ONLINE APPENDIX FOR "FX INTERVENTIONS AND CAPITAL-CONSTRAINED BANKS: EVIDENCE FROM USD/ILS SPOT, FORWARD, AND OPTION MARKETS"

A INTERVENTION REGIMES SINCE 2008

The Bank of Israel (BOI) has intervened in the foreign exchange market since 2008 to counter persistent appreciation pressure on the Israeli new shekel (ILS), especially in the aftermath of the Global Financial Crisis (GFC). Over this period, the BOI has altered its intervention regime multiple times. We document these regimes below.

A.1 Overt Interventions

Although the initial intervention was not pre-announced, we classify it under overt interventions to preserve chronological continuity. Following a hiatus of more than a decade, the BOI began purchasing foreign currency in the spot market on March 13-14, 2008 to stabilize disorderly market conditions.[1] Indicators such as heightened intra-day volatility, widened spreads, and sharp nonlinear movements in the spot rate signaled that recent ILS appreciation was not supported by fundamentals.[2]

A.1.1 Intervention Regime I

On March 20, 2008, the BOI announced plans to build up foreign exchange reserves – which totaled USD 29 billion at the end of February 2008 – over a two-year period beginning on March 24. The stated target range was USD 35-40 billion.

A.1.2 Intervention Regime II

On July 10, 2008, in response to renewed and pronounced appreciation of the ILS against the USD, the BOI announced an increase in its daily USD purchases to USD 100 million.

A.1.3 Intervention Regime III

On November 11, 2008, the BOI announced an increase in its foreign exchange reserve target range to USD 40-44 billion, maintaining its daily USD purchases at USD 100 million.

A.2 Secret Interventions

A.2.1 Intervention Regime IV

In August 2009, the BOI announced the termination of its committed daily USD purchases initiated in July 2008. It emphasized a shift to conditional intervention, indicating that future FX operations would occur during periods of pronounced exchange rate volatility deemed inconsistent with Israel's macroeconomic fundamentals. This policy revision reflected the BOI's intent to gradually unwind the extraordinary measures adopted in response to the GFC. Subsequently, the BOI refrained from FX intervention from July 2011 for roughly two and a half years.

A.3 Overt and Secret Intervention

A.3.1 Intervention Regime V

On May 13, 2013, the BOI announced the resumption of USD purchases aimed at offsetting projected current account surpluses linked to the expected increase in natural gas exports following the onset of commercial production from the Tamar gas field on March 30, 2013.[3] The BOI projected total purchases of USD 2.1 billion

A.3.2 Intervention Regime VI

On January 14, 2021, the BOI shifted its intervention strategy by announcing its intention to purchase USD 30 billion over the course of the year. While the total intervention volume was disclosed upfront, the BOI refrained from specifying the timing or the daily amounts of its purchases.[4]

B CONTROLS, INSTRUMENTS, AND DESCRIPTIVE STATISTICS

TABLE B1
CONTROLS AND INSTRUMENTS

Variable	Description	Source
ATMV; BF; RR	At-the-money option/butterfly spread/risk reversal contracts on the USD/ILS spot rate with maturities of one week, one month, three months, six months, nine months, and twelve months. For butterfly spreads and risk reversals, we report values for option deltas of 10 and 25. All option prices are quoted in implied volatilities (percent), and reflect the midpoint between the bid and ask prices, recorded daily at 17:00 New York time.	Bloomberg.
$\overline{BF}$; $\overline{RR}$	Risk reversal/butterfly spread divided by ATMV.	Bloomberg.
CDS	The credit default swap spread reflects the cost of insuring Israeli sovereign debt against default over a 5-year horizon. It is quoted in basis points (bps).	Bloomberg.
CITI_Surprise_Index	The index is expressed in bps of aggregated standard deviations of macroeconomic surprises and is unbounded. To ensure comparability with the coefficients of other explanatory variables, we rescale the index by dividing it by 1,000.	Bloomberg.
EUR/USD	One euro in terms of U.S.dollars, recorded daily at 17:00 New York time (corresponding to midnight in Israel).	Bloomberg.
FXI_t	Net amount of USD purchased by the BOI in the USD/ILS spot market. In USD billion.	Bank of Israel.
IL_CPI_Surprise	Difference between the actual change in the IL CPI (p.a.) and the average annual change in the forecasted provided by a panel of professional forecasters on the day before the official CPI release.	Bank of Israel.
IL_Monetary_Surprise	Difference between the actual BOI's policy interest rate and the average prediction made by approximately 12 professional forecasters on the day before the Bank of Israel's interest rate decision.	Bank of Israel.
LIBOR	One-month U.S. LIBOR rate. In percent.	Bloomberg.
NEER	Nominal effective exchange rate of the ILS. Computed as the trade-weighted arithmetic average of the foreign value of the ILS vis-à-vis a basket of 24 currencies representing 31 countries. This index captures 97.3% of Israel's trade volume by partner share. The exchange rates are recorded daily at 17:00 New York time. A higher index value reflects a depreciation of the ILS.	Bloomberg & own calculations.

NS_FFR_Surprise	Unanticipated change of the federal funds rate target, inferred from movements in federal funds futures within a 30-minute window surrounding scheduled FOMC meetings. This data is an updated version of Nakamura and Steinsson (2018) and has recently been used in Miranda-Agrippino and Ricco (2021).	M. Acosta.[5]
NS_Policy_Surprise	Unanticipated change in the path of future interest rates, measured within a 30-minute window surrounding scheduled FOMC meetings. It is the first principal component of unanticipated changes in five short-term interest rates: (i) the federal funds rate immediately following the FOMC meeting, (ii) the expected federal funds rate following the next FOMC meeting, and (iii) the expected three-month eurodollar interest rates at horizons of two, three, and four quarters ahead. This data is an updated version of Nakamura and Steinsson (2018) and has recently been used in Miranda-Agrippino and Ricco (2021).	M. Acosta.[6]
TELBOR	One-month Israeli interbank rate. In percent.	Bank of Israel.
USD/ILS	One U.S. dollar in terms of ILS, recorded daily at 17:00 New York time (corresponding to midnight in Israel).	Bloomberg.
VIX	Implied volatility derived from options on the S&P 500 index. In percent.	CBOE.
ΔProb. of appr.$_{t-11,t-1}$	One-day lagged two-week change of the left tail of the risk-neutral density. It is $+2\%$, $+3\%$, $+6\%$, $+9\%$, and $+10\%$ for the one-month up to the twelve-month horizon.	Own calculations.
ΔProb. of depr.$_{t-11,t-1}$	One-day lagged two-week change of the right tail of the risk-neutral density. It is -2%, -3%, -6%, -9%, and -10% for the one-month up to the twelve-month horizon.	Own calculations.

TABLE B2
DESCRIPTIVE STATISTICS OF THE USD/ILS OPTIONS DATA

	Mean	Median	Std	Min	Max	AR(1)	N
At-the-money implied volatilities:							
ATMV1w	6.63	6.35	1.49	3.54	11.43	0.947	1826
ATMV1m	6.56	6.35	1.29	3.96	10.33	0.994	1826
ATMV3m	6.64	6.47	1.14	4.29	9.72	0.997	1826
ATMV6m	6.73	6.54	1.05	4.76	9.41	0.998	1826

