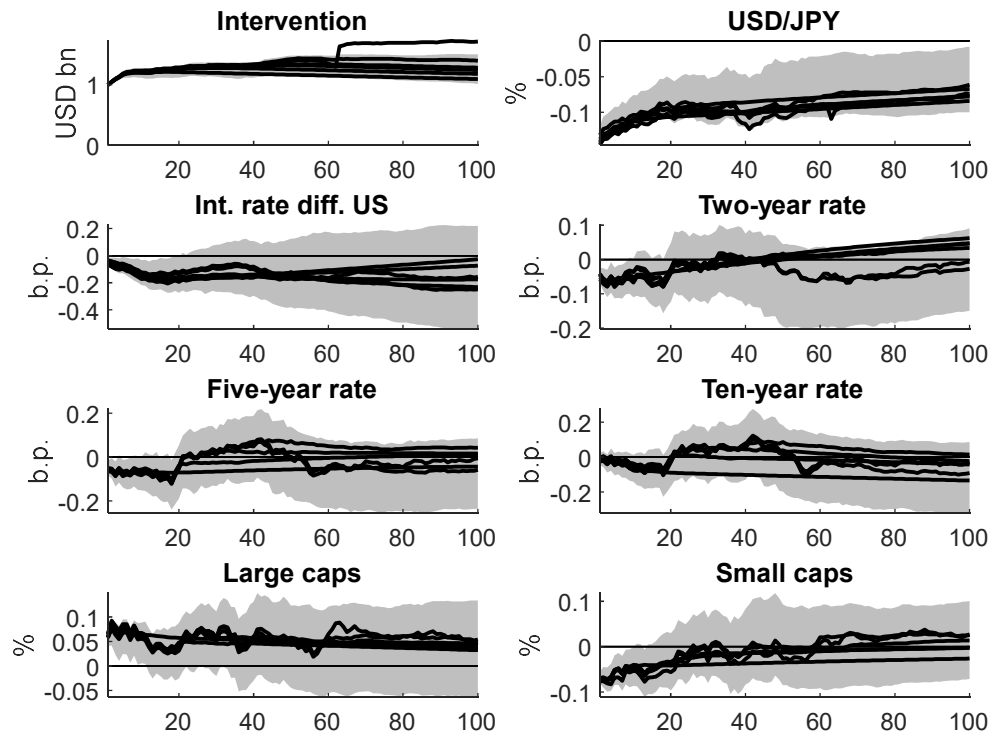
Then, we consider further modifications of the sample. We cut 1, 2, 3, 4, and 5 years of observations both at the beginning and at the end of the sample, and estimate the model on all 25 different subsamples. The results shown in [Figure C4](#) indicate that the estimated impact is

larger when excluding more recent years, but that the effect is of similar order of magnitudes across subsamples.

Finally, regarding statistical inference, we use an alternative bootstrap methodology, i.e. the residual-based moving block bootstrap proposed by Jentsch and Lunsford (2019) for Proxy-SVARs as an alternative to the wild bootstrap. Following the suggestion of the authors, we set the block length to 45, given our sample size, perform 1,000 replications, and focus on 68% confidence bands as this bootstrap is known to produce much wider confidence bands. Additionally, we report 90% error bands. [Figure C5](#) shows that our main results are robust. There is a depreciation of the currency that is statistically significant for more than two quarters according to the 68% confidence bands and for about one quarter when looking at the 90% intervals. The impact on interest rates is largely insignificant, but stock prices respond significantly based on the 68% level for a few days following the shock.

