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Measuring the Effect of Foreign Exchange Intervention Policies on Exchange Rates

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Central bank intervention in foreign exchange markets is a common tool to influence exchange rates. Although central bankers are convinced of their policy's effectiveness, econometric estimates of precise effects differ across studies. The difficulties with estimations mostly result from a lack of adequate data. This article highlights different econometric approaches that aim to mitigate estimation problems. Techniques comprise control and matching approaches, event studies, as well as the use and imputation of high-frequency data. Their comparison reveals a trade-off between clear identification of the effect and establishing its validity over a sustained period.

Central bank intervention motives and practices

Although many central banks in developed countries—like the U.S. Federal Reserve and the European Central Bank—no longer intervene in currency markets, instead letting their exchange rates currently float freely, emerging market economies' (EME) monetary authorities intervene frequently. Fratzscher et al. (2019) find that these central banks intervene an average of once a week. Moreover, in most cases, central banks carry out interventions against an appreciating trend to stabilize, if not weaken, their domestic currency; potentially intending to foster exports. As EME countries frequently resort to foreign exchange interventions and the major developed countries might reconsider intervention practices in the future, policy makers would profit from precisely measured effects of past interventions.

Regarding intervention effects, it is important to distinguish between sterilized and unsterilized interventions. In sterilized interventions, central banks keep the domestic monetary base constant. If a central bank sells domestic currency, the domestic money supply increases. In an accompanying operation, labelled sterilization, the bank will sell e.g. domestic government bonds, ultimately maintaining an unchanged money supply. The effect on the exchange rate can then be analyzed independently of confounding effects working via interest rate or money supply changes. In the following, I exclusively discuss studies concerning sterilized interventions.

Endogeneity problems in the empirical estimation

The effectiveness of sterilized interventions on the exchange rate is actively debated in the literature and is, ultimately, an empirical issue. Notably, the empirical estimation concerning the effectiveness is not straightforward. Interventions influence the exchange rate while, simultaneously, exchange rate movements influence central bankers' behavior and their intervention decisions. A subsequent decision to intervene will depend on the exchange rate reaction to previous interventions and, in this way, influence the size and longevity of ensuing

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interventions. Moreover, macroeconomic effects that bring about exchange rate changes can lead to an underestimation of the actual intervention effect if these underlying shocks are not accounted for. For example, consider a central bank that purchases foreign currency to halt an appreciating trend of its domestic currency. Disadvantageous underlying market developments—which caused the appreciation in the first place—can dampen the intervention's effectiveness. The exchange rate might continue to appreciate and the intervention deemed unsuccessful if these fluctuating market circumstances are not controlled for using appropriate data. When estimating the causal effect of interventions on the exchange rate, the aforementioned simultaneous relationship between interventions and exchange rate behavior as well as the effect of omitted variables—like macroeconomic developments—are referred to as endogeneity problems. This endogeneity leads to biased estimates.

To establish an unbiased effect of sterilized interventions, several econometric approaches have been developed and applied. These include (i) standard instrumental variable techniques, (ii) approaches for weekly and daily data, like event studies, as well as control and matching approaches, (iii) an approach for lower-frequency data relying on a measure of international capital flows and (iv) the use and imputation of high-frequency data. In the following, I layout the basic concepts behind these approaches.

In search of instrumental variables

An often-used approach to overcome endogeneity bias in regression analysis is to find suitable instrumental variables (IV) that are correlated with the problematic regressor—here central bank interventions—but uncorrelated with the dependent variable—here the exchange rate. In the present case, adequate instruments are hard to identify. Dominguez and Frankel (1993), for instance, instrument actual interventions with public news concerning intervention policy. Today, however, public central bank announcements are used to influence the exchange rate directly and, therefore, are unsuitable to act as an instrument. An instrumentation of interventions with intra-day volatility of exchange rates, as conducted by Barroso (2018), seems to yield reasonable results. Although intra-day volatility might be correlated with exchange rate movements, Chamon et al. (2017) corroborate Barroso's (2018) IV estimates in an event study described in the next paragraph.