TABLE B3
DESCRIPTIVE STATISTICS OF THE USD/ILS OPTIONS DATA

	Mean	Median	Std	Min	Max	AR(1)	N
At-the-money implied volatilities:							
ATMV1w	6.63	6.35	1.49	3.54	11.43	0.947	1826
ATMV1m	6.56	6.35	1.29	3.96	10.33	0.994	1826
ATMV3m	6.64	6.47	1.14	4.29	9.72	0.997	1826
ATMV6m	6.73	6.54	1.05	4.76	9.41	0.998	1826
ATMV9m	6.81	6.61	1.00	5.07	9.21	0.999	1826
ATMV12m	6.86	6.67	0.96	5.18	9.05	0.999	1826
Butterfly spreads:							
10-Δ:							
BF101w	0.794	0.90	0.44	-1.67	1.92	0.429	1826
BF101m	0.738	0.73	0.12	0.46	1.12	0.918	1826
BF103m	1.008	0.98	0.21	0.59	1.45	0.976	1826
BF106m	1.186	1.14	0.25	0.65	1.73	0.982	1826
BF109m	1.269	1.19	0.29	0.69	1.92	0.983	1826
BF1012m	1.452	1.41	0.32	0.78	2.20	0.985	1826
25-Δ:							
BF251w	0.136	0.20	0.30	-2.45	1.20	-0.052	1826
BF251m	0.236	0.23	0.04	0.14	0.37	0.945	1826
BF253m	0.327	0.31	0.07	0.19	0.50	0.984	1826
BF256m	0.384	0.37	0.08	0.21	0.59	0.986	1826
BF259m	0.419	0.39	0.10	0.22	0.63	0.990	1826
BF2512m	0.474	0.46	0.11	0.25	0.71	0.990	1826
Risk reversals:							
10-Δ:							
RR101w	0.658	0.60	0.43	-0.42	2.77	0.95	1826
RR101m	1.088	0.93	0.67	-0.12	3.33	0.99	1826
RR103m	1.438	1.14	0.87	-0.05	3.58	0.997	1826
RR106m	1.649	1.31	0.98	0.00	3.76	0.998	1826
RR109m	1.750	1.41	1.05	0.16	4.12	0.998	1826
RR1012m	1.950	1.67	1.09	0.26	4.30	0.998	1826
25-Δ							
RR251w	0.396	0.37	0.26	-0.12	1.49	0.976	1826
RR251m	0.597	0.5	0.37	-0.07	1.83	0.994	1826
RR253m	0.782	0.61	0.47	-0.02	1.92	0.998	1826
RR256m	0.892	0.70	0.53	0.01	1.99	0.998	1826
RR259m	0.949	0.78	0.57	0.10	2.13	0.999	1826
RR2512m	1.045	0.88	0.58	0.18	2.24	0.999	1826

Notes: The table reports descriptive statistics for daily USD/ILS options data, quoted in implied volatilities and in percent (except for the columns "AR(1)" and "N"). The data includes at-the-money implied volatilities ("ATMV"), 10-Δ and 25-Δ butterfly spreads ("BF10" and "BF25"), and 10-Δ and 25-Δ risk reversals ("RR10" and "RR25"). For each indicator, data is available for six different maturities ranging from one week ("1w") to twelve months ("12m"). The sample covers the period from January 1, 2013 to December 31, 2019, totaling 1,826 trading days. Data source: Bloomberg.

Control variables in our benchmark specification. Below, we discuss the economic rationale and the expected sign of the coefficients for each control variable.

- *Euro/Dollar.* Following Augustin, Chernov, and Song (2020), we use the EUR/USD exchange rate to capture broad USD depreciation trends, given the euro's global significance. We expect a USD depreciation (ΔEUR/USD > 0) to correspond with an ILS appreciation (H_a: $\delta < 0$).[7]

- *Financial uncertainty.* Following the literature reviewed in Goldberg and Krogstrup (2023), we expect rising global financial uncertainty, proxied by the VIX (ΔVIX > 0), to trigger safe-haven capital flows (e.g., into the USA). Accordingly, periods of elevated uncertainty should be associated with an appreciation of the USD (H_a: $\delta > 0$).

- *Israeli monetary and macro shocks.* We also include variables capturing Israeli monetary policy surprises ("IL_Monetary_Surprise") and consumer price index (CPI) surprises ("IL_CPI_Surprise"). An unexpected monetary tightening (IL_Monetary_Surprise > 0) is expected to attract foreign capital and strengthen the ILS (H_a: $\delta < 0$). Similarly, a positive CPI surprise (IL_CPI_Surprise > 0), often leading to monetary tightening, should also attract foreign capital, implying as well a negative coefficient (H_a: $\delta < 0$).

- *US monetary and macro shocks.* We control for US monetary surprises as proposed by Nakamura and Steinsson (2018), including short-term ("NS_FRR_Surprise") and longer-term ("NS_Policy_Surprise") surprises, derived from unexpected high-frequency changes in the Federal Funds rate (based on Federal Funds futures) and the path of future interest rates around FOMC meetings. A US monetary tightening (e.g., NS_FRR_Surprise > 0) is expected to appreciate the USD against the ILS (i.e. H_a: $\delta > 0$).

  Additionally, we include the CITI US surprise index ("CITI_Surprise_Index") to control for unexpected macroeconomic news. A positive index value indicates better-than-expected US macroeconomic data, which should be associated with USD appreciation (H_a: $\delta > 0$)).

C STANDARD INSTRUMENTS IN FOREIGN EXCHANGE OPTION MARKETS

C.1 *FX Option Spot Deltas*

In over-the-counter (OTC) markets, FX option quotes refer to the implied volatilities (IVs)[8] according to the Garman and Kohlhagen (1983) (GK) pricing formula. In this pricing framework, the spot delta for European call and put options is equal to:

$$\Delta_C \equiv \exp^{-r^f \tau} \Phi(d), \tag{C1}$$

$$\Delta_P \equiv -\exp^{-r^f \tau} \Phi(-d), \tag{C2}$$

with

$$d = \frac{\ln(S_t/F_t) + \sigma^2/2(T-t)}{\sigma\sqrt{T-t}}, \tag{C3}$$

where S_t denotes the spot exchange rate; $F_t = K \exp\left[(r^d - r^f)\tau\right]$ is the forward exchange rate implied by interest rate parity; r^d and r^f are the domestic and foreign risk-free interest rates (in logs), respectively; $\Phi(\cdot)$ is the standard normal cumulative distribution function; K is the strike price; and σ is the option-implied instantaneous volatility of the spot exchange rate. The time to maturity is given by $\tau = T - t$, where t denotes the current date and T the option's expiration date.

C.2 *Market Quoting Convention*

By market convention, FX option prices are quoted in terms of implied volatility for three standard instruments: at-the-money options (ATMV), butterfly spreads (BF), and risk reversals (RR), across a range of deltas. These instruments are typically highly liquid (Bossens, Rayée, Skantzos, and Deelstra, 2010) and are available for six standard maturities, spanning from one week to one year.

C.2.1 *At-The-Money Volatility*

The ATMV corresponds to the value on the implied volatility smile curve at a strike that reflects the price – expressed in terms of IVs – of a delta-neutral straddle. A long straddle is defined as a portfolio comprising a long call and a long put option with identical strike prices and maturity. It is delta-neutral[9] when $d = 0$.[10]

C.2.2 *Implied Volatility Smile Curve*

Following Backus, Foresi, and Wu (2004), we describe the implied volatility smile – a graph plotting IVs against moneyness – using a second-order polynomial in the moneyness parameter d:

$$IV(d) = \gamma_0 \left(1 + \gamma_1 d + \gamma_2 d^2\right). \tag{C4}$$

Here, d measures moneyness and is centered such that $d = 0$ corresponds to the at-the-money (ATM) strike. The parameter γ_0 reflects the level of the implied volatility smile and serves as an estimate of the ATMV:

$$ATMV = \gamma_0 = IV(0). \tag{C5}$$

Hence, by construction, *at-the-money* is defined as $d = 0$.[11]

C.2.3 *Butterfly Spreads*

The 25-Δ BF spread equals the difference between the arithmetic mean of a 25-Δ call and a 25-Δ put minus the ATMV:

$$BF25 = 0.5 \left[IV(d(25c)) + IV(d(25p))\right] - ATMV, \tag{C6}$$

where the numbers in parenthesis refer to the call and put option's z-value.

A BF spread is thereby constructed by buying an option with a strike price K_1 and an option with a higher strike price K_3 (that is $K_1 < K_3$). In parallel, two options with a strike price $K_2 = (K_1 + K_3)/2$ are sold to reduce the initial costs of this option trading strategy.[12]

For the long BF position, this strategy leads to profits on a gross basis whenever the realized volatility at expiry is lower than the implied volatility at inception,[13] and thus reflects market pricing of tail risks and dispersion. In other words, BF spreads capture asymmetries in the IV-moneyness function and reflect the implied excess kurtosis of the risk-neutral distribution (RND) of future exchange rate returns.