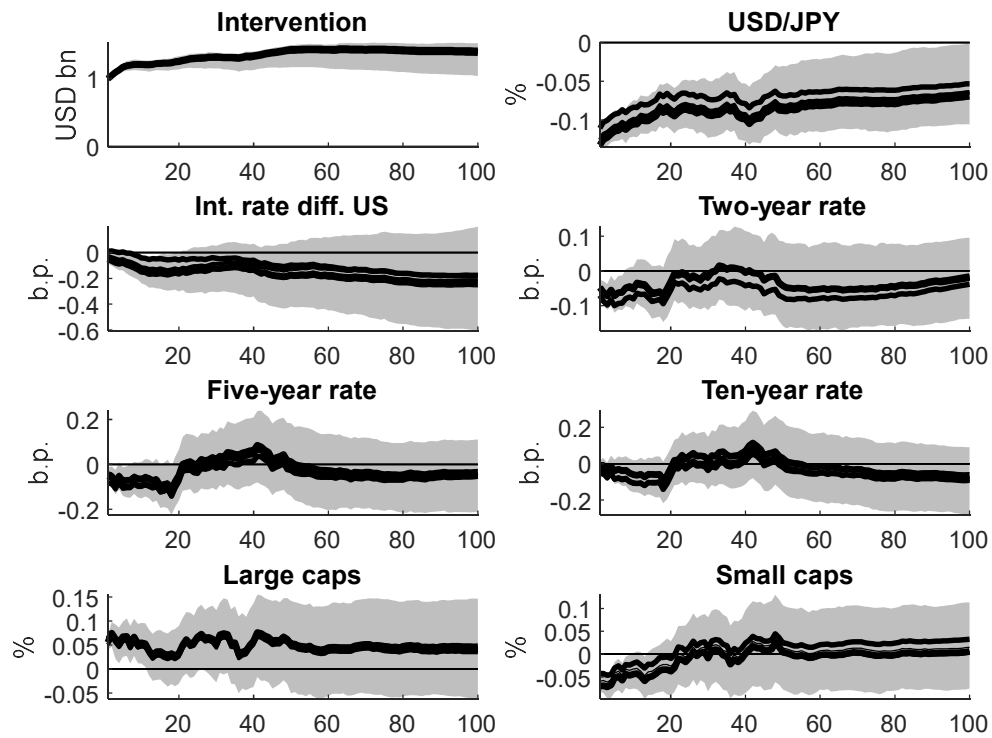
**Figure C1: Robustness to using alternative lag length**

The figure shows the responses of the endogenous variables to an intervention shock of one standard deviation over a horizon of 100 trading days based on a SVAR( $p$ ), for  $p=10,20,30,40,60,70$  identified with an external instrument, along with 90% confidence bands using 200 bootstrap replications for the baseline specification with  $p=50$ .



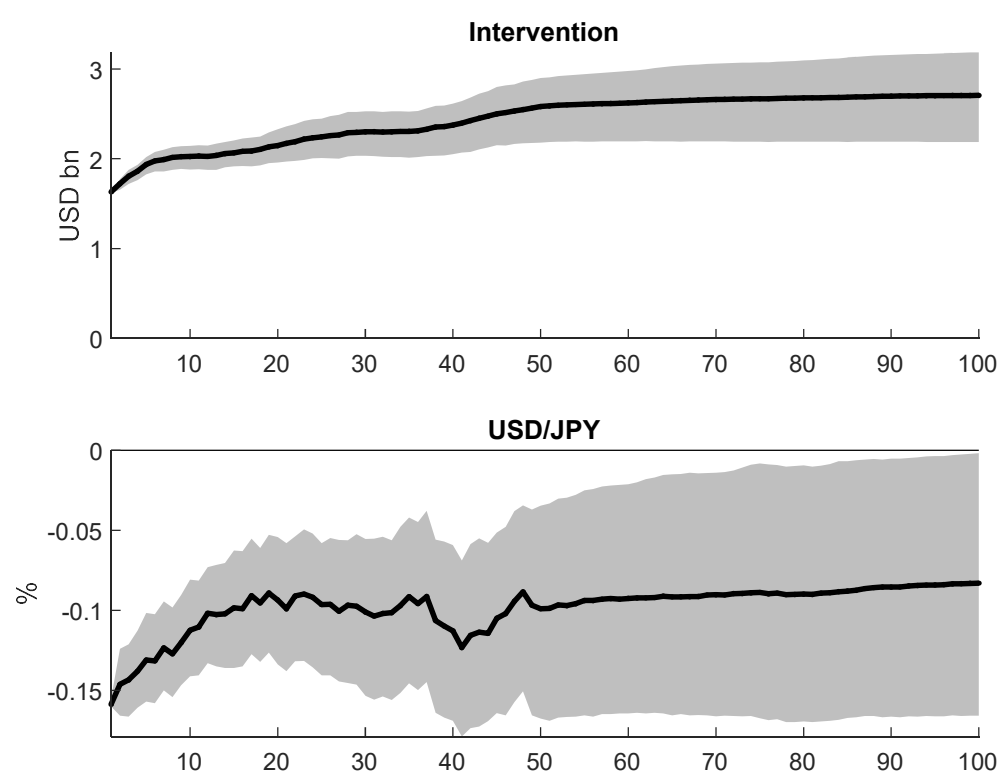
**Figure C2: Robustness to alternative definition of intervention sequence**