Event studies, and control and matching approaches

Chamon et al. (2017) conduct an event study using a synthetic control approach for weekly Brazilian intervention data. In 2013, the Banco Central do Brasil announced a major sterilized foreign exchange intervention program with daily sales of foreign exchange swaps against the US dollar. The program was intended to counteract the stark depreciation of the Brazilian real after the Fed's announcement to scale down bond purchases within its quantitative easing policy. The study's findings point to a cumulative appreciation that is more than 10 percentage points in excess of a counterfactual exchange rate without interventions over several weeks.

The authors examine the intervention effect within a window of 12 weeks prior to and after the announcement. The synthetic control approach relies on a counterfactual exchange rate, which is constructed with exchange rate data from 16 comparable, mostly EME countries. Statistical weights given to the different countries are based on the co-movements with the Brazilian real prior to the intervention announcement. Given the different countries' exchange rates and appropriate weights, the Brazilian exchange rate can be accurately replicated from them. Based on the after-announcement exchange rate movements of the control group countries, an artificial exchange rate for the Brazilian real is estimated and

used as the counterfactual. The actual exchange rate movement is then compared to it. This approach takes into account common underlying macroeconomic drivers that affect many EMEs at once—in this case the anticipated change in US monetary policy. These underlying driving forces could have caused endogeneity bias in standard regression analyses. The possibility that countries in the control group also intervened in foreign exchange markets following the Brazilian central bank's announcement is, however, not taken into account. This can potentially lead to an underestimation of the intervention effect. The authors' control approach is suitable for event studies with a major change in intervention policy, but not for the study of frequent interventions.

Fratzscher et al. (2019) apply a related matching approach in a panel data study. The technique pairs intervention periods to similar periods without interventions for each individual country. More specifically, placebo event periods are constructed that resemble the actual intervention episodes in prior exchange rate movements but are not followed by an intervention. The authors compare effects in actual intervention events to those in placebo events. If pairs of matched episodes are highly similar, endogeneity biases can be avoided and an undiluted effect of foreign exchange interventions established. However, to establish structural effects a high degree of similarity in episode is needed. The similarity should stem from data reflecting a broad range of macroeconomic policies that potentially affect exchange rate behavior.

The authors' data set consists of daily data on sterilized interventions for 33 countries over a maximum period of 16 years. Most countries are classified as narrow band regimes with target exchange rate changes of +/-2% at most—typical for emerging market economies. The authors find that for free-floating regimes, interventions are successful at moving the exchange rate in the intended direction over the short term in more than 60% of the cases. In comparison, placebo events show a success rate of 48%. For narrow-band regimes, intervention events have a statistically significantly higher success rate than placebo events—84% compared to 77%—in stabilizing the exchange rate.

Kearns and Rigobon (2005) conduct an event study relying on daily data about Australian central bank interventions from 1986 to 1993 and interventions by the Bank of Japan from 1991 to 2002. Both central banks underwent a regime change in their intervention practices during those periods; they reduced the frequency of interventions while increasing their size, which the authors regard as unrelated to underlying macroeconomic effects. Essential to the approach, Kearns and Rigobon (2005) take advantage of this structural break in the data to estimate their model equations.

An economic model with three distinct equations displays exchange rate responses to interventions, the endogenous decision of a central bank whether to intervene and, if so, to what extent. The first equation builds on the uncovered interest parity; the domestic currency value is *ceteris paribus* positively affected by interest rate differentials between the home country and foreign countries, secondly a risk premium that investors demand if domestic and foreign bonds are imperfect substitutes, and, finally, the expected future exchange rate. The authors assume that interventions impact these variables. A second equation determines when a central bank intervenes via specifying a threshold level dependent on previous exchange rate patterns. If the actual exchange rate exceeds this threshold, the central bank will intervene by purchasing or selling domestic currency. Finally, the third equation determines the size of the intervention once the threshold is exceeded. The parameters in the model—concerning the effect of an intervention on the exchange rate, the effect of the exchange rate on the decision to intervene, the threshold to intervention and variances of random shocks—are then estimated with the help of

statistical moments (probabilities, means, variances etc.) in the data. In a so-called simulated generalized method of moments procedure, the parameters are chosen in such a way that moments of simulated data resulting from those parameters approach the real data's statistical moments. To obtain the number of moments required for the estimation, the structural break in the data resulting from the policy regime change is used. Kearns and Rigobon (2005) assume that the regime change merely altered the intervention threshold while leaving all other parameters unaffected. Hence, they obtain a second set of moments while the amount of parameters only increases by one—a new threshold for interventions after the regime change. This type of identification is of course restricted to event studies where policy regimes change.