Thinking about how BF spreads behave in response to changes in implied volatility, recall that option vega peaks at-the-money and declines for deep in-the-money or out-of-the-money options. Referring to Equation C6, this structure implies that the high central vega at K_2 (the ATMV strike) is largely offset by the smaller vegas of the outer wings. As a result, the butterfly spread exhibits a low net vega – typically not zero, but generally quite muted (see Section C.3.2 for details).

With regards to the BOI's FXI activities, this implies: the larger the BOI's FX intervention volumes are – and provided these intervention activities are unexpected throughout the time to maturity of the BF spread – the more profitable BF spreads should be,[14] as interventions are expected to stabilize the targeted FX rate.[15]

C.2.4 *Risk Reversals*

The 25-Δ RR is defined as the difference in IVs between a 25-Δ call and a 25-Δ put option:[16]

$$RR25 = IV(d(25c)) - IV(d(25p)). \tag{C7}$$

The strategy involves a long out-of-the-money USD call (ILS put) and a short out-of-the-money USD put (ILS call), both with identical option deltas (in absolute terms) and maturity. These strikes are chosen such that the call strike K_2 exceeds the FX forward rate F_t, and the put strike K_1 lies below it; i.e., $K_1 < F_t < K_2$.

RRs thus capture asymmetries in the IV-moneyness function and reflect the implied skewness of the RND of future exchange rate returns. A positive RR indicates a tilt toward USD appreciation against the ILS, with market participants valuing protection against large upside USD moves more than downside risks.

Under the GK framework – the standard for FX option pricing – RRs are approximately vega-neutral (see Section C.3.2 for details), as the vegas of the constituent options nearly offset. Hence, RR values are primarily sensitive to changes in slope and skew, rather than to shifts in the overall level of IV.

When examining the effect of FX interventions by the BOI, we hypothesize that surprise spot purchases targeting ILS depreciation should increase RR values.[17] If interventions successfully shape second-moment expectations, the regression coefficient on FXI shocks in explaining RR changes should be positive.

C.3 Call and Put Options

C.3.1 Relation to the Three Standard Instruments

From the previous sections, we learn that FX call and put options can easily be derived from the three price quotes of the ATMV, RR and BF spread:

$$IV(d(25c)) \approx \text{ATMV} + \text{BF25} + \frac{1}{2} \cdot \text{RR25}.$$

Similarly, for the FX put option:

$$IV(d(25p)) \approx \text{ATMV} + \text{BF25} - \frac{1}{2} \cdot \text{RR25}.$$

C.3.2 Option Vega Under the Garman-Kohlhagen Pricing Formula

The sensitivity of an option's price to changes in implied volatility – known as option vega – is given by the GK pricing formula. For both European-style FX call and put options, vega is expressed as:

$$\text{Vega} = S_t \sqrt{\tau} \cdot \phi(d) \cdot e^{-r^f \tau}.$$

where $\phi(\cdot)$ represents the standard normal probability density function.

At-the-money options. Note that vega is symmetric across calls and puts (due to $\phi(\cdot)$) and reaches its maximum when the option is at-the-money (ATM), i.e., when $d = 0$, or $\phi(0) = \frac{1}{\sqrt{2\pi}} \approx 0.3989$. Consquently, $\text{Vega}_{\text{ATMV}} > 0$.

Call and put options. For a 25-Δ call option:

$$d(25c) = \Phi^{-1}\left(0.25 \cdot \exp\left(r^f \tau\right)\right).$$

For a 25-Δ put option:

$$d(25p) = -d(25c) = -\Phi^{-1}\left(0.25 \cdot \exp\left(r^f \tau\right)\right).$$

Note that due to the symmetry of $\phi(\cdot)$, the option vega of a 25-Δ call option and a 25-Δ put option are equal. Given the decomposition of call and put options into ATMV, RRs, and BF spreads, we see that

$$\text{Vega}_{\text{25-}\Delta\text{Call}} = S_t\sqrt{\tau}\cdot\phi(d(25c))\cdot e^{-r^f\tau} \approx \text{Vega}_{\text{ATMV}} + \text{Vega}_{\text{BF25}} + \frac{1}{2}\cdot\text{Vega}_{\text{RR25}}.$$

Similary for a 25-Δ put option

$$\text{Vega}_{\text{25-}\Delta\text{Put}} = S_t\sqrt{\tau}\cdot\phi(d(25p))\cdot e^{-r^f\tau} \approx \text{Vega}_{\text{ATMV}} + \text{Vega}_{\text{BF25}} - \frac{1}{2}\cdot\text{Vega}_{\text{RR25}}.$$

Risk reversals. Since $\text{Vega}_{\text{25-}\Delta\text{Call}} = \text{Vega}_{\text{25-}\Delta\text{Put}}$ under the GK pricing formula, we see that $\text{Vega}_{\text{RR25}} \stackrel{!}{=} 0$. Therefore, in theory, the risk reversal has zero vega, assuming:

- Symmetric strikes in delta-space,
- Identical maturities, and
- Constant volatility and interest rates

Butterfly spreads. For the BF spread, we see that

$$\text{Vega}_{BF} = 0.5\left[\text{Vega}_{\text{25-}\Delta\text{Call}} + \text{Vega}_{\text{25-}\Delta\text{Put}}\right] - \text{Vega}_{ATM} = \text{Vega}_{\text{25-}\Delta\text{Call}} - \text{Vega}_{ATM}.$$

Therefore,

$$\begin{aligned}
\text{Vega}_{BF} &= 0.5\left[\text{Vega}_{\text{25-}\Delta\text{Call}} + \text{Vega}_{\text{25-}\Delta\text{Put}}\right] - \text{Vega}_{ATM}, \\
&= \text{Vega}_{\text{25-}\Delta\text{Call}} - \text{Vega}_{ATM}, \\
&= S_t\sqrt{\tau}\cdot e^{-r^f\tau}\left[\phi(d25c) - \phi(0)\right], \\
&= S_t\frac{\sqrt{\tau}\cdot e^{-r^f\tau}}{\sqrt{2\pi}}\left[e^{-d25c^2/2} - 1\right].
\end{aligned}$$

Under realistic market conditions, Vega_{BF} will be negative and small (in absolute value).

C.3.3 *Implications for the BOI's FXI Regime*

In our paper, Figure 3 shows that BOI interventions are associated with a reduction in at-the-money implied volatilities at the onset of unexpected FXIs. Building on the preceding discussion, we expect subsequent FXIs to reduce the price of at-the-money options (as $\text{Vega}_{\text{ATMV}} > 0$), leave risk reversals unaffected (as $\text{Vega}_{\text{RR}} \approx 0$), and increase butterfly spreads (as $\text{Vega}_{\text{BF}} < 0$) for typical market interest rates and standard maturities).

D DAILY CROSS-CORRELATION BETWEEN THE MAIN VARIABLES AND THE OPTIONS DATA

Table D1 reports the daily cross-correlations between the main variables used in our empirical analysis and the price quotes of the option trading strategies (Tables D2–D4). As shown, the cross-sectional correlations among the main variables are generally weak, underscoring their statistical independence.

TABLE D1
CROSS-CORRELATION BETWEEN THE MAIN VARIABLES

	ΔUSD/ILS	ΔEUR/USD	ΔNEER	ΔForward$_{3m}$	Foreign flows - total	Local flows - real sector	Local flows - financial sector	Local flows - inst. investors	Δ5-year Israeli CDS	ΔLIBOR	ΔTELBOR
Spot and forward exchange rates:											
ΔUSD/ILS	1										
ΔEUR/USD	-0.50	1									
ΔNEER	0.79	0.05	1								
ΔForward$_{3m}$	0.89	-0.42	0.74	1							
Flows:											
Foreign flows - total	0.13	-0.07	0.10	0.15	1						
Local flows - real sector	-0.18	-0.01	-0.19	-0.22	-0.55	1					
Local flows - financial sector	-0.04	0.06	-0.03	-0.04	-0.16	-0.09	1				
Local flows - inst. investors	0.23	-0.01	0.23	0.23	-0.28	-0.22	0.04	1			
Misc:											
Δ CDS	0.05	-0.01	0.03	0.09	0.04	-0.07	0.05	0.05	1		
ΔLIBOR	-0.05	-0.03	-0.08	-0.05	-0.01	0.09	-0.03	-0.13	-0.02	1	
ΔTELBOR	-0.04	0.01	-0.04	-0.05	-0.07	0.03	-0.04	0.03	-0.02	0.04	1

Notes: This table presents cross-correlations among selected variables. For variable definitions, refer to Appendix B of this online appendix. The sample period is January 1, 2013 to January 31, 2020.