The figure shows the responses of the endogenous variables to an intervention shock of one standard deviation over a horizon of 100 trading days based on a SVAR(50) identified with an external instrument using a 1, 2, 3, and 4 day disconnect between actual interventions to define a new intervention sequence, along with 90% confidence bands using 200 bootstrap replications for the baseline specification using a 5-day disconnect.



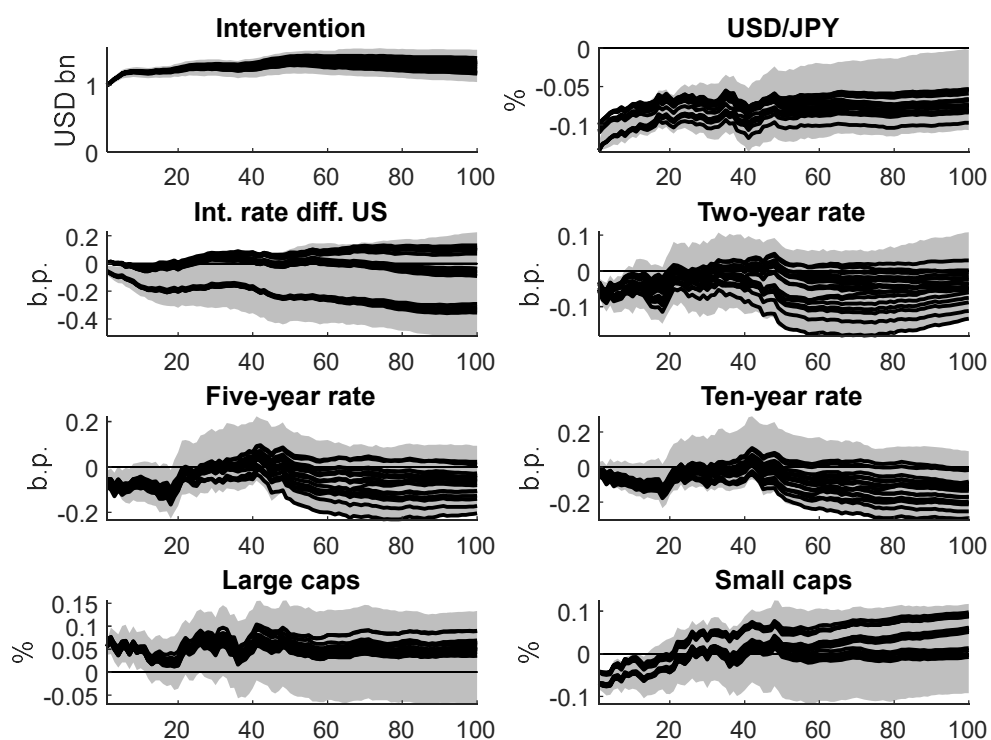
**Figure C3: Robustness to using intervention volume as instrument**

The figure shows the responses of the endogenous variables to an intervention shock of one standard deviation over a horizon of 100 trading days from an SVAR(50) identified with an external instrument, which is based on the 10%-winsorized intervention volume on the first day of an intervention sequence, along with 90% confidence bands using 200 bootstrap replications.



