The Immediate Impact and Persistent Effect of FX Purchases on the Exchange Rate*

Itamar Caspi, Amit Friedman, and Sigal Ribon
Bank of Israel

In recent years, foreign exchange (FX) interventions have been routinely used by the Bank of Israel and other central banks as an additional monetary instrument to moderate appreciation trends of the domestic currency. This paper analyzes the immediate effect of the Bank of Israel's FX interventions on the exchange rate and its persistence over time. To identify this effect, we first measure the intraday impact of FX intervention using a novel confidential, high-frequency, minute-by-minute data set of interventions between 2009 and 2017. Next, we use our measure to estimate the persistence of FX intervention shocks over longer horizons (in trading days), using local projections. We find that FX intervention shocks cause, on impact, USDILS exchange rate depreciation in over 90 percent of the cases. We also find that this effect has a persistent effect on the USDILS exchange rate for 40–60 trading days.

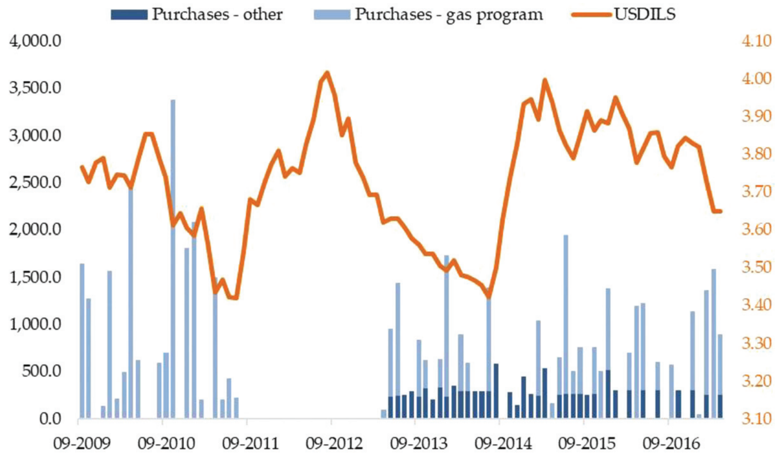
JEL Codes: C22, E58, F31.

1. Introduction

In recent years, FX interventions have been routinely used as an additional monetary instrument by central banks in developing as

*We thank Nadav Ben-Zeev, Luckas Frei, Ethan Ilzetzki, Martin Eichenbaum, Matteo Maggiori, Peter Karadi, and participants in the Bank of Israel Research Seminar, the BoI–SNB–CEPR Conference on Foreign Exchange Market Intervention, and the BIS for helpful discussions, comments, and suggestions. We also thank the BOI's liquidity desk/dealing room staff members—Ketty Cohen, Oren Hadjes, and Michael Blank, and Polina Artstein, Talia Moshe, and Iftach Teicher for excellent research assistance. Finally, we thank the editor and two anonymous referees for useful comments and suggestions. The views expressed here are solely those of the authors and do not necessarily reflect the views of the Bank of Israel, or any of its staff. Author e-mails: Itamar.caspi@boi.org.il; sigal.ribon@boi.org.il; amit.friedman@boi.org.il.

Figure 1. FX Purchases by the Bank of Israel and the USDILS Exchange Rate



Source: Bank of Israel.
Note: Purchases are specified in millions of USD per month. September 2009–April 2017.

well as advanced economies around the world. Discretionary, sterilized purchases of foreign currency, which are often matched by accommodative monetary policy, are carried out to moderate the appreciation trend of the local currency. The Bank of Israel has used FX purchases for similar purposes in recent years as well, and these purchases have tended to intensify during periods of exchange rate appreciation (see Figure 1).

This paper analyzes the effect of FX purchases made by the Bank of Israel (BoI) on the exchange rate, using novel, proprietary, and confidential data that consist of high-frequency, minute-by-minute observations of the exchange rate and FX purchases. The on-impact intraday effects of FX interventions are measured in terms of the change in the U.S. dollar–Israeli shekel (USDILS) exchange rate during intraday intervention spells. Next, we use the intraday measure to estimate the causal effect of FX intervention shocks, defined as the unanticipated part of interventions, on the nominal effective exchange rate.

Our empirical strategy follows Angrist, Jordà, and Kuersteiner (2018), Angrist and Kuersteiner (2011), and Jordà and Taylor

(2016), who combine the potential outcome framework (i.e., the Rubin causal model) and the local projections method (Jordà 2005) to estimate the causal effect of a policy treatment (FX interventions in our case) and its persistence in a dynamic setting. The appeal of this empirical strategy is that it makes explicit the conditions needed for the identification of a causal effect. Also, it is rather robust to misspecification in the estimated model.[1]

Theoretically, sterilized FX purchases, such as those carried out by the BoI, can affect the level of the exchange rate through two main channels: the portfolio balance channel and the signaling channel. The former operates under the assumption that domestic and foreign bonds are not perfect substitutes. The latter operates under the assumption that purchases of foreign currency by the central bank send a signal to markets about future policy moves—either that the central bank is about to pursue an accommodative monetary policy in the future, or that the central bank has an implicit exchange rate floor, a "resistance" level. While the first channel is pertinent whenever a "big" player is active in the market, the second channel is unique to the central bank and hence makes the dollars purchased by the central bank special. The first channel's effects are probably more transitory, at least when markets function normally; but the second channel's effects might have a medium-term effect on the exchange rate. This suggests that a complete assessment of the policy must consider both the immediate impact of FX intervention and the persistence of this impact over time.

Most of the recent literature on the impact of interventions in the FX market by the central bank is empirical and uses daily or intraday data to study the effect of these interventions. A critical issue in this literature is endogeneity, which limits the ability of researchers to treat intervention shocks as exogenous. Put simply, FX interventions tend to be triggered by exchange rate movements generated by other factors, and hence the identification of their impact is difficult. A possible solution is to focus on the "intervention window," i.e., the exact time spell around the FX intervention, based on intraday data.

[1]In a closely related paper, Kuersteiner, Phillips, and Villamizar-Villegas (2016) investigate the effectiveness of sterilized foreign exchange interventions by exploiting a discontinuous policy rule used by the Central Bank of Colombia.

This methodology, however, is limited: while the existence of a short-term impact is a necessary condition for discretionary intervention to be effective, it is insufficient for a macroeconomic analysis of the policy, which also requires an assessment of the persistence of the initial impact of the FX intervention over time. For this reason, in this paper, we apply both methodologies.

Recent surveys (e.g., Engel 2014; Menkhoff 2013; Neely 2005, 2011) conclude that empirical studies that examine high-frequency data usually find an immediate effect on the exchange rate in the right direction, and the results on the effect on volatility are mixed. However, these studies are usually incapable of providing evidence for the persistence of the initial effect in the week, month, or quarter after the intervention (Engel 2014).

Villamizar-Villegas and Perez-Renya (2015) from Colombia's central bank survey the empirical literature and conclude that the effect of FX interventions is small and very transitory. Menkhoff (2013) reviews studies that examine intervention in developing countries and reports that these studies usually find that intervention affects the level of the exchange rate, while the results for the effect of interventions on volatility are mixed. A small number of studies use lower frequencies: weekly, monthly, or quarterly data. This strand of literature usually employs instrumental-variable methods to solve the above-mentioned endogeneity problem to identify the "clean" effect of intervention. Adler, Lisack, and Mano (2015), using monthly data and a panel of countries, find strong evidence that intervention has a statistically and economically significant effect on the exchange rate. Adler and Tovar (2011), using a panel of 15 countries for the period 2004–10, excluding the financial crisis years (2008–09), find that intervention slows the pace of appreciation but is less efficient when the economy is open to capital flows.

Blanchard, Adler, and de Carvalho Filho (2015) show that intervention can ease the pressure associated with exogenous capital flows on the exchange rate. Basing their study on a cross-country regression analysis and using quarterly data, they find that exchange rate appreciation in response to capital imports is lower in countries identified as "interveners" than in other countries.