Table D4 reports cross-correlations among the at-the-money volatility measures ("ATMV") across six maturities, ranging from one week ("1w") to twelve months ("12m"). The table also includes correlations between these price quotes and the log return of the USD/ILS spot exchange rate ("Δ USD/ILS").

TABLE D2
CROSS-CORRELATION BETWEEN THE USD/ILS AT-THE-MONEY IMPLIED VOLATILITIES AND THE USD/ILS SPOT RATE

	ATMV1w	ATMV1m	ATMV3m	ATMV6m	ATMV9m	ATMV12m	ΔUSD/ILS
ATMV1w	1						
ATMV1m	0.952	1					
ATMV3m	0.920	**0.984**	1				
ATMV106m	0.885	0.957	**0.989**	1			
ATMV109m	0.861	0.933	**0.975**	**0.996**	1		
ATMV1012m	0.835	0.910	0.958	**0.988**	**0.997**	1	
Spot exchange rate:							
ΔUSD/ILS	0.040	0.030	0.015	0.004	0.000	0.000	1

Notes: This table displays cross-correlations between daily USD/ILS at-the-money implied volatilities (quoted in percent) for six maturities ranging from one week ("1w") to twelve months ("12m"). The final row reports the correlation between these price quotes and the log return of the USD/ILS spot exchange rate ("$\Delta USD/ILS$"). Cross-correlations greater than or equal to 0.975 appear in bold. The data span January 1, 2013 to January 31, 2020. Source: Bloomberg.

Table D3 reports cross-correlations between the price quotes of the 10-Δ and 25-Δ butterfly spreads (“BF10” and “BF25”) across six maturities, ranging from one week (“1w”) to twelve months (“12m”). The final row displays the correlation between these price quotes and the log return of the USD/ILS spot exchange rate (“Δ USD/ILS”).

TABLE D3
CROSS-CORRELATION BETWEEN THE USD/ILS BUTTERFLY SPREADS AND THE USD/ILS SPOT RATE

	BF101w	BF101m	BF103m	BF106m	BF109m	BF1012m	BF251w	BF251m	BF253m	BF256m	BF259m	BF2512m	ΔUSD/ILS
10-Δ:													
BF101w	1												
BF101m	0.402	1											
BF103m	0.400	0.925	1										
BF106m	0.421	0.893	**0.984**	1									
BF109m	0.371	0.891	**0.977**	**0.984**	1								
BF1012m	0.393	0.862	0.959	**0.984**	**0.983**	1							
25-Δ:													
BF251w	0.734	-0.025	-0.056	-0.058	-0.075	-0.074	1						
BF251m	0.326	0.914	0.898	0.872	0.884	0.850	-0.064	1					
BF253m	0.318	0.882	0.953	0.938	0.950	0.926	-0.095	0.946	1				
BF256m	0.352	0.859	0.944	0.961	0.965	0.961	-0.095	0.915	**0.977**	1			
BF259m	0.331	0.850	0.933	0.948	0.969	0.962	-0.096	0.906	0.969	**0.991**	1		
BF2512m	0.352	0.815	0.908	0.937	0.951	0.967	-0.107	0.868	0.938	**0.978**	**0.983**	1	
Spot exchange rate:													
Δ USD/ILS	0.087	0.049	0.036	0.036	0.025	0.024	0.071	0.024	0.017	0.016	0.015	0.005	1

Notes: This table presents cross-correlations between daily USD/ILS butterfly spread price quotes (expressed in percent) across six maturities ranging from one week (“1w”) to twelve months (“12m”). Two option delta specifications are included: ±10% (“BF10”) and ±25% (“BF25”). The final row reports the correlation between these price quotes and the log change in the USD/ILS spot exchange rate (“$\Delta USD/ILS$”). Cross-correlations greater than or equal to 0.975 appear in bold. The sample period spans January 1, 2013 to January 31, 2020. Source: Bloomberg.

Finally, Table D2 reports cross-correlations between price quotes of the 10-Δ and 25-Δ risk reversals ("RR10" and "RR25") across six maturities, ranging from one week ("1w") to twelve months ("12m"). The final row presents the correlation between these price quotes and the log return of the USD/ILS spot exchange rate ("Δ USD/ILS").

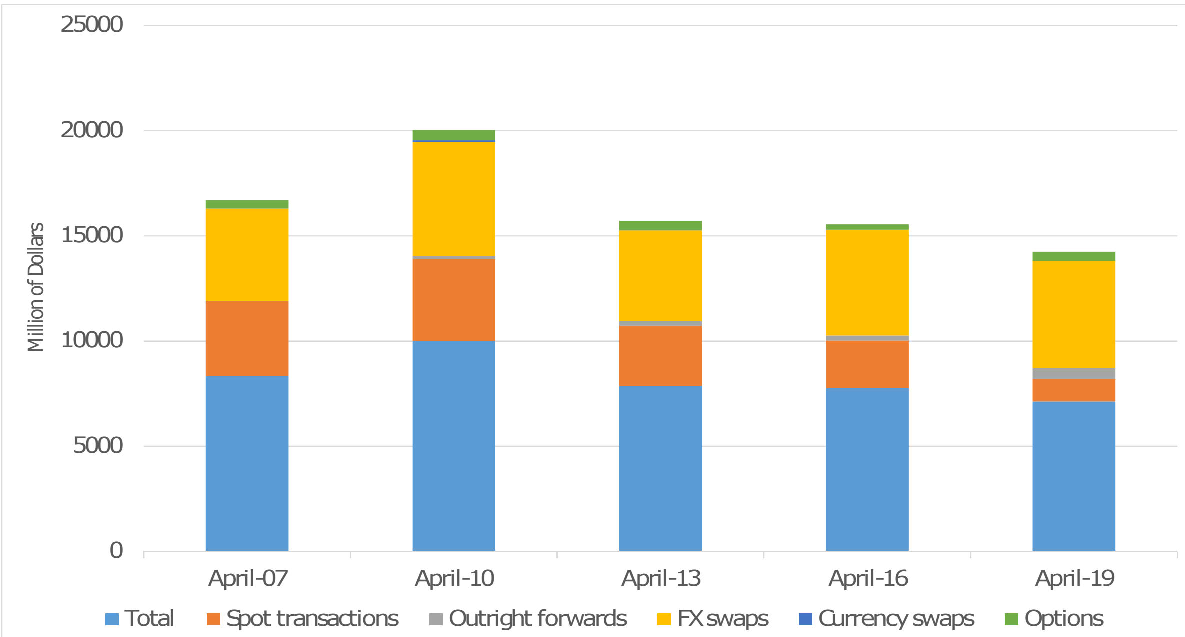
TABLE D4
CROSS-CORRELATION BETWEEN THE USD/ILS RISK REVERSALS AND THE USD/ILS SPOT RATE

	RR101w	RR101m	RR103m	RR106m	RR109m	RR1012m	RR251w	RR251m	RR253m	RR256m	RR259m	RR2512m	ΔUSD/ILS
10-Δ:													
RR101w	1												
RR101m	0.818	1											
RR103m	0.720	0.970	1										
RR106m	0.658	0.931	**0.987**	1									
RR109m	0.621	0.908	**0.975**	**0.996**		1							
RR1012m	0.599	0.886	0.961	**0.990**	**0.994**	1							
25-Δ:													
RR251w	0.916	0.929	0.870	0.825	0.797	0.780	1						
RR251m	0.811	**0.998**	0.972	0.935	0.912	0.890	0.927	1					
RR253m	0.716	0.967	**0.999**	**0.987**	**0.975**	0.960	0.867	0.971	1				
RR256m	0.658	0.930	**0.987**	**0.999**	**0.995**	**0.990**	0.824	0.934	**0.988**	1			
RR259m	0.628	0.910	**0.976**	**0.996**	**0.999**	**0.995**	0.802	0.915	**0.977**	**0.997**	1		
RR2512m	0.600	0.886	0.960	**0.989**	**0.992**	**0.999**	0.780	0.892	0.963	**0.990**	**0.995**	1	
Spot exchange rate:													
ΔUSD/ILS	0.096	0.056	0.043	0.033	0.028	0.026	0.089	0.057	0.044	0.034	0.030	0.026	1

Notes: This table presents cross-correlations between daily USD/ILS risk reversal price quotes (expressed in percent) across six maturities ranging from one week ("1w") to twelve months ("12m"), and for two option delta specifications: ±10% ("RR10") and ±25% ("RR25"). The final row reports the correlation between these price quotes and the log return of the USD/ILS spot exchange rate ("$\Delta USD/ILS$"). Cross-correlations greater than or equal to 0.975 are shown in bold. The sample period spans January 1, 2013 to January 31, 2020. Source: Bloomberg.