The authors' estimate for the parameter measuring the effect of sterilized interventions on the exchange rate is substantial. It indicates an Australian dollar appreciation of 1.3-1.8% following a sale of US$ 100 million in exchange for Australian dollar. For the case of Japan, an equivalent purchase of Yen merely has an effect of 0.02% appreciation. The difference in estimates shows that they cannot simply be assigned to other periods and countries; Kearns and Rigobon (2005) speculate about underlying market structures as a crucial factor affecting the estimates. The Australian foreign exchange market is smaller, such that equal-sized interventions could have larger impacts.

Furthermore, the economic model rests on strong assumptions. In the estimation process, the authors assume that the regime change only alters the threshold level for intervention; all other elements, for instance the degree of the central bank's response to exchange rate movements is assumed to be invariant. This might not reflect reality, as an intervention's effectiveness could differ between the two regimes once market participants have updated their expectations according to the new policy regimes.

A further noteworthy factor influencing the effectiveness of interventions is the presence of capital controls. Kuersteiner et al. (2018) compare interventions by the Central Bank of Columbia during episodes with and without capital movement restrictions. The authors find that foreign exchange interventions exhibit greater effectiveness when capital controls are present. Capital controls hinder arbitrage such that economic agents cannot exploit mismatches in the covered interest rate parity. This means that market participants cannot fully exploit positive interest rate differentials via forward contracts on currency prices. Hence, the central bank has greater power to influence exchange rates. Moreover, Kuersteiner et al. (2018) find asymmetric effects between the issuance of put and call options. Only the purchase of US dollars via the issuance of put options exhibits the immediate intended effect of a Columbian peso depreciation. A sale of US dollars on the other hand displays a less clear effect. Following an initial unexpected depreciation, the peso only appreciates significantly after a week. The authors assign this asymmetry to market uncertainty concerning central bank behavior during call option interventions.

A measure of international capital flows

Blanchard et al. (2015) adopt a different approach to bypass endogeneity bias. The authors rely on a measure of global, country-independent, capital flows. They use quarterly data for 35 emerging market and advanced economies without reserve currency status (e.g. the U.S. or the Euro Area hold this status) over the 1990 to 2013 period. A vector autoregression for each country—which is a combination of different time-series regressions that are potentially interrelated—includes the path of the exchange rate, sterilized foreign exchange interventions, capital flows to and from the country, the interest rate, and a measure for global capital flows. These global capital flows are not country-specific. The authors assume that each country

is individually too small to significantly affect these global flows, which are hence regarded as an exogenous measure.

The method exploits differences in countries' intervention responses to the exogenous capital flow measure and analyzes how this affects their exchange rates. In the data, an increase in global capital flows is associated with increased gross capital inflows. In response, the domestic currency appreciates. Central banks in the panel respond to different extents with foreign exchange interventions to accumulate foreign reserves, thereby trying to moderate the currency's appreciating trend behavior. Blanchard et al. (2015) split the sample in two parts—countries that mostly intervene and those that mostly let their exchange rates float when facing global capital flow shocks. Intervening countries are found to exhibit significantly lower increases in their currencies' values when global capital inflows surge. Moreover, differences in appreciation are statistically significant over three to four quarters, implying the long-run effectiveness of foreign exchange interventions.

High frequency analyses

A final approach discussed in this article exploits high frequency data, for instance at hourly or minute intervals. Neely (2005) notes that if the time interval of the data is short enough and the timing of intervention can be measured precisely, the problem of simultaneity can be avoided. More specifically, imagine 5-minute interval data. If it is possible to pinpoint an intervention in a 5-minute interval and a central bank responds to exchange rate movements with a time lag of at least five minutes, the resulting change in the exchange rate would be a consequence of the intervention. The advantage is that the intervention cannot be a consequence of exchange rate changes, which occur within or after the 5-minute time interval containing the intervention. However, as the data intervals are very short, the estimated effects on the exchange rate are merely valid for short periods and it is not possible to make statements about exchange rate effects over weeks or even several days.