Fratzscher et al. (2015) examine the effectiveness of intervention using a unique database containing daily data from 33 countries (including Israel) between 1995 and 2011. In general, they find that intervention usually "succeeds"; that is, it achieves the exchange rate movement in the desired direction, and hence can be an effective policy instrument, especially when applied in high dosages and when consistent with moving the exchange rate toward its fundamental equilibrium. However, they estimate only the short-term impact of interventions.

A few studies examine the effectiveness of intervention by the Bank of Israel since 2008. Sorezcky (2013) addresses this question, somewhat indirectly, for the period when the Bank of Israel intervened mostly with fixed, preannounced quantities. He tests whether the intervention in the foreign currency market is reflected in an exchange rate that deviates from the one predicted by a VAR system that includes an exchange rate equation without intervention. He finds that most of the effect was obtained when the Bank announced a change in the intervention regime, in particular, a movement from the fixed purchase of $25 million per day to $100 million per day, and later during the transition to variable, discretionary purchases. Ribon (2017), using the instrumental-variable approach, finds that the Bank of Israel's purchases contributed to the depreciation of the shekel. Purchases equal to the monthly average in the period examined, $830 million, contributed to devaluation in the effective exchange rate by about 0.6 percent, compared to a month with no intervention. However, she does not test the persistent effect of an intervention shock.

In the context of the existing literature, the contribution of this paper is twofold: first, we measure the impact of FX purchases directly, using proprietary, confidential, high-frequency Israeli data. Second, we estimate the persistence of the initial shock, using a robust and simple "model-free" methodology, which was originally suggested by Jordà (2005), that requires only a parsimonious and economically clear set of identifying assumptions. Technically, it requires only single-equation regression analysis.

Our main results are as follows: (i) FX intervention has a high "success rate" on impact. In over 90 percent of intervention cases, the exchange rate moved in the desired direction (i.e., that of depreciation, as all the interventions we analyze are purchases); (ii) The effect of an intervention shock persists for about 40 to 60 trading days (between two and three calendar months) before it attenuates or becomes statistically insignificant. This result means that the exchange rate returns during the 40 to 60 days are still affected by the initial intervention shock on day 1. These results, coupled with the actual intervention pattern of the Bank of Israel in recent years, allow us, at least in principle, to quantify the aggregate effect of FX intervention over time. The result is that since 2013, FX purchases have led to an average depreciation of between 2 and 3 percent. It is important to emphasize that this result reflects only the impact of the intervention shocks—i.e., the effect of the unexpected purchases, given that the regime was in place, and not the possible effect of the regime itself on the level of the exchange rate, which we cannot estimate.[2]

The paper is organized as follows. Section 2 provides some details and stylized facts on FX interventions made by the Bank of Israel since March 2008. Section 3 briefly discusses the economic theory behind FX interventions. In particular, it presents in short the channels through which sterilized interventions might affect the spot exchange rate. Section 4 describes the measurement of the short-term impact of intervention on the exchange rate. Section 5 describes the methodology that is applied to estimate the persistence of the short-term intervention shock over time. Section 6 presents our main results and a robustness analysis, and Section 7 concludes.

2. FX Interventions by the Bank of Israel

In March 2008, for the first time in a decade, the Bank of Israel intervened in the FX market. The decision to purchase FX was made against the backdrop of a sharp and rapid appreciation of the shekel, which real fundamental factors could not account for in full. This provided an opportunity to replenish international reserves, which as a share of GDP had declined steadily over a decade and had reached an uncomfortably low level. Initially, purchases were carried out daily, in fixed, preannounced amounts of $25 million, which were later augmented to $100 million. In August 2009, when reserves reached a level that was deemed at the time adequate, the BoI moved to a discretionary intervention regime, under which the

[2] In analogy to the monetary shocks literature, our focus is on the unsystematic part of the rule under which monetary policymakers act and not on the effect of operating according to a given rule.

timing and volume of FX purchases were not communicated to the public in advance. On May 2013, the BoI announced that in addition to the above-mentioned discretionary policy, a preannounced quantity would be purchased to offset the appreciation pressures arising from the commencement of the production of natural gas.[3] Since that announcement, the two-tier regime remained in effect until the end of 2018. Although the annual gas purchase volume was communicated to the market before every calendar year, the accurate timing and daily quantities were unknown to the market in advance. Thus, while daily FX purchases were anticipated up to August 2009, since that date they have been unanticipated, and therefore can be used to construct proxies for intervention shocks.

Like other modern central banks, the BoI operates under a dual lexicographic mandate that includes price stability and economic activity, in that order. The rationale behind FX purchases is to maintain the competitiveness of the tradable sector under transitory global conditions that result in an overvalued exchange rate, relative to its fundamentals.[4] Also, since 2013, inflation has been persistently lower than the midpoint of the inflation target range (1 to 3 percent). FX purchases, which aim at curbing appreciation pressures, were in accordance with the price stability target of the BoI. Hence, FX purchases brought about a double-margin operation that enabled the BoI to remain active even after the interest rate was reduced to an unprecedented near-zero low level.[5]

3. Theoretical Background

Theoretically, sterilized FX purchases affect the level of the exchange rate through two main channels. The first, the portfolio balance

[3]On April 30, 2013, natural gas from the Tamar reservoir started to flow and to partially replace imported fossil fuels. A few days later the Bank of Israel announced that $2.1 billion would be purchased by the end of 2013. The gas purchases serve as a temporary substitute for the lack of a sovereign wealth fund.

[4]The Israeli economy emerged from the 2008 global financial crisis relatively unscathed. Its relative robustness led to massive capital inflows already before the crisis, a phenomenon that only intensified after the outbreak of the crisis (Eckstein and Friedman 2011).

[5]The interest rate rose to 0.5 percent in 2009 and, after a hiking cycle, fell again to 0.1 percent in March 2015, where it has remained until the end of our sample.

channel, is at work when the local currency is not a perfect substitute for foreign currency. The second, the signaling channel, is at work when the purchases send a signal to markets either that the central bank is about to pursue an accommodative monetary policy in the future, or that the central bank has an implicit exchange rate floor, a "resistance" level below which it will act. In the current jargon, FX purchases made through the signaling channel can also be interpreted as a form of "forward guidance." In addition to these mechanisms, FX purchases may have a different type of impact when implemented at the zero lower bound, where the distinction between sterilized and unsterilized intervention is blurred.

While the portfolio balance channel is pertinent whenever a big player is active on the market,[6] the signaling channel is unique to the central bank and hence makes the FX purchased by the central bank special. One can argue that the first channel's effect tends to be more transitory. For example, Perez-Reyna and Villamizar-Villegas (2019) show that the effects of FX interventions through the portfolio balance channel are significant, though short-lived, when commercial banking constraints are binding; but the second channel's effect can have a medium-term effect on the exchange rate. A sizable and persistent effect on the exchange rate can naturally have a macroeconomic effect—on output, prices, and the interest rate.[7]

It is worth emphasizing that in what follows, our definition of a structural intervention shock is broad, in the sense that it accounts for unanticipated shocks to intervention as well as shocks concerning the Bank's expected future policy in the forex market or concerning the future path of interest rate. The presence of such "forward-guidance shocks" might cause an identification problem in cases where the central bank applies explicit forward guidance as well as FX interventions, as forward guidance is essentially signaling about future rates. However, we argue that this issue is of lesser importance in the Israeli case since official forward guidance was not introduced

[6]For example, a large commercial bank or firm can sometimes in a single day buy or sell FX at quantities that are substantial relative to the daily market turnover.

[7]See Bauer and Rudebusch (2014) for a discussion on the signaling channel in the context of bond purchases. The authors find that bond purchases have important signaling effects that lower expected future short-term interest rates.

by the Bank of Israel until November 2015, and excluding the period where it was used does not affect our results.