E FOREIGN EXCHANGE TRANSACTION VOLUMES AND RELATIVE BID-ASK SPREADS FOR THE THREE OPTION STRATEGIES

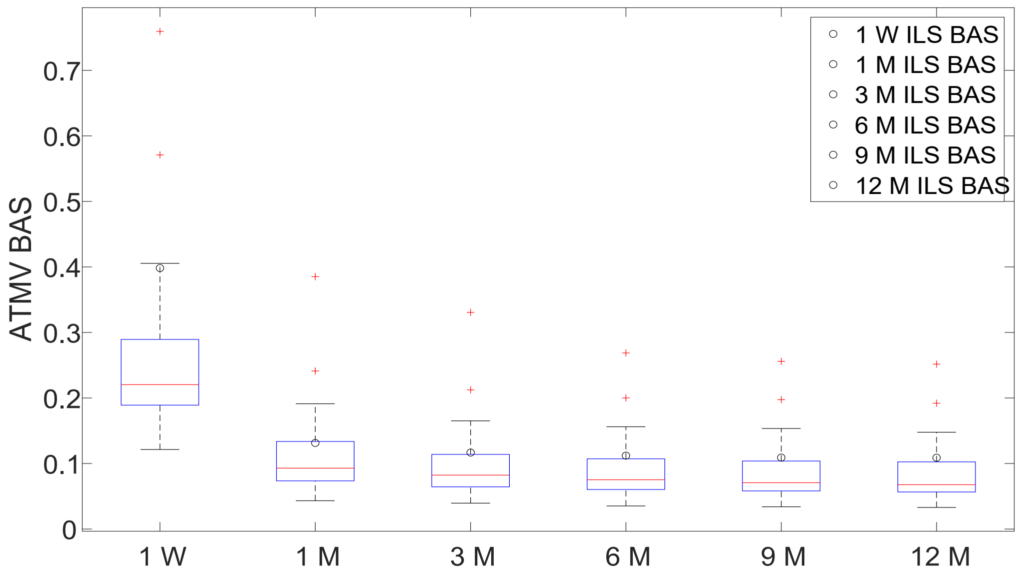
FIGURE E1
DAILY FOREIGN EXCHANGE TRANSACTION VOLUME



Notes: This figure illustrates the daily average volume of over-the-counter foreign exchange (FX) transactions involving the Israeli shekel (ILS) in April of each survey year. The transaction categories include spot, forward, FX swap, currency swap, and option markets. Data are sourced from the BIS Triennial Central Bank Survey, conducted every three years. Source: https://www.bis.org/statistics/rpfx19.htm.

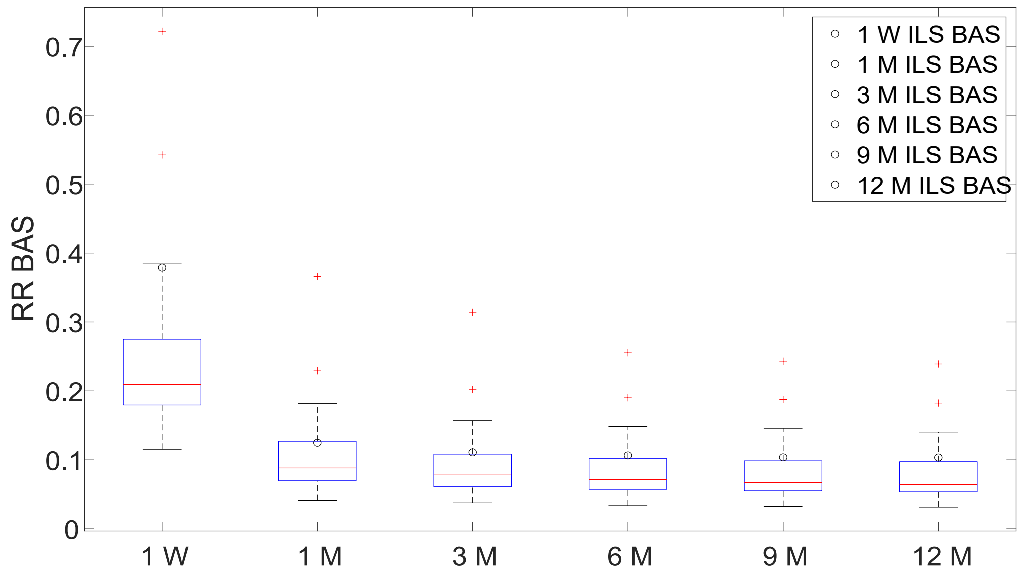
We also present box plots of the relative bid-ask spread (BAS) for the three option strategies examined in the paper, across 28 currency pairs and six maturities ranging from one week ("1W") to twelve months ("12M"). The currency pairs are retrieved from Bloomberg and are listed below: Australian dollar (AUD)/USD, euro (EUR)/Czech koruna (CZK), EUR/pound sterling (GBP), EUR/Japanese yen (JPY), EUR/Norwegian kroner (NOK), EUR/Swedish krona (SEK), EUR/USD, GBP/Swiss franc (CHF), GBP/JPY, GBP/USD, USD/Canadian dollar (CAD), USD/Chilean peso (CLP), USD/Colombian peso (COP), USD/CZK, USD/Danish krone (DDK), USD/Hungarian forint (HUF), USD/Icelandic krona (ISK), USD/ILS, USD/JPY, USD/Mexican peso (MXN), USD/New Zealand dollar (NZD), USD/NOK, USD/Polish zloty (PLN), USD/SEK, USD/South-Korean won (KRW), USD/CHF, USD/Turkish lira (TRY).

FIGURE E2
RELATIVE BID-ASK SPREAD FOR ATMV OPTIONS ACROSS SIX MATURITIES



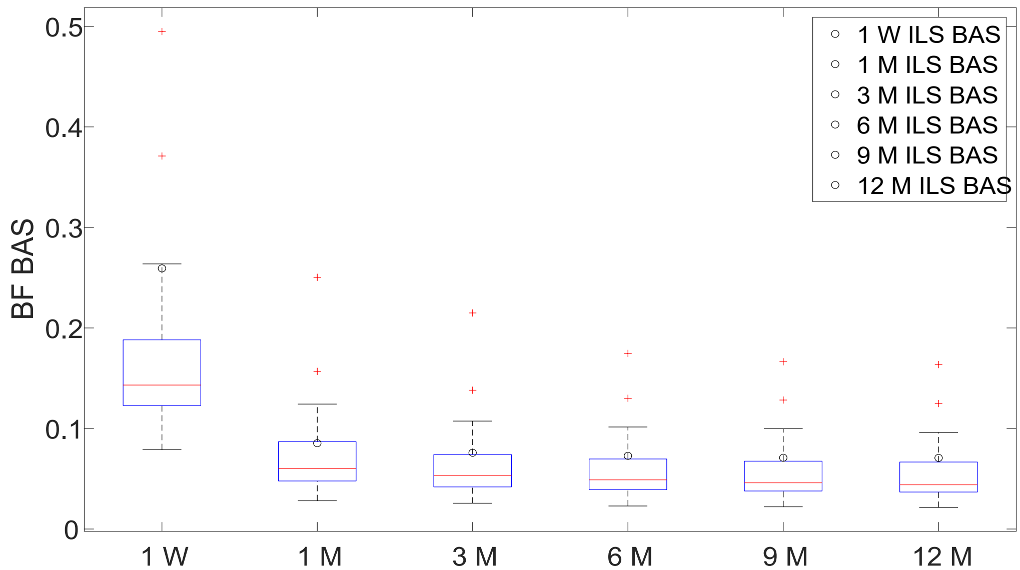
Notes: This figure presents box plots of the quoted bid-ask spreads (BAS) for at-the-money implied volatility (ATMV) options, expressed as a percentage of the corresponding mid-quote, across 28 currency pairs and six maturities ranging from one week ("1W") to twelve months ("12M"). Dots indicate the average relative BAS for USD/ILS ATMV contracts. The sample period spans January 1, 2013 to December 31, 2020. Source: Bloomberg.