**Figure C4: Robustness in subsamples**

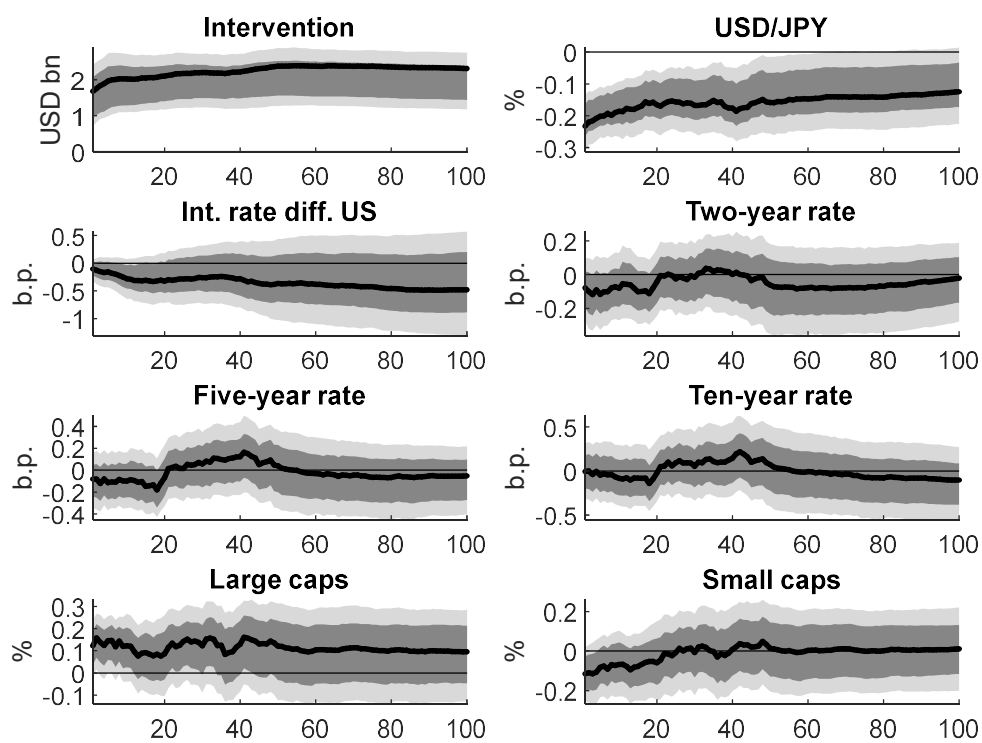
The figure shows the responses of the endogenous variables to an FX intervention shock of one standard deviation over a horizon of 100 trading days from an Proxy-SVAR(50) in 25 subsampled constructed by cutting 1, 2, 3, 4, and 5 years at the start or the end of the sample, along with 90% confidence bands of the baseline specification using the full sample and 200 bootstrap replications.





**Figure C5: Robustness to an alternative bootstrap procedure**

The figure shows the responses of the endogenous variables to an FX intervention shock of one standard deviation over a horizon of 100 trading days from an Proxy-SVAR(50), along with 90% (dark grey) and 68% (light grey) confidence bands based on a residual-based moving block bootstrap using 1,000 replications.



## Appendix D. Evidence for the US, Euro Area and UK (detailed version of Section 5)

In the following we turn to an analysis of the US, Euro Area, and the UK, both for their own sake and as tests of the external validity to alleviate concerns that the results for Japan may be driven by unknown specifics. All three countries have had floating exchange rates throughout the sample period.

**United States.** In the US, the Treasury has the legal responsibility for FX interventions, as in Japan. It closely cooperates with the Federal Reserve. On behalf of both, the Federal Reserve Bank of New York conducts the market operations, which it sterilizes. Interventions were relatively frequent until the early 1990s. Subsequently, they are less frequent, while after 1995 there are only a few, albeit important, cases. For comparability, we use the same sample, extended model specification, and lag length as for Japan. For the period before the introduction of the Euro, we use the Deutsche Mark/USD exchange rate as reference cross-rate and the German short-term rate to compute the interest rate differential.<sup>1</sup>

Table D1 contains summary statistics for US interventions. There are 38 actual interventions in the sample – most are sales of the foreign currency, typically Deutsche Mark/Euro or Yen – such that the unconditional intervention probability on a given day is below 1%. As for Japan, the conditional probability is substantially larger, implying that in the US there is also a tendency to intervene in sequences, although they are on average shorter. The average

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<sup>1</sup> To measure stock prices of large (small) companies we use the Dow Jones Industrial Average 30 Index and the Russel 2000 Index, respectively. We obtain all financial data for the US model, including interest rates, from Bloomberg. The mnemonics are: *DJITR Index*, *RU20INTR Index*, *USGG3M Index*, *USGG2YR Index*, *USGG5YR Index*, and *USGG10YR Index*.

daily volume as well as the maximum daily purchase and sale are smaller as well – at USD 0.38, 1.31 and 1.60 billion, respectively.