4. Measuring the On-Impact Effect of FX Intervention

To measure the immediate impact of FX purchases, and circumvent the endogeneity/simultaneity problem, we use high-frequency, intraday, data. The approach follows an event-study methodology: we measure the return to intervention, defined as the on-impact shock that is manifested in the exchange rate market once the BoI intervenes and during the intervention window. These shocks to the exchange rate allow us to construct various measures of intervention success and efficacy over time.

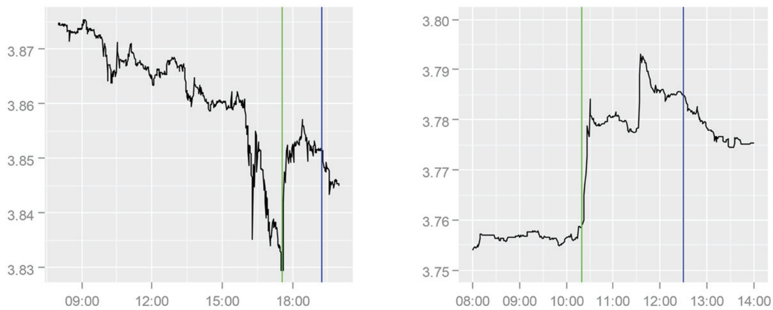
Our data set includes minute-by-minute USDILS quotes collected by Reuters from several contributors' quotes (Reuters ticker: ILS=RR). The data are merged with records of the BoI's dealing-room FX transactions operational system, which contains records on the timestamp, the sum, the counterparty, and the price of each FX transaction. The result is a unique proprietary data set, which is confidential due to market sensitivities. We use this data set to measure the total effect of the intervention during the intervention window, which typically lasts several hours. The total effect of an intervention in an intervention day is based on the exchange rate percentage change during an intervention window, that is, just before the intervention starts and immediately after the last intervention transaction on that day.

The implicit assumption behind these computations is that the data-generating process of the exchange rate is a random walk and that the change in the short intervention spell can be fully attributed to the intervention. These intervention shocks are measured in USDILS terms.[8]

Figure 2 presents two typical intervention spells and the intraday effect on the exchange rate. Figure 3 shows the efficiency of interventions and the distribution of returns. According to Figure 3, the

[8]We choose to base our analysis in USDILS terms, as our data are available in these terms, even though the relevant exchange rate for the local economy is the effective exchange rate weighting of the foreign currencies by their share in Israel's foreign trade.

Figure 2. The Impact of FX Intervention: Two Typical Examples

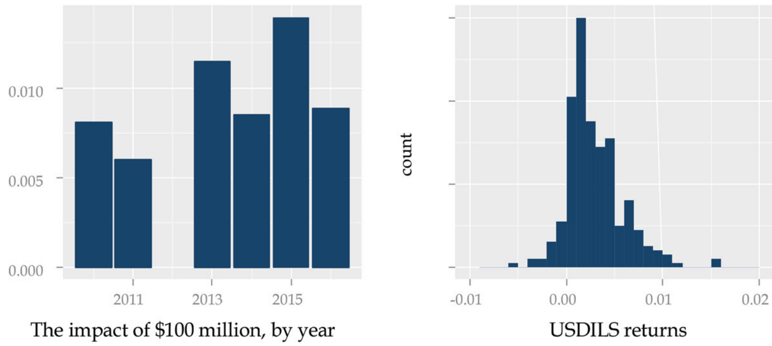


Note: The two snapshots above show the USDILS rate on two trading days during which the Bank of Israel intervened in the FX market. The left line indicates the entry point of the Bank of Israel into the market and the right line indicates the exit point. The impulse of intervention is measured by the exchange rate returns between the exit and entry points. The snapshot on the left points to the importance of using high-frequency data to identify the impact of intervention. The impact of intervention cannot be detected based on daily data due to intraday endogeneity.

impact of a given volume of intervention remained relatively stable during the years analyzed, with a somewhat stronger effect of smaller volumes of intervention relative to larger ones. Moreover, FX purchases succeeded in generating USDILS depreciation in 91 percent of the cases. Looking on the development of the daily exchange rate, we find that the daily change in the USDILS exchange rate on days of intervention is −0.09 percent, on average, whereas on other days it is 0.01 percent. These figures emphasize the endogeneity issue, revealing the tendency of the Bank of Israel to intervene in days in which the ILS appreciates, while when the USDILS is generally stable or depreciating the Bank refrains from intervening, as was the case during 2011–13.

In addition to the full intervention spell effect described above, we also measure the approximated initial impulse of intervention, based on a fixed-length 30-minute window around the first intervention. This measure is "cleaner" in the sense that it does not contain traces of intraday endogeneity, but rather captures only a fraction of the full daily effect. We will refer to this alternative measure in the robustness tests presented in Section 6.

Figure 3. The Average Yearly Efficiency of Intervention between 2010 and 2016 and the Distribution of the Returns to Intervention under the Discretionary Purchase Regime between September 8, 2009 and April 28, 2017



Note: The figure on the left presents the average effect of purchases of $100 million on the USDILS rate (the daily effect mentioned above), by year, based on unweighted observations. For example, in 2015, purchases of this amount resulted in a depreciation of slightly more than 1.2 agorot (100 agorot = 1 shekel). The figure on the right presents the distribution of the returns to each intervention episode during the discretionary period (August 11, 2009 and on). The histogram is based on hundreds of observations.

5. Estimating the Persistence of FX Intervention Shocks

This section describes the method and assumptions used to assess the persistence of our intraday measure of the effect of FX interventions on the nominal effective exchange rate. First, we put our empirical challenge in the potential outcomes framework (Rubin 1974, 1977). Second, we define a structural intervention shock and explicitly state the assumptions behind our identification strategy. Finally, we describe the econometric model used to estimate the dynamic response of the exchange rate to FX intervention shocks.

We start by letting y_t denote the outcome variable, which in our case is the log of the end-of-day nominal effective exchange rate (NEER). Let FXI_t denote the intraday measure of change in the USDILS exchange rate during an intervention spell within day t, where $FXI_t = 0$ when no intervention takes place.

Next, denote by $\boldsymbol{W}_t$ a vector of variables that potentially serve as good predictors of y_t. Finally, let $\boldsymbol{\mathcal{X}}_t$ denote the information set available in period t that includes lagged values of both y_t and FXI_t as well as $\boldsymbol{W}_t$. We further assume that the central bank's intervention decision function, denoted by $FXI_t(\boldsymbol{\mathcal{X}}_t, \varepsilon_t, \theta)$ is linear, where ε_t is a random FX intervention policy shock that is uncorrelated with $\boldsymbol{\mathcal{X}}_t$ and $\theta \in \Theta$ is a set of parameters

In the SVAR and local projections literature (see Jordà 2005), it is common to analyze the causal effect of a certain shock on the endogenous variable through the lens of an impulse response function (IRF) for an unanticipated shock of size one, defined as

$$IRF(h) \equiv E_t(y_{t+h}|\varepsilon_t = 1) - E_t(y_{t+h}|\varepsilon_t = 0), \tag{1}$$

where h denotes the horizon and E_t denotes the expectation operator, conditioned on information available until period t. Another useful exposition of the IRF can be made couched in terms of *potential outcomes.*

Given ε_t, we can estimate its IRF using the local projections method of Jordà (2005), which is based on estimating the following set of h-steps-ahead predictive regressions:

$$y_{t-1+h} - y_{t-1} = \alpha_{(h)} + \beta_{(h)}\varepsilon_t + u_{(h),t-1+h}, \tag{2}$$

for $h = 1, \ldots H$, where $y_{t-1+h} - y_{t-1}$ denotes the cumulative change from time $t-1$ to time $t-1+h$ in the log of the USDILS times 100, i.e., the cumulative percentage change in the exchange rate with respect to its level at the end of day $t-1$.[9]

The series of estimated coefficients $\hat{\beta}_{(1)}, \ldots, \hat{\beta}_{(H)}$ from Equation (1) provides a consistent estimate of the cumulative impulse response function of an unexpected FX intervention shock of size one. In other words, $\hat{\beta}_{(h)}$ is the estimate of the cumulative percentage change in the USDILS due to a change of size one in ε_t after h periods.