FIGURE E3
RELATIVE BID-ASK SPREAD FOR THE RISK REVERSALS ACROSS SIX MATURITIES



Notes: This figure presents box plots of the quoted bid-ask spreads (BAS) for risk reversal (RR) contracts, expressed as a percentage of the corresponding mid-quote, across 28 currency pairs and six maturities ranging from one week ("1W") to twelve months ("12M"). Dots indicate the average relative BAS for USD/ILS RR contracts. The sample period spans January 1, 2013 to December 31, 2020. Source: Bloomberg.

FIGURE E4
RELATIVE BID-ASK SPREAD FOR THE BUTTERFLY SPREADS ACROSS SIX MATURITIES



Notes: This figure presents box plots of the quoted bid-ask spreads (BAS) for butterfly spread (BF) contracts, expressed as a percentage of the corresponding mid-quote, across 28 currency pairs and six maturities ranging from one week ("1W") to twelve months ("12M"). Dots indicate the average relative BAS for USD/ILS BF contracts. The sample period spans January 1, 2013 to December 31, 2020. Source: Bloomberg.

F SPECIFICATION ANALYSIS OF FIRST-STAGE REGRESSION

We experimented with several additional instruments to refine our baseline specification. These included the deviation of the USD/ILS spot rate from an implicit target level,[18] under the assumption that the BOI intervenes when the ILS appears misaligned relative to its historical average. We also tested deviations from several different historical averages for the one-month ATMV and 25-Δ RR as FXI triggers (Galati, Melick, and Micu, 2005). None of these variables yielded statistically significant results in the first-stage regression and were excluded for parsimony. We further tested alternative controls, including changes in the five-year Israeli CDS spread – following Nedeljkovic and Saborowski (2019) – but found no improvement in model fit or CU-GMM performance.

The final first-stage regression results are shown in Table F1. Most coefficients exhibit the expected signs. We also find that a one percentage point appreciation of the ILS vis-à-vis a basket of currencies ("Δ NEER" > 0) prior to the start of an FXI spell is associated with an USD 16 million increase in FXI volume, consistent with a "leaning against the wind" FXI strategy. Likewise, an FXI of USD 1bn on day $t-1$ predicts and an increase in the FXI volume of USD 167m on day t.

Because all the instruments of this specification are used as instruments in our CU-GMM regression, we report the Montiel Olea and Pflueger (2013) statistic to assess instrument strength. The test statistic exceeds the critical threshold, allowing us to reject the null of weak identification and proceed confidently with the CU-GMM estimator. This result is important, as weak instruments may otherwise lead to poorly-defined finite sample moments (see Hahn, Hausman, and Kuersteiner (2004) and Donald and Newey (2000)).

To assess the robustness of our benchmark specification, we estimate multiple

TABLE F1
FIRST-STAGE REGRESSION

Controls	Dependent variable: FXI_t (in USD billion)
Intercept	0.014***
	(7.15)
$\Delta EUR/USD_{t-1,t}$	0.012***
	(2.83)
$\Delta VIX_{t-5,t}$	0.00027
	(0.52)
$IL\_Monetary\_Surprise_t$	0.089
	(0.69)
$IL\_CPI\_Surprise_t$	0.006
	(0.24)
$NS\_FFR\_Surprise_t$	−0.285
	(−0.77)
$NS\_Policy\_Surprise_t$	0.475
	(1.18)
$CITI\_Surprise\_Index_t$	0.067
	(1.23)
Instruments	
FXI_{t-1}	0.174***
	(3.97)
$\mathbb{1}_{\{FXI_{t-6,t-1}>0\}}$	0.008**
	(1.97)
$\Delta NEER_{t-3,t-1}$	−0.016***
	(−3.76)
$\Delta NEER_{t-13,t-3}$	−0.006***
	(−3.63)
Adjusted R^2	6.2
Effective F Statistic	15.99
Critical Value	15.65

Notes: The dependent variable is the daily foreign exchange intervention volume ("FXI_t"), measured in USD billions, sourced from the Bank of Israel for the period January 1, 2013 to December 31, 2019. Summary statistics for the explanatory variables are provided in Table 3 in the paper. The VIX is expressed in percent. Detailed information on the other controls and instruments are available in Online Appendix B. To assess instrument strength in the GMM estimation, the Montiel Olea and Pflueger (2013) test statistic is reported using the Newey-West variance estimator, along with the corresponding critical value under a bias tolerance of 0.10. The t-statistics (in parentheses below the coefficients) are Newey-West HAC corrected. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

variants of our first-stage regression in Table F2. Specification [1] confirms the significance of the one-day lagged FXI volume, while the coefficients for the two-day lagged FXI volume and the weekly FXI dummy – equal to one if the BOI intervened in the previous week – are statistically insiginficant. In specification [2], we introduce the log return of the USD/ILS spot rate across different horizons and lag structures, as well as the deviation from its one-year moving average $\Delta MA(USD/ILS)_{t-1}$ as a proxy for the unobserved fundamental value. The deviation variable lacks explanatory power,

TABLE F2
FIRST-STAGE REGRESSION SPECIFICATION ANALYSIS

	[1]	[2]	[3]	[4]	[5]
Controls					
Intercept	0.016***	−0.006	−0.005	0.013***	0.013***
	(7.43)	(−0.23)	(−0.22)	(6.65)	(6.81)
ΔEUR/USD$_{t-1,t}$	0.012***	0.012***	0.012***	0.012***	0.012***
	(2.72)	(2.88)	(2.86)	(2.81)	(2.81)
ΔVIX$_{t-5,t}$	−0.00001	0.00024	0.00027	−0.00001	0.00021
	(−0.02)	(0.47)	(0.51)	(−0.02)	(0.40)
IL_Monetary_Surprise$_t$	0.075	0.086	0.086	0.089	0.095
	(0.57)	(0.64)	(0.66)	(0.71)	(0.75)
IL_CPI_Surprise$_t$	0.012	−0.005	−0.002	0.009	0.004
	(0.53)	(−0.21)	(−0.08)	(0.39)	(0.17)
NS_FFR_Surprise$_t$	−0.396	−0.311	−0.293	−0.331	−0.317
	(−1.07)	(−0.86)	(−0.80)	(−0.89)	(−0.86)
NS_Policy_Surprise$_t$	0.526	0.442	0.447	0.490	0.497
	(1.30)	(1.14)	(1.14)	(1.21)	(1.24)
CITI_Surprise_Index$_t$	0.058	0.088	0.087	0.078	0.077
	(1.04)	(1.62)	(1.59)	(1.46)	(1.41)
Instruments					
FXI$_{t-1}$	0.18***	0.17***	0.17***	0.17***	0.17***
	(4.17)	(3.97)	(3.89)	(3.95)	(3.95)
FXI$_{t-2}$	0.02				
	0.40				
$\mathbb{1}_{\{FXI_{t-6,t-1}>0\}}$	0.01	0.01	0.01*	0.01*	0.01*
	(1.53)	(1.41)	(1.66)	(1.85)	(1.93)
ΔUSD/ILS$_{t-3,t-1}$		−0.01***	−0.01		
		(−2.56)	(−1.19)		
ΔUSD/ILS$_{t-13,t-3}$		−0.0042***	−0.0003		
		(−2.48)	(−0.09)		
ΔUSD/ILS$_{t-61,t-1}$		−0.0013**	−0.0016		
		(−2.20)	(−1.47)		
ΔMA(USD/ILS)$_{t-1}$		0.01	−0.01		
		(0.90)	(−0.84)		
ΔNEER$_{t-3,t-1}$			−0.01	−0.02***	−0.02***
			(−0.85)	(−3.66)	(−3.64)
ΔNEER$_{t-13,t-3}$			−0.01	−0.01***	−0.01***
			(−1.61)	(−2.90)	(−2.98)
ΔNEER$_{t-61,t-1}$			0.0002	−0.0017***	−0.0016***
			(0.15)	(−2.57)	(−2.42)
ΔCDS$_{t-21,t-1}$				−0.0004**	
				(−1.99)	
ΔVIX$_{t-11,t-1}$				0.0005	
				(1.12)	
Adjusted R^2	4.32	6.43	6.49	6.36	6.27
Effective F Statistic	13.43	13.19	10.32	12.48	14.69
Critical Value	15.02	16.51	16.86	17.44	17.37