Melvin et al. (2009) construct a time series of 30-second intervals for Russian central bank interventions via an electronic trading platform over three weeks in March 2002. The bank placed limit orders to keep the exchange rate vis-à-vis the US dollar within a specific range. The authors analyze the effect of these order placements on the exchange rate's volatility via regression analysis. The small intervals between data points should omit endogeneity bias from simultaneity. A dummy variable for intervention days in the regression of exchange rate volatility on trading volumes indicates a significant reduction in volatility on those days. To produce this day effect, the Russian Central Bank placed high amounts of limit orders on intervention days. In the first week of March 2002, 1% of its foreign reserves were used up by orders. Moreover, to achieve the substantial reduction in volatility, the Russian central bank could also rely on strict capital controls. This limits the validity of the authors' findings to regimes that employ such controls.

Scalia (2008) applies a high-frequency approach with hourly data for Czech National Bank interventions in 2002. The central bank intervened in foreign exchange markets to halt an appreciating trend of the Czech Koruna. The author aggregates data on time-stamped orders and transactions in an electronic spot market. With regression analysis concerning exchange rate responses to general CZK/EUR transactions, the author establishes a significant effect of these transactions. The average effect amounts to a nominal exchange rate depreciation of the Koruna of 7.6 basis points (0.076%) for a purchase of €10 million. If investors learn of central bank interventions, this effect increases to 10.9 basis points.

When hourly data on intervention amounts is not available, Chen et al. (2012) document how to interpolate it from daily data given hourly exchange rate data. The

authors apply their approach to Japanese Central Bank data, which is also examined by Kearns and Rigobon (2005). Resorting to Bayesian Markov-Chain Monte Carlo methods, they can augment their intervention data to achieve a one-hour interval. Given that the central bank does not respond within a one-hour window to exchange rate changes, it is possible to obtain unbiased estimates of the parameters for both the central bank reaction function and the exchange rate response function. The Bayesian estimation method to infer hourly intervention data relies on two key equations. First, an exchange rate response function to hourly interventions and, second, a central bank reaction function determining hourly interventions following changes in the exchange rate that took place more than one hour before. The two equations yield conditional parameters of the effect of interventions on exchange rates and vice versa—conditional on guesses for the other respective parameter, guesses for the hourly intervention data, and error terms. Moreover, a conditional distribution for hourly intervention data emerges. Sampling repeatedly from these conditional distributions yields point estimates for the parameters that specify the sought-after effect.

Applying this method to other countries, one should change the assumed central bank reaction function such that it matches the bank's policy course. An advantage of the data augmenting technique is that it does not require the assumption of a structural break, as used by Kearns and Rigobon (2005), to identify intervention effects. The effects of the two approaches are, after all, very similar. Chen et al. (2012) find a slightly higher effect of a 1 trillion yen purchase (1.8% compared to 1.5%). Note, however, that the comparison is between an hourly effect and a daily effect here. Both studies merely establish short-term effects.

Conclusion

The choice of a suitable econometric approach to estimate the effect of central bank interventions on exchange rates depends crucially on the data a researcher has at hand. High-frequency data is valuable because it can avoid simultaneity bias between exchange rate movements and central bank interventions. If precise knowledge of the intervention timing is lacking, high-frequency data can even be inferred from lower-frequency data. However, long run effects may be more difficult to estimate if the data horizon and time intervals are short. The estimated effect of an intervention from standard regression analysis merely refers to the high-frequency time interval. With low-frequency data (weekly, monthly, or quarterly) at hand, matching and control approaches can prevent biases arising from underlying economic effects. Their estimates might still be plagued by simultaneity biases as intervention amounts are aggregated. The advantage is that effects can be established over longer horizons, which should provide invaluable advice to policymakers. All discussed studies point to an effectiveness of foreign exchange interventions. The precise impacts, however, depend on each markets' trading volume and the presence of capital controls. Thus, emerging market economies—characterized by smaller trading volumes—need smaller intervention amounts to influence their exchange rate patterns. Interventions help them to reduce volatility and attract foreign investment, improve their competitiveness in international trade or accumulate foreign reserves to use when borrowing terms become too restrictive.

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