Unfortunately, estimating Equation (2) is impossible since the vector of potential outcomes and the shock of interest ε_t are unobservable. Nonetheless, under certain conditions, it is possible to

[9]A similar approach is used in papers that study the effect of monetary policy shocks, where a shock is defined as the change in the futures funds rate during a tight window around Federal Open Market Committee (FOMC) (or other central bank) statements (e.g., Gertler and Karadi 2015; Swanson 2017).

recover the causal effect of ε_t on y_{t+h}, using an endogenous variable and a proper set of controls (Angrist, Jordà, and Kuersteiner 2018; Angrist and Kuersteiner 2011; Jordà and Taylor 2016). Specifically, we use FXI_t as the endogenous variable and make the following identifying assumption:

ASSUMPTION 1 *(structural FX intervention shocks). Let* ε_t *denote the residual from a linear projection of* FXI_t on $\boldsymbol{\mathcal{X}}_t$, i.e., $\varepsilon_t = FXI_t - E(FXI_t|\boldsymbol{\mathcal{X}}_t)$. *The following conditions hold for* ε_t:

(i) *independence of potential outcomes;*

(ii) *contemporaneous uncorrelatedness of* ε_t *with other structural shocks.*

Part (i) of Assumption 1 states that FXI_t is as good as a randomly assigned shock once we control for the variables[10] in $\boldsymbol{\mathcal{X}}_t$. Under the assumption that the response of the central bank is linear, the residual (or innovation) from a linear projection of FXI_t on $\boldsymbol{\mathcal{X}}_t$ represents an idiosyncratic source of random variation that is independent of potential outcomes. This includes situations where our intraday measure of FX interventions is not completely unexpected, and hence not randomly assigned, but can still be randomized by a proper set of predictors (control variables).

Part (ii) of Assumption 1 states that this residual is "structural" in the sense that it is contemporaneously unrelated to other primitive shocks that might affect the economy and the exchange rate simultaneously (e.g., monetary policy shocks). This part of the assumption states that the randomness that is left after conditioning on $\boldsymbol{\mathcal{X}}_t$ is related solely to the random element of the central bank's reaction function and not to other primitive and unanticipated shocks. We argue that this assumption is plausible in cases where FXI_t is estimated within a tight window around an intervention spell, during which it is known that most of the variance of the exchange rate is due to actions taken by the central bank.

[10] In the treatment effect literature, this assumption is usually referred to as the *selection-on-variables* assumption.

Equipped with Assumption 1, we are now able to estimate the persistence of FXI shocks, using the following set of h-step-ahead predictive regressions for $h = 1, \ldots, H$:

$$y_{t-1+h} - y_{t-1} = \alpha_{(h)} + \beta_{(h)} FXI_t + \gamma_{(h)} \boldsymbol{\mathcal{X}}_t + u_{(h),t-1+h}, \qquad (3)$$

where $y_{t-1+h} - y_{t-1}$ denotes the cumulative change from time $t-1$ to time $t - 1 + h$ in the log of the USDILS.[11]

If Assumption 1 indeed holds, Equation (3) provides a consistent estimate of the cumulative impulse response function of an unexpected FX intervention shock of size one.[12] In turn, statistical inference regarding the direction and magnitude of $\beta_{(h)}$ is done using Newey-West HAC robust standard errors, due to the dependent and potentially heteroskedastic structure of the regression error,[13] $u_{(h),t-1+h}$.

6. Results

We estimate the impulse response function of the nominal USDILS rate to an FX intervention shock identified using the methodology described in the previous section. We use daily data for the period September 2009 through May 2017—a total of 1,857 trading days. The sequence of h coefficients is the cumulative effect on day $t + h$ (relative to the level of the exchange rate on $t-1$) of an intervention shock to the exchange that occurred on day t.

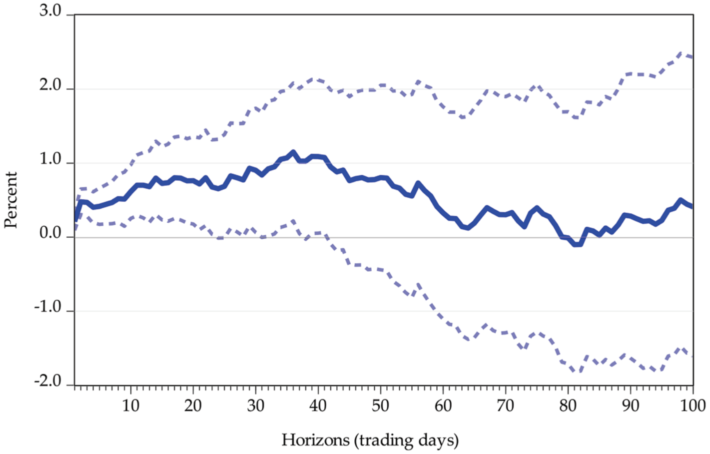
Figure 4 shows the estimated impulse response for our baseline specification where we do not include any control variables. The first point in the graph is the immediate same-day estimated response of the exchange rate to the intervention. Theoretically, this point

[11] At this point, it is important to note that in Equation (1) we implicitly assume that the data-generating process for y_t is approximately linear in both, and that the regression is saturated, i.e., that the distribution of the control variables that appear in $\boldsymbol{\mathcal{X}}_t$ is the same for both the treatment (intervention days) and control (days without intervention) groups.

[12] Formally, for consistency, we need to impose additional conditions that relate to stationarity and mixing properties of the process (y_t, FXI_t, X_t). For details, see Angrist and Kuersteiner (2011).

[13] Specifically, heteroskedasticity and autocorrelation consistent (HAC) standard errors are estimated using the Bartlett kernel where the bandwidth is set to h.

Figure 4. The Cumulative Effect of an FX Intervention Shock of Size 1 Percent



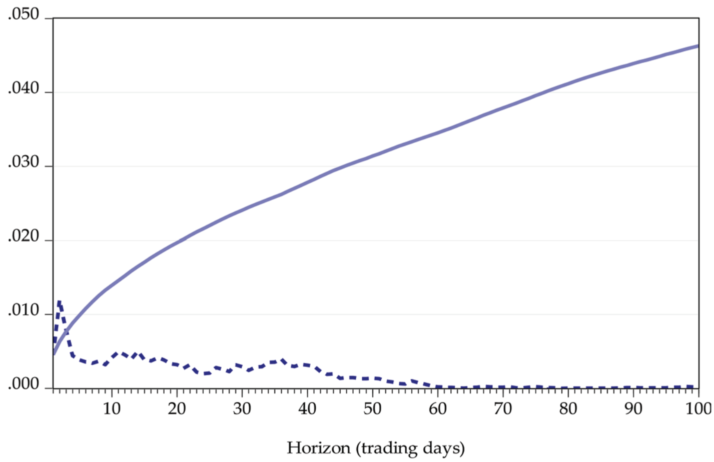
Note: This figure presents the cumulative IRF of an FX intervention shock of size one in the log of the USDILS exchange rate times 100 (solid line) $\pm 1.65 \times$ HAC standard errors (dashed lines that represent a 90 percent confidence interval). Results are based on Equation (3) without control variables.

should have a unit value; the smaller estimated response may represent the diminishing effect of the intervention on the same day, or an appreciation just before the start of the intervention.

For this specification, the effect accumulates to around 1 (as a proportion of the size of the intervention) after about 15 trading days, and the cumulative change in the exchange rate becomes insignificant after about 40 trading days (about two calendar months). As expected, the uncertainty around the point estimate increases over time, as other economic and financial factors (including further intervention shocks) affect the development of the exchange rate in this time span. Our baseline specification, as portrayed in Equation (3), allows a drift term to the exchange rate, represented by $\alpha_{(h)}$. We do not find any empirical support for a negative trend vis-à-vis the dollar, as the estimated intercept coefficient is insignificant for all horizons up to 100 trading days (about 140 calendar days, which amounts to roughly six months).