Notes: The dependent variable is the size of foreign exchange interventions ("FXI_t"), measured in USD billions and available daily from January 1, 2013 to December 31, 2019. To assess instrument strength in the GMM estimation, we report the Montiel Olea and Pflueger (2013) test statistic based on the Newey-West variance estimator, alongside its critical value under a bias tolerance of 0.10. Summary statistics for all explanatory variables are reported in Table 3 in the paper. The t-statistics (in parentheses below the coefficients) are Newey-West HAC corrected. *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively.

whereas the log return series consistently show significance. The negative sign aligns with the observation in Section 3.1.1 in the paper whereby the BOI intervenes more aggressively (in the sense of buying more USDs) during periods of stronger preceding currency appreciation. Specification [3], which jointly includes lagged NEER and USD/ILS spot rate movements, produces weak instruments and is thus excluded. Specification [4] replaces the USD/ILS spot rate with changes in the five-year Israeli CDS spread and the VIX. While only the CDS variable is statistically significant, its economic effect is negligible. Specification [5] reaffirms the relevance of lagged NEER movements. Given the NEER's role as a measure of international competitiveness, this implies that the BOI's reaction function may incorporate factors aligned with its objective of preserving competitiveness though FXIs (Cukierman, 2019). In addition, the United States is by far Israel's largest export destination (Al Jazeera Staff, 2025), accumulating USDs instead of other currencies via these interventions is a natural policy choice.

Overall, specifications [2]-[5] support characterizing the BOI's FXI activities as "leaning against the wind" – countering short-term shekel appreciation pressures to support the Israeli economy.

To conclude, the sensitivity analysis in this section reveals that the estimated coefficients are qualitatively and quantitatively consistent across alternative specifications. This lends confidence to the robustness of our first-stage regression. While the adjusted coefficient of determination $\bar{R}^2$ is lower than in prior studies estimating similar reaction functions (i.e., first-stage regressions in the GMM framework) – e.g., Galati et al. (2005), Disyatat and Galati (2007), Galati, Higgins, Humpage, and Melick (2007), and Ito and Yabu (2007) – we do not consider this a major concern. Our primary objective is not to maximize explanatory power, but to mitigate simultaneity bias in the second-stage estimation. Accordingly, the relatively modest $\bar{R}^2$ is acceptable given the consistent performance of the selected instruments.

G ECONOMETRIC ASSESSMENT OF THE LONGER-TERM EFFECT OF FOREIGN EXCHANGE INTERVENTIONS

While the literature predominantly finds that FX interventions exert only short-lived effects on spot exchange rates – see Galati et al. (2005) and the survey in Villamizar-Villegas and Perez-Reyna (2017) – Menkhoff, Rieth, and Stöhr (2021) document a statistically significant impact of the BOJ's USD transactions (including both USD purchases and sales) on the USD/JPY spot rate for 250 trading day. They trace this longer-term effect to the high persistence of FXI volumes. Importantly, they emphasize that prior empirical studies that found only short-lived effects lacked either methodological rigor or used only coarse and imprecise proxies for the undisclosed FXI data. They also consider the fact that previous studies treated actual FXI volumes as the true FXI shock – which potentially leads to attenuation bias – as a possible explanation for the often reported short-lived effects.

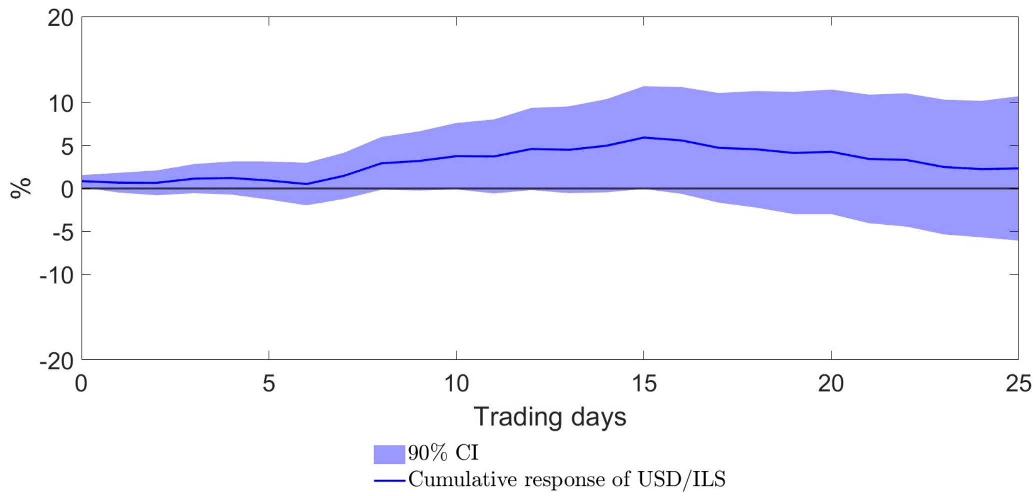
To assess whether the BOI's FXIs aligns with the latter study or the previous studies, we now examine the longer-term effects of the BOI's FXI regime using fitted FXI volumes and employing the local projection-instrumental variable (LP-IV) approach (Ramey and Zubairy, 2018), an approach that is robust to the shortcomings in many other previous studies. Specifically, we regress horizon-specific log returns from $t-1$ to $t+h$ on the size of USD purchases on day t (FXI_t), where h denotes the forecast horizon. Panel (a) evaluates the USD/ILS spot rate, Panel (b) the nominal effective exchange rate (NEER), and Panel (c) the three-month cross-currency basis (CCB). For the spot rate and NEER, h ranges from 0 to 25 trading days; for the CCB, we extend the horizon up to 100 trading days.

All regressions include the control variables specified in Table F1, adjusted to reflect the relevant forecast horizon. The instrument set corresponds to that used in Appendix Table F1. Figure G1 presents the estimates for the standard LP-IV approach. As robustness checks, we explore alternative estimation procedures, including bias corrections for the coefficients and standard errors proposed by Hjalmarsson (2011) and Boudoukh, Israel, and Richardson (2021), and find that our results remain consistent across specifications.

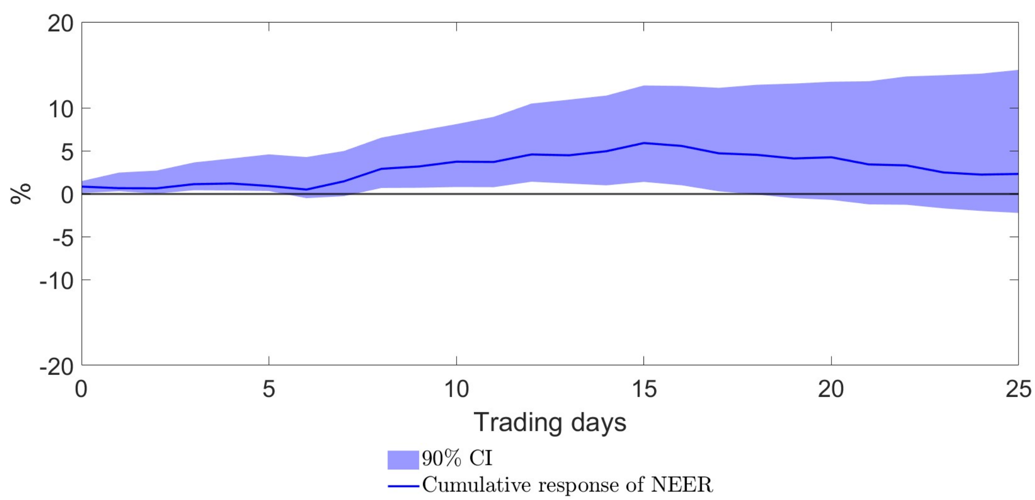
The point estimates suggest that the strong contemporaneous effect of FXI on the