The right column in Table D1 shows that we have 25 non-censored observations for the instrument, including both purchases and sales of foreign currency and the maxima of each. We construct it analogously to the case of Japan, that is, we use only starts of sequences, which are defined as having at least five preceding days without intervention. The instrument is strong. The  $F$ -statistic is 3842.3 and 16.7, when testing its relevance for instrumenting the residuals of the cumulated intervention equation and the exchange rate equation, respectively, in the extended eight-variable model. To ensure that it is uncorrelated with US monetary policy shocks, we compare all 25 days with the dates of Federal Open Market Committee (FOMC) meetings. There is no overlap.

Figure D1 contains the dynamic effects of an intervention shock of one standard deviation. This corresponds to an initial purchase of foreign currency of about USD 50 million and, on average, a few additional purchases over subsequent days. The US-Dollar depreciates immediately by roughly 5 basis points. The effect is statistically significant at the 90% level. The currency remains significantly below trend for about 40 trading days. Then, it gradually returns to the level where it would have been without the surprise intervention and from which it cannot be distinguished statistically two months after the shock.

The interest rate differential does not respond upon impact. This indicates that there is no confounding US monetary policy shock, which is consistent with our earlier assertion that none of the 25 non-censored instrument observations coincides with a FOMC meeting. From the second day after the exogenous intervention onwards, however, the interest differential declines significantly and persistently, potentially reflecting a more accommodative stance of the Federal Reserve. In line with the drop in the short-term rate, longer-term interest rates drop significantly as well; by roughly half of a basis point after 5 days. The impact dies out after

about 10 days. The value of firms increase, but only the impact effect for large companies is statistically significant.

Qualitatively, the estimates for the US are similar to those for Japan. Our results indicate, for a purchase of foreign currency, a significant depreciation of the domestic currency, a tendency for interest rates to fall, and a tendency for stock prices to increase – in particular those of larger companies. This is reassuring as it suggests that our earlier estimates reveal a more general pattern of the asset market effects of surprise FX interventions, which can be an effective tool for stabilizing the exchange rate.

However, there are also some interesting differences between the countries. Consistent with the raw data, which show that the US typically intervenes with smaller volumes (see Table D1), a one standard deviation shock in the US is substantially smaller in terms of US-Dollars than in Japan. Moreover, while there is a tendency in both countries to intervene in sequences, the intervention response in the US is less hump-shaped, peaking earlier. In line with the lower volume of cumulative sales of USD for a given initial intervention, the depreciation is more short-lived and less statistically significant than in Japan. Table D2 shows that interventions also play a smaller role for fluctuations of the exchange rate in the US. They explain an average of between 1% and 2% of the forecast error variance, depending on the horizon. They have essentially no explanatory power for longer-term interest rates and stock prices, but contribute up to 5% to the variability of the interest rate differential.

At the same time, interventions are more effective in the US. An unexpected initial purchase of foreign currency worth USD 1 billion has an impact effect of 0.85% on the exchange rate. In Japan, a shock of the same size implies an impact effect of 0.13%. One potential explanation for this difference is that the signaling channel, whereby interventions signal the future stance of policy, is more powerful during the sample period in the US. In particular, there is only one non-censored proxy observation (March 18, 2011) for the US

during the period when the federal funds rate was at the zero lower bound. In sharp contrast, about half (27) of the non-censored proxy-observations for Japan coincide with periods when the short-term rate was below 0.5%. As Japanese policy rates already fell to zero in the early 2000s and attempts to pursue unconventional monetary policies faltered, the effectiveness of monetary policy – and thus part of the signaling channel – was essentially clogged during a large part of the sample. In contrast, this seems to have been less of a constraint on the effectiveness of FX interventions in the US.

This interpretation aligns with the significant and persistent drop of the short-term interest rate differential in the US, which falls by about 30 basis points two months after an intervention shock of USD 1 billion. For a same-sized shock, the differential barely moves in Japan, falling by less than half of a basis point, and the response is essentially indistinguishable from zero. It is also in line with the larger explanatory power of intervention shocks for US short-term interest rate differentials, where they explain up to 5%. In Japan, they contribute less than half of a percent to the variance of that variable.