Figure 5 shows the standard error of the estimated regression alongside the R^2 for each horizon. As expected, the share of the

Figure 5. R^2 and Standard Error of Estimated Equation



Note: This figure presents the standard error of the regression (solid line) and the R-squared (dashed line) at different horizons. Results are based on Equation (3).

variation in the change in the exchange rate over h trading days explained by the initial shock at time t declines and the standard error of the regression rises as h increases.[14] Based on our estimated impulse response function, we can calculate a back-of-the-envelope estimate to the ex post effectiveness of the intervention in the medium term.

Based on the models in Table 1, choosing $H = 40$ to 60 trading days, we find, that on average, the cumulative effect of intervention in the first period is between 1.3 and 2 percent depending on the model, and for the second period, which is characterized by larger

[14] Although the methodology we apply is robust to any future shock to the exchange rate, including a future intervention shock, we also estimated the IRF based on truncated data that do not include additional FX interventions in the window between $t-1$ and $t-1+h$ where $h = 7$, 14. This test, which is based on the impact of a single intervention, leaves us only with 10.5 percent of the observations in the full sample, as many interventions overlap in a 14-day window. The IRF based on this truncated sample points to a significant impact of the same magnitude as our benchmark estimation of FXI for up to 14 days. The estimation results for the truncated data are presented in the online appendix, which is available at http://www.ijcb.org.

Table 1. The Cumulative Response of the Nominal Effective Exchange Rate of the Shekel to FX Interventions

	Model						
Horizon	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
1	0.21	0.18	0.17	0.18	0.18	–0.12	0.32
	(0.07)	(0.07)	(0.07)	(0.07)	(0.17)	(0.17)	(0.08)
5	0.42	0.39	0.39	0.42	0.42	–0.35	0.67
	(0.15)	(0.14)	(0.14)	(0.14)	(0.14)	(0.34)	(0.14)
10	0.61	0.56	0.55	0.60	0.59	–0.35	0.90
	(0.22)	(0.19)	(0.19)	(0.19)	(0.19)	(0.52)	(0.19)
25	0.69	0.63	0.62	0.75	0.72	0.62	0.51
	(0.42)	(0.38)	(0.37)	(0.34)	(0.35)	(1.09)	(0.38)
50	0.80	0.75	0.74	0.99	0.91	0.95	0.43
	(0.76)	(0.69)	(0.68)	(0.56)	(0.58)	(1.55)	(0.71)
100	0.41	0.40	0.38	0.72	0.52	0.14	–0.36
	(1.22)	(1.13)	(1.12)	(0.99)	(1.01)	(2.11)	(1.22)
Control Variables							
FXI_{t-1}	X	√	√	√	√	X	X
Δy_{t-1}	X	X	√	√	√	X	X
Interest Rate Spread	X	X	X	√	√	X	X
VIX	X	X	X	X	√	X	X
Sample	Full Sample	Full Sample	Full Sample	Full Sample	Full Sample	First Period	Second Period

Note: The dependent variable is the h-period cumulative change in log of the nominal USDILS exchange rate times 100. Newey-West robust standard errors that allow for correlated and heteroskedastic residuals are shown in parentheses. Estimation sample covers September 8, 2009–April 28, 2017 and includes 1,855 observations (trading days) and hundreds of intervention episodes. An increase in the USDILS indicates depreciation, contrary to the common convention. Thus, positive betas suggest that a positive FXI_t leads to depreciation.

volumes of interventions and shocks, the cumulative effect is on average between 1.6 and 2.6 percent. In general, we may conclude that the nominal exchange rate depreciated on average by about 1.5–2.5 percent relative to its level had there not been any interventions.

7. Robustness Analysis

7.1 Adding Controls

As noted above, the on-impact response on the day of the intervention is smaller than unity. This phenomenon may reflect the existence of some endogeneity in the measurement of the daily change in the exchange rate, partly due to the difference in the specification of the time window for the construction of the measured return and the full business day, which also reflects the additional change in the exchange rate before and after intervention took place during the day. Because the Bank of Israel sometimes intervenes in days characterized by appreciation, the net daily change measured in the exchange rate on those days is smaller than the intraday return. Intervention can also be linked to external factors such as uncertainty in global financial markets.

Therefore, we include in alternative specifications of the regression exogenous variables that may account for these effects and thus improve the ability to identify the true effect of the intervention, both on impact ($h = 1$) and on the following trading days, thus assisting in overcoming possible endogeneity due to the central bank's reaction to other external factors. We choose to add to the baseline specification lagged values of FXI_t, the lagged first difference of log USDILS rate, the lagged interest rate differential between the Bank of Israel interest rate and the Federal Reserve interest rate (which was fixed for most of the period), and the lagged log of VIX index[15] to account for a possible effect of uncertainty in the markets.[16] The domestic interest rate is set according to a monthly

[15] The CBOE one-month expected volatility index of the S&P 500 stock index.

[16] We also experimented with adding the risk reversal index, the moving-average standard deviation measure of the exchange rate and the dollar–euro cross-rate to our baseline specification and found that the results did not qualitatively change.

cycle and, for most trading days, it is exogenous to the decision to intervene on a specific date.

The results, reported in Table 1, show that the effect of intervention shocks, including the on-impact estimated effect, remains qualitatively similar to that in the baseline specification, although its persistence is somewhat stronger when the interest rate spread is added (see column 4 in the table), with the effect remaining significant for roughly 60 trading days without showing a diminishing trend to zero as earlier.

The phenomenon of the increasing effect during the first days after the intervention, which occurred in the benchmark specification, holds for this specification as well.

We also experimented with adding to the baseline specification the rate of change in the exchange rate on the day, 10 days, or 30 days before an intervention to account for possible predictability of the decision to intervene, but the effect was not significant and did not alter the results qualitatively. This result provides additional reassurance that the shock we identify is essentially unanticipated.

It may be that the persistence of the effect of interventions on the exchange rate depends on the market perception of the tendency of the Bank to intervene. Put simply, FX interventions themselves may exhibit some level of persistence; thus, excluding lags of FXI_t might be restrictive. To control for this possibility, we added to our baseline specification the moving average over different horizons of a dummy variable in order to indicate whether any intervention occurred in the previous period. For all lag lengths we tested, starting from 1 business day to 30 business days, our results concerning the effect of intervention on the exchange rate remained qualitatively unchanged. We find that when controlling with a dummy for a 1-day lag or a 3-day lag the contribution of this variable was insignificant, but we do find that a tendency to intervene in the previous 10, 20, or 30 days does give a significant positive contribution on the exchange rate in the next month or so. Thus, our main finding on the persistence of the intervention effect remains unchanged (see Figure 6).

7.2 An Alternative Measure of the Intervention Shock

The main indicator we use as the identified intraday intervention shock is the change in the exchange rate within the daily intervention

Figure 6. The Impulse Response Function including Intervention Dummy for Previous 10 Business Days

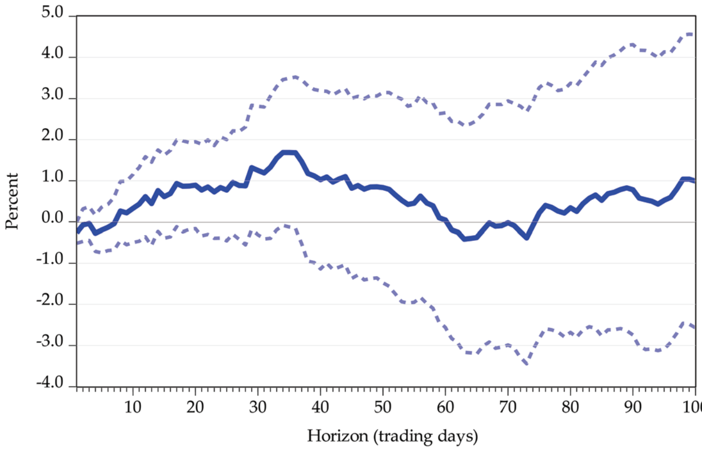
Note: This figure presents the cumulative IRF of an FX intervention shock of size one in the log of the nominal USDILS exchange rate times 100 (solid line) $\pm 1.65 \times$ HAC standard errors (dashed lines). Results are based on Equation (3), where we add the moving average of a dummy variable over three days in order to indicate whether any intervention occurred on a certain day.

spell, starting with the first intervention during the day and ending with the last one, in the case where the central bank intervened more than once during that day. The advantage of this measurement is that it considers the full spell of intervention. Nonetheless, the drawback of this measurement is the possibility that it contains endogenous reactions of the central bank during the day to intraday developments in the exchange rate that may be due to or independent of the bank's intervention.