**Euro Area.** Next, we present some tentative evidence for the Euro Area and the UK. Starting with the Euro Area, the European Central Bank (ECB) intervened only during two episodes. The first episode comprises four intervention days in fall of 2000, shortly after its inception, when the Euro depreciated continuously against the USD amid uncertainty about the monetary policy of the newly created central bank and strong US growth. The second episode corresponds to a single event on March 18, 2011. Several major central banks sold JPY to weaken the currency, which appreciated sharply due to a repatriation of funds of Japanese insurance companies and the closing of carry trades funded in JPY following the Tohoku earthquake.

The ECB does not officially publish the intervention days or volumes. However, there seem to have been only a few specific intervention days that can be dated relatively precisely

based on financial press involving unofficial ECB statements and trading rumors. We identify these dates using Factiva news search. We use the same search to obtain approximations of the implied volumes, which were estimated by market participants and partly communicated unofficially by ECB members in media articles. For the intervention on September 22, 2000, we assume USD sales worth 2.5 billion based on Roussel et al. (2000).<sup>2</sup> For November 3 and 6, 2000, we assume USD sales totaling 1.2 billion, drawing on Tannenbaum (2000). We found no information about the intervention volume on November 9, 2000, so we simply set it to the same size as the previous two intervention days, that is, sales of USD 0.6 billion. Finally, for March 18, 2011, we assume sales of JPY worth USD 0.3 billion based on Suoninen (2011).

As before, we use an indicator for the first day of a sequence as instrument based on the five-day criterion, implying that we have three non-censored observations for the proxy. Given this limited number, we set the lag length to 25 and focus on the bivariate model containing the cumulated intervention series and the exchange rate. Moreover, we start the analysis with the inception of the Euro on January 1, 1999.

The left column of [Figure D2](#) shows the responses of the intervention level and the nominal exchange rate vis-à-vis the USD to an intervention shock of one standard deviation. As there is some persistence in the intervention data due to the sequence in November 2000, the cumulated interventions peak after about one trading week and then revert slowly to trend.

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<sup>2</sup> The exact references are as follows: Roussel, Edward, Sonja Dieckhoefer, Tom Kohn, Hellmuth Tromm and Vincent del Giudice. 2000. G-7 Nations Intervene for First Time to Boost Euro (Update 7), Bloomberg News (BN), Sep. 09, 2000; Suoninen, Sakari. 2011. ECB Forex Reserves Rise after Yen Intervention – Reuters News. Thomson Reuters Eikon, Mar. 29, 2011; Tannenbaum, Mark. 2000. Euro Falls as Appeal of U.S. Economy Outweighs ECB Purchases. Bloomberg News (BN), Nov. 6, 2000.

The Euro depreciates significantly upon impact, weakening by roughly 5 basis points. Thereafter, it remains below trend for 5 trading weeks. For the first three weeks the depreciation is statistically significant.

**United Kingdom.** Finally, we turn to the UK. The Bank of England publishes intervention dates and volumes. We limit the analysis to the period 1994 onwards to exclude the extraordinary FX market conditions and interventions related to the speculative attacks against the British Pound in the early 1990s. This data limitation implies that we now have only two actual interventions in the sample. Therefore, we keep the reduced lag length and the bivariate model as used for the Euro-case. Moreover, we analyze the EUR/GBP exchange rate because the interventions occurred in this particular market. The right column of Figure D2 shows that the intervention shock corresponds to a purchase of Euros worth USD 2 million. The unexpected intervention leads to an immediate weakening of the Pound, which drops by roughly 2 basis points. The currency remains significantly below trend for about two weeks, and thereafter returns to the level where it would have been without the shock.

In summary, we find that the cases of Euro Area and UK interventions in the FX market tend to support the experience of Japan and the US, despite serious data limitations. While the pattern of observations is qualitatively similar across countries, the intervention impact appears stronger for the US, Euro Area, and UK than for Japan.