We therefore test an alternative proxy that measures the change in the dollar–shekel exchange rate within a fixed window of 30 minutes around the first intervention on days when interventions occurred. This measure may underestimate the effect of interventions when there were several spells of them during the day, but the advantage is that the "fixed" and "tight" features of the window size minimize the endogeneity concern.

We estimate Equation (3) using this alternative measure, and find that qualitative results, namely the pattern of the IRF, remain

Figure 7. The Impulse Response Function Using a 30-Minute Window



Note: This figure presents the cumulative IRF of an FX intervention shock of size one in the log of the nominal USDILS exchange rate times 100 (solid line) $\pm 1.65 \times$ HAC standard errors (dashed lines). Results are based on Equation (3), where FXI_t is defined as the change in the USDILS during the first 30 minutes of an intervention spell.

unchanged (Figure 7). The effect is insignificant, but its point estimate is greater than zero for most of the first 60 trading days, as was found to be the case in the baseline specification. A possible explanation for the insignificance of the effect based on a 30-minute FX shock is that it captures only part of the full intervention shock.

7.3 Intraday Endogeneity

The assumption we have made through this study on the exogeneity of intervention shocks might be too strong. In particular, at least in short time spells, the exchange rate can deviate from purely random-walk behavior. For example, momentum or other patterns in the data might be at work in the minutes or hours before interventions occur and, in turn, might affect the decision of whether or not to intervene.

Our approach to relieving potential endogeneity bias concerns is twofold. First, we formally elaborate on the problem at hand and run simulations to assess the direction of bias and possible solutions qualitatively. Second, and based on the insights from the simulation study, we run additional regressions where we use intraday data from before interventions to minimize endogeneity concerns. In other words, instead of assuming that the return on the exchange rate during intervention spells is exogenous, we assume that interventions respond to intraday momentum and adjust for it by controlling for changes up to the shock.

7.3.1 Simulation Study[17]

During intervention days, we can decompose the daily return on the exchange rate Δy_t to three components, namely

$$\Delta y_t = \varepsilon_{PRE,t} + FXI_t + \varepsilon_{POST,t}, \tag{4}$$

where $\varepsilon_{PRE,t}$ is the pre-intervention return, FXI_t is the intervention shock (i.e., the return during the intervention spell), and $\varepsilon_{POST,t}$ is the post-intervention return.

Figure 8 presents the empirical distribution of the daily return on the exchange rate and the three components defined by Equation (4) *during intervention days*. Three clear patterns emerge. First, as discussed before, interventions are effective because most of the returns during intervention spells are positive. Second, we can see that the distribution of pre-intervention returns is somewhat skewed to the left, indicating the potential response of the Bank of Israel to sharp intraday appreciation in the USDILS. Finally, the distribution of post-intervention returns seems to be skewed to the left, indicating a possible decay of the effect of interventions during the time after interventions and before closing time.

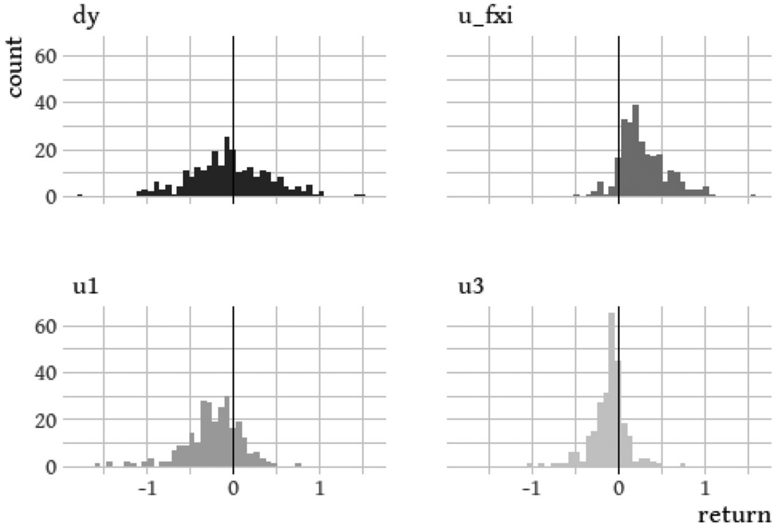
Figure 9 presents the empirical distribution of daily exchange rate return in days with and without interventions. As we can see, the distribution of daily returns on intervention days is skewed to the left and exhibits fat tails.

Recall that the estimated regression (without controls) is

$$y_{t-1+h} - y_{t-1} = \alpha_{(h)} + \beta_{(h)} FXI_t + u_{(h),t-1+h}. \tag{5}$$

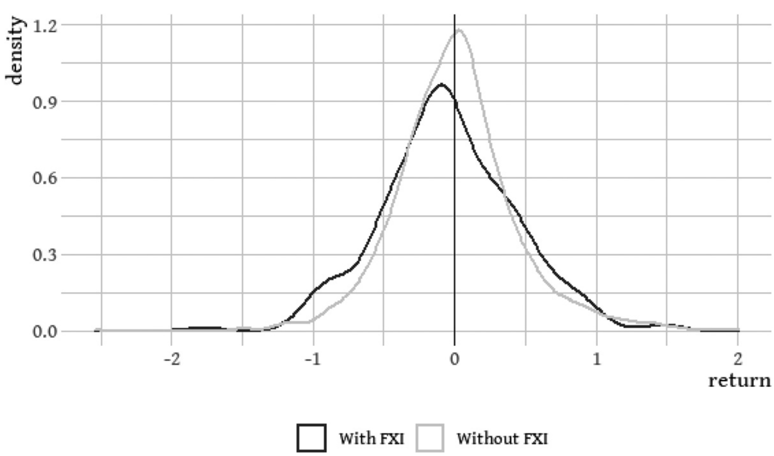
[17]We would like to thank Lukas Frei for highlighting and elaborating this point in his discussion for this paper.

Figure 8. The Distribution of Intraday USD/ILS Return During Interventions Days



Note: This figure shows USD/ILS intraday returns during days with interventions. The return during the trading day is denoted by dy, the return prior to the intervention is denoted by u1, the return during the intervention window is denoted by u_fxi, and the return after the intervention is u3.

Figure 9. The Distribution of Daily USD/ILS Returns, with and without Interventions



We consider two cases:

(i) an exogenous FXI shock, where $\text{Corr}\,(\varepsilon_{PREt}, FXI_t) = 0$,

(ii) an endogenous FXI shock, where $\text{Corr}\,(\varepsilon_{PREt}, FXI_t) < 0$,

where the former states that interventions are independent of the (intraday) pre-intervention return, and the latter states that the central bank responds to a prior intraday appreciation of the exchange rate by intervening ("leaning against the wind").