**Table D1: Descriptive statistics for FX interventions by the US**

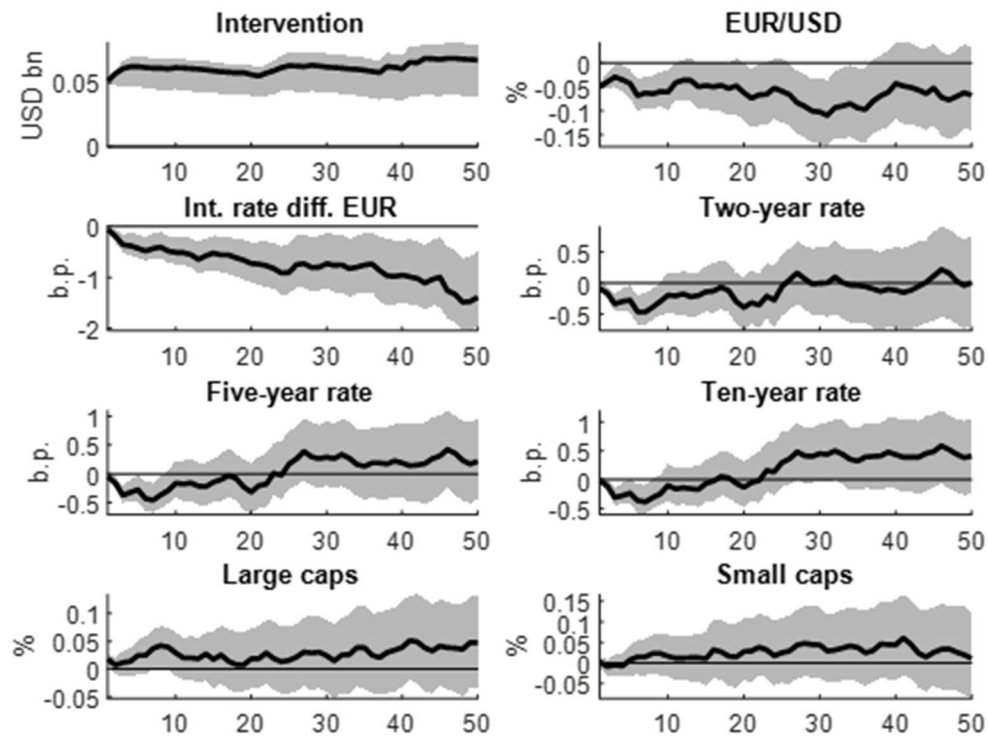
This table provides summary statistics for all interventions covered by our sample in the left column and for the first day of all intervention sequences in the right column.

	All interventions	Instrument (start of sequence)
<i>Number of interventions</i>		
Number of interventions	38	25
Purchases of foreign currency	7	6
Sales of foreign currency	31	19
Unconditional probability	0.006	0.004
Conditional on previous intervention	0.105	0
<i>In billion USD</i>		
Average intervention	-0.38	-0.33
Average purchase	0.36	0.41
Average sale	-0.55	-0.57
Median intervention	-0.25	-0.20
Maximum purchase	1.31	1.31
Maximum sale	1.60	1.60



**Figure D1: The dynamic effects of FX intervention shocks in the US**

The figure shows the responses of the endogenous variables to an intervention shock of one standard deviation over a horizon of 50 trading days based on a SVAR(50) identified with an external instrument, along with 90% confidence bands using 200 bootstrap replications.



**Table D2: Forecast error variance decomposition for the US**

This table shows, for the US case, the contribution of the estimated intervention shocks to the forecast error variance of the respective time-series (in percent) at horizons varying between 1 day and 100 days.

Horizon	Inter- vention	USD/ EUR	Int. rate diff.	Two- year rate	Five- year rate	Ten- year rate	Large caps	Small caps
1	99.6	0.6	0.0	0.0	0.0	0.0	0.0	0.0
5	99.2	0.4	0.5	0.2	0.2	0.2	0.0	0.0
10	98.5	0.7	0.8	0.4	0.3	0.2	0.1	0.0
50	90.6	1.1	2.9	0.1	0.2	0.4	0.1	0.1
100	83.3	1.5	5.1	0.1	0.3	0.7	0.5	0.4

**Figure D2: The effects of FX intervention in the Euro Area and UK**

The figure shows the responses of the endogenous variables to an intervention shock of one standard deviation over a horizon of 25 trading days based on a bivariate SVAR(25) identified with an external instrument, along with 90% confidence bands using 200 bootstrap replications, for the Euro Area (left column, solid lines) and for the UK (right column, dashed lines).