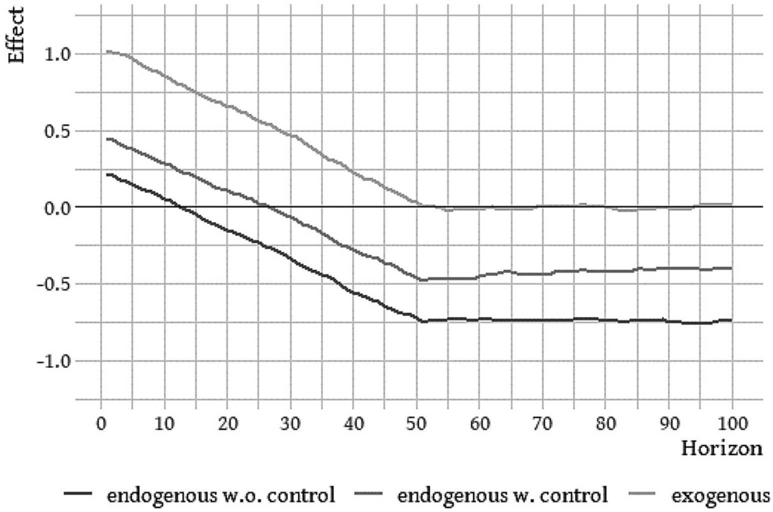
Throughout the simulation, we assume that $\varepsilon_{PRE,t}, \varepsilon_{POST,t} \sim N(0, \sigma)$ and FXI_t follows a half-normal distribution, i.e., $FXI_t = |z_t|$, where $z_t \sim N(0, 1)$. In addition, we assume that the effect of FXI_t on y_t is equal to unity on impact and follows a linear decay up to $h = 50$ periods, consistent with our previous results.

We simulate three scenarios. In the first scenario, we assume that intervention shocks are purely exogenous and occur with a random probability of 0.2 percent (roughly the frequency of intervention days we see in the data). In the second scenario, we assume that interventions depend on the realization of $\varepsilon_{PRE,t}$. In particular, we assume that the central bank intervenes whenever the realization of $\varepsilon_{PRE,t}$ is below the 20th percentile. Finally, in the third scenario, we also assume a dependency between the intervention shock and $\varepsilon_{PRE,t}$, only now we *partly* control for $\varepsilon_{PRE,t}$ in the regression by adjusting for it, but only for days where it is "observed," i.e., only in days where $FXI_t > 0$, and assume it is zero otherwise.

Within each simulation, we run 200 replications where $T = 1,857$ (our sample size). The IRF is estimated base on Equation (5) (with and without controls). The output of the simulation is the mean of the 200 IRFs for each three scenarios discussed above.

The results of our simulation study are presented in Figure 10. The first scenario, an exogenous FXI shock, is estimated correctly (on average)—the effect on day 0 is 1, and it decays linearly during the next 50 days (gray line). In contrast, when interventions are correlated with the pre-intervention return (darker gray and black lines), the estimated effect exhibits significant attenuation bias. Controlling for pre-intervention returns during days of interventions mitigates the bias, thus pushing the estimate from the black line to the

Figure 10. Simulation Results



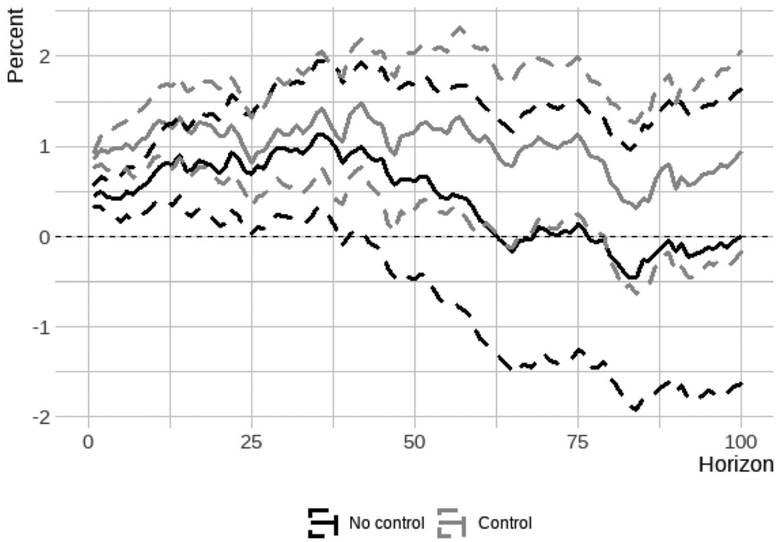
darker gray line, but not entirely since the control is only defined on intervention days and is assumed to be zero otherwise.

The two key takeaways from our simulation study are as follows: First, if the central bank responds to intraday movements of the exchange rate (USDILS appreciation in our case), and this reaction function is not taken into account in the regression, the estimated IRF is attenuated. These results might explain the fact that the contemporaneous impact on the benchmark estimate that we find in our baseline specification (Figure 4) is less than 1. Second, controlling for intraday returns before interventions during days with interventions mitigates attenuation bias.

7.3.2 Adjusting for Pre-intervention Intraday Movements

The second takeaway from our simulation study, namely that adding pre-intervention intraday return to the regression might mitigate attenuation bias, leads to estimating our baseline specification (Equation (3)), only now we add to the set of controls the percent change of the USDILS exchange rate between the opening rate and the rate at the beginning of the intervention spell. For days without

Figure 11. The Cumulative Effect of an FX Intervention Shock of Size 1 Percent, with and without Controlling for Intraday Momentum Before Intervention

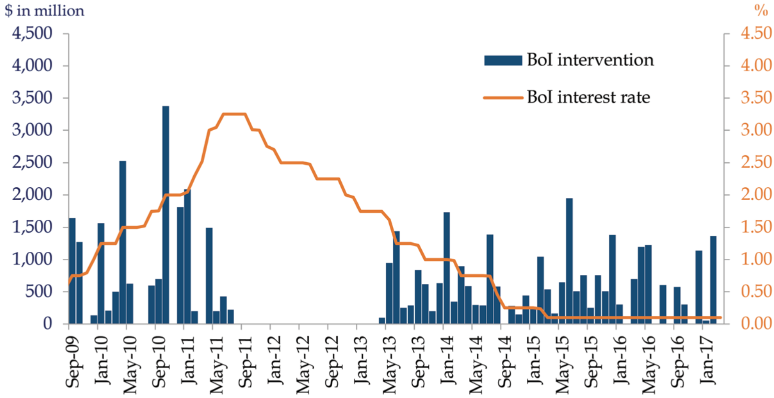


interventions, we assume that the "pre-intervention return" equals zero.

Figure 11 provides a comparison of our benchmark results and the results when adding pre-intervention returns to the regression. The results accord well with the simulation study discussed above. Briefly, it appears that adding the pre-intervention control results in a higher IRF throughout its entire path. Interestingly, the contemporaneous impact moves from 0.5 in the benchmark specification to nearly 1 in the new specification. Taken at face value, this result means that ignoring intraday returns may have underestimated the effect of interventions.

In addition, the point estimate of the cumulative effect of intervention after controlling for intraday momentum is more stable around 1 percent relative to the effect with no controls that shows some pick-up in the first 35 days.

Figure 12. The Volume of Interventions and the Bank of Israel Interest Rate



Source: Bank of Israel.

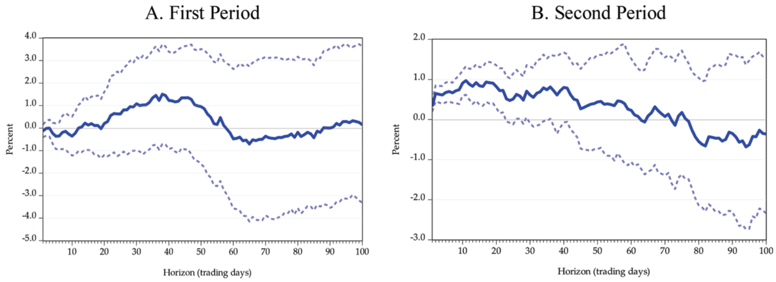
7.4 Subsamples

Figure 12 shows the volume of interventions alongside the Bank of Israel interest rate, which is the main monetary instrument. We may distinguish between two periods of intervention. In the first period, starting in August 2009 and ending in April 2011, interest rate hikes accompanied the interventions. The second period, from April 2013 to April 2017, following a period of about a year and a half during which the bank was in practice out of the market (although the policy framework did not change), is characterized by an accommodative monetary policy with interest rate reductions, reaching a minimum of 0.1 percent. As we have some theoretical reasons to believe that the impact of FX purchases might be a function of the overall monetary stance, we estimate the persistence of the effect of intervention separately for these two subperiods by adding an interaction term for each of the two periods.

We find, for our baseline specification, that intervention had a weaker and insignificant effect on the exchange rate during the first period, while in the second period the effect was statistically significant (Table 1 and Figure 13).[18] We relate this difference in the

[18] We obtain very similar results for both periods when also including the control variables shown in Table 1.

Figure 13. The Impulse Response Function for Subsamples



Note: These figures present the cumulative IRF of an FX intervention shock of size one in the log of the nominal USDILS exchange rate times 100 (solid lines) $\pm 1.65\times$ HAC standard errors (dashed lines). Results are based on Equation (3). Panel A present results for the first period of interventions (September 2009–April 2011) and panel B is for the second period (April 2013–April 2017).

effect of intervention between the two periods to a more efficient signal of the purchases considering the future policy in an overall environment of accommodative policy, while in the first period FX purchases worked in an opposite direction to the interest rate hikes at the time. This finding is in line with these of Kaminsky and Lewis (1996), who show that the exchange rate tends to move significantly in the direction implied by intervention only when interventions are followed by monetary policy that is consistent with the direction of intervention.

8. Conclusions

Like several other central banks in developing as well as advanced economies around the world, the Bank of Israel in recent years has used FX interventions as an additional monetary policy instrument in an environment characterized by an accommodative monetary policy with near-zero interest rates. In the present paper, we analyze the effect of FX purchases by the Bank of Israel on the exchange rate using a unique proprietary data set that consists of high-frequency, minute-by-minute observations of the exchange rate and the timing and volume of FX purchases. The on-impact intraday effects of FX intervention are measured in terms of the change in the USDILS exchange rate during intraday intervention spells. Next, we use this measure to estimate the causal effect of FX intervention shocks (i.e., the unanticipated interventions) on the exchange rate.

Our empirical strategy follows Angrist, Jordà, and Kuersteiner (2018), Angrist and Kuersteiner (2011), and Jordà and Taylor (2016). In particular, we combine the potential outcome framework (the Rubin causal model) and the local projections method (Jordà 2005) to estimate the causal effect of a policy treatment (FX interventions in our case) and its persistence in a dynamic setting. We find that FX intervention shocks—that is, unexpected FX purchases—cause, on impact, USDILS depreciation in over 90 percent of the cases and that this effect has a persistent impact on the nominal effective exchange rate for about 40–60 trading days. These results are robust to the inclusion of several control variables and an alternative measure of the short-term impact of FX intervention. We find, however, some evidence of the instability of this effect throughout the sample period.

Based on this finding and the timing and volume of actual interventions, we infer that the level of the exchange rate depreciated by about 1.5–2.5 percent on average between 2013 and 2017, a period when FX intervention was frequently applied. It is important to emphasize that this result reflects the marginal contribution of unexpected FX purchases, given that the discretionary intervention regime was in place throughout the investigated period, and not the possible impact of the regime itself on the level of the exchange rate.

One obvious drawback of our research is that we remain silent about the medium-term macroeconomic effect of interventions. We do not estimate the effects of interventions on macroeconomic variables such as output, exports, and inflation, which are the final target of interventions in the eyes of policymakers. Hence, any linkage between our results and such macroeconomic effects can only be done indirectly. Accordingly, linking intraday measures of the effect of FX interventions to lower-frequency economic variables remains a major challenge to this literature, and we believe it is an important topic for further research.

References

Adler, G., N. Lisack, and R. Mano. 2015. "Unveiling the Effects of Foreign Exchange Intervention: A Panel Approach." IMF Working Paper No. 15/130.

Adler, G., and C. E. Tovar. 2011. "Foreign Exchange Intervention: A Shield against Appreciation Winds?" IMF Working Paper No. 11/165.

Angrist, J. D., O. Jordà, and G. M. Kuersteiner. 2018. "Semiparametric Estimates of Monetary Policy Effects: String Theory Revisited." *Journal of Business and Statistics* 36 (3): 371–87.

Angrist, J. D., and G. M. Kuersteiner. 2011. "Causal Effects of Monetary Shocks: Semiparametric Conditional Independence Tests with a Multinomial Propensity Score." *Review of Economics and Statistics* 93 (3): 725–47.

Bauer, M., and G. D. Rudebusch. 2014. "The Signaling Channel for Federal Reserve Bond Purchases." *International Journal of Central Banking* 10 (3, September): 233–90.

Blanchard, O., G. Adler, and I. de Carvalho Filho. 2015. "Can Foreign Exchange Intervention Stem Exchange Rate Pressures from Global Capital Flow Shocks?" IMF Working Paper No. 15/159.

Eckstein, Z., and A. Friedman. 2011. "The Equilibrium Real Exchange Rate for Israel." *BIS Papers* 57: 201–13.

Engel, C. 2014. "Exchange Rates and Interest Parity." In *Handbook of International Economics*, ed. G. Gopinath, E. Helpman, and K. Rogoff, 453–522. Elsevier.

Fratzscher, M., O. Gloede, L. Menkhoff, L. Sarno, and T. Stohr. 2015. "When is Foreign Exchange Rate Intervention Effective? Evidence from 33 Countries." DIW Discussion Paper No. 1518.

Gertler, M., and P. Karadi. 2015. "Monetary Policy Surprises, Credit Costs, and Economic Activity." *American Economic Journal: Macroeconomics* 7 (1): 44–76.

Jordà, O. 2005. "Estimation and Inference of Impulse Responses by Local Projections." *American Economic Review* 95 (1): 161–82.

Jordà, Ò., and A. M. Taylor. 2016. "The Time for Austerity: Estimating the Average Treatment Effect of Fiscal Policy." *Economic Journal* 126 (590): 219–55.

Kaminsky, G. L., and K. K. Lewis. 1996. "Does Foreign Exchange Intervention Signal Future Monetary Policy?" *Journal of Monetary Economics* 37 (2): 285–312.

Kuersteiner, G. M., D. C. Phillips, and M. Villamizar-Villegas. 2016. "Effective Sterilized Foreign Exchange Intervention? Evidence from a Rule-based Policy." Borradores de Economia No. 964.

Menkhoff, L. 2013. "Foreign Exchange Intervention in Emerging Markets: A Survey of Empirical Studies." *The World Economy* 36 (9): 1115–1243.

Neely, C. J. 2005. "An Analysis of Recent Studies of the Effect of Foreign Exchange Intervention." *Review* (Federal Reserve Bank of St. Louis) 87 (6): 685–717.

———. 2011. "A Foreign Exchange Intervention in an Era of Restraint." *Review* (Federal Reserve Bank of St. Louis) 93 (5): 403–24.

Perez-Reyna, D., and M. Villamizar-Villegas. 2019. "Exchange Rate Effects of Financial Regulations." *Journal of International Money and Finance* 96 (September): 228–45.

Ribon, S. 2017. "Why the Bank of Israel Intervenes in the Foreign Exchange Market, and What Happens to the Exchange Rate." Discussion Paper No. 2017.04, Bank of Israel.

Rubin, D. 1974. "Estimating Causal Effects of Treatments in Randomized and Nonrandomized Studies." *Journal of Educational Psychology* 66 (5): 688–701.

———. 1977. "Assignment to Treatment Group on the Basis of a Covariate." *Journal of Educational Statistics* 2: 1–26.

Sorezcky, A. 2013. "Was the Bank of Israel Intervention in the Foreign Exchange Market Effective?" (in Hebrew). *Bank of Israel Review* 86 (January): 7–45.

Swanson, E. 2017. "Measuring the Effects of Federal Reserve Forward Guidance and Asset Purchases on Financial Markets." NBER Working Paper No. 23311.

Villamizar-Villegas, M., and D. Perez-Reyna. 2015. "A Survey of the Effects of Sterilized Foreign Exchange Intervention." Discussion Paper No. 862, Banco de la Republica de Colombia.