FIGURE G1
LONGER-TERM EFFECT OF A USD 1 BILLION FX INTERVENTION SHOCK

(a) CUMULATIVE RETURNS OF THE USD/ILS SPOT RATE



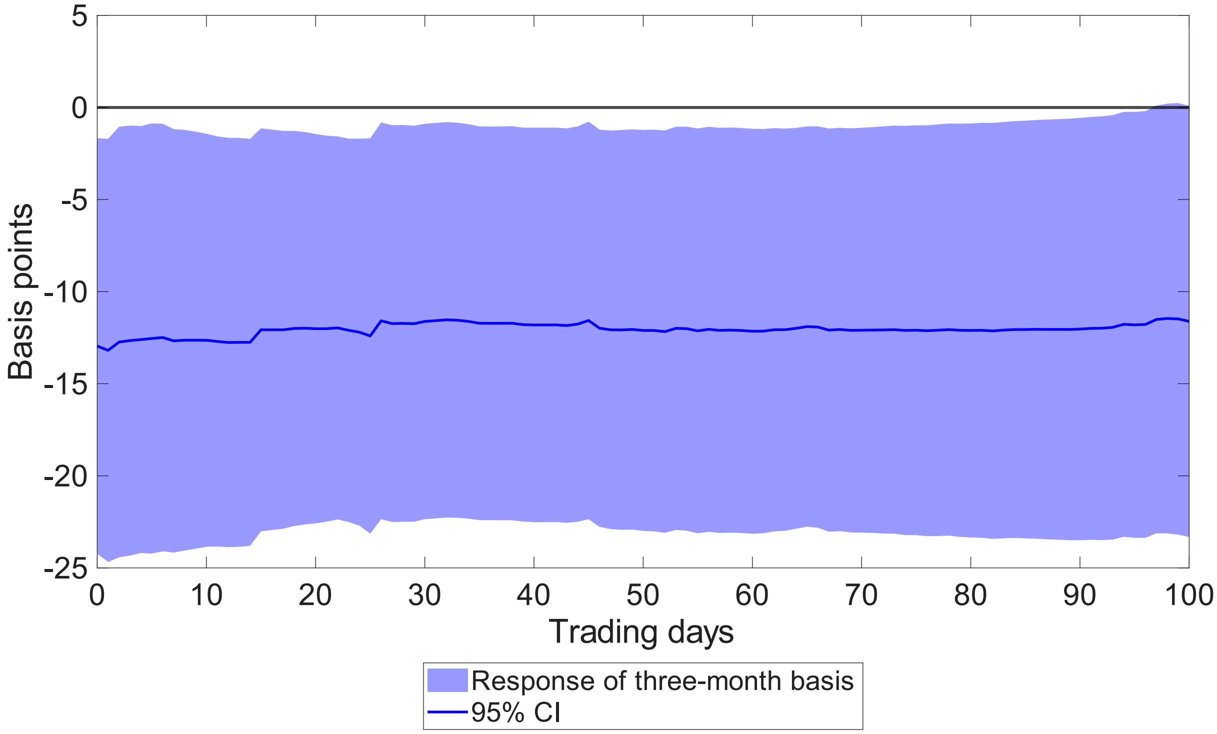
(b) CUMULATIVE RETURNS OF THE NEER



foreign value of the ILS is not reversed over the subsequent 25 trading days (Panels (a) and (b)). Statistically significant results are observed only for the NEER, and only within the first 17 trading days. Given that the NEER includes several infrequently traded currencies, this pattern supports the hypothesis that the USD/ILS spot market is informationally more efficient relative to the broader currency basket.

The findings for the CCB (Panel (c)) are particularly notable: cumulative returns re-

(c) CUMULATIVE RETURNS OF THE 3-MONTH USD/ILS CROSS-CURRENCY BASIS



Notes: The figure presents the estimated cumulative impact of an unexpected $ 1 billion purchase via foreign exchange intervention (FXI) on the log returns of the USD/ILS spot rate (Panel (a); in percent) and the NEER (Panel (b); in percent), for trading days $0, 1, \ldots, 25$. Panel (c) depicts the response of the three-month USD/ILS cross-currency basis (in bps) for trading days $0, 1, \ldots, 100$. Day 0 corresponds to the first trading date on which FXIs (i.e., USD purchases) were initiated within each FXI spell. In Panels (a) and (b), the solid lines show the cumulative response, while the shaded areas display the 90% confidence intervals. For Panel (c), the solid line displays the cross-currency basis response, and the shaded region indicates the 95% confidence interval. Estimates are generated using the local projection instrumental variable (LP-IV) methodology (see, e.g., Ramey and Zubairy (2018)) with HAC standard errors.

main significantly negative for up to 90 trading days following BOI interventions. This sustained widening of the basis implies that FXI activity by the BOI contributes to persistent deviations from covered interest rate parity, consistent with the predictions of the models in Amador, Bianchi, Bocola, and Perri (2020) and Fanelli and Straub (2021). Notably, Andrew Abir, Deputy Governor of the BOI, suggested in his 2020 analysis that the bank's FX interventions may have exacerbated the deterioration in the CCB (Abir, 2020); an observation that aligns with our empirical results.

H VERBAL INTERVENTIONS

To examine whether our empirical findings are primarily driven by "verbal" rather than actual FX interventions, as posited in our paper, we manually collect Bloomberg news articles in which a senior BOI official – namely the governor or deputy governor – explicitly mentions FXIs. We identify twelve such articles, with corresponding publication dates reported in Table H1. In untabulated results, we find that these publication days are associated with elevated USD/ILS spot market volatility, indicating that verbal interventions convey information deemed relevant by FX market participants.

TABLE H1
VERBAL INTERVENTIONS BY THE BOI

Date	Verbal intervention
4/8/2013	Bank of Israel confirms intervention in forex market Monday
5/13/2013	Bank of Israel unexpectedy cut rates and reveals shekel plan
3/24/2014	HSBC says central bank may impose shekel floor
3/1/2017	BOI says forex intervention still on table
3/2/2017	BOI says reserves can exceed $100b limit
7/6/2017	Israeli govt' to put aside $1.5b for fx intervention
9/29/2017	BOI's Flug: FX intervention in small banks' version of QE
1/31/2018	Bank of Israel official urges patience on shekel strength
12/25/2018	Yaron doesn't rule out intervention in forex market
4/18/2019	Israeli central bank might resume intervening in the forex
11/26/2019	Bank of Israel holds base rate at 0.25%, intervenes in forex market
11/30/2019	Bank of Israel prefers Forex buys to interest cuts for now, says official

Notes: Data are manually collected from Bloomberg's news terminal. The sample spans the period from January 1, 2013 to December 31, 2019.

We next examine whether our contemporaneous FXI results in Table 4 in the paper are driven by interventions rather than actual trading activity. To do so, we re-estimate the benchmark specification excluding all dates on which BOI officials made public FXI-related statements (see Table H1). As incorporating a verbal intervention dummy may introduce endogeneity bias, we do not pursue that specification. The results, reported in Table H2, indicate that FXIs remain highly effective even in the absence of concurrent verbal signaling. Effect sizes are quantitatively similar to those obtained for the full sample, underscoring that the identified FXI response is not merely a function of central bank communication.

TABLE H2
CONTEMPORANEOUS RELATIONSHIP BETWEEN THE EXCHANGE RATE AND FOREIGN EXCHANGE INTERVENTIONS ON NON-VERBAL INTERVENTION DAYS

Dependent variable: $\Delta \ln(\text{USD/ILS}_t)$ (in %)			
	[1]: OLS	[2]: CU-GMM	[3]: 2SLS
Intercept	−0.02***	−0.03**	−0.03**
	(−2.81)	(−2.27)	(−2.26)
FXI_t	0.54***	0.93**	0.91**
	(4.67)	(2.03)	(1.97)
$\Delta\text{EUR/USD}_{t-1,t}$	−0.41	−0.41	−0.41
	(−22.98)	(−21.16)	(−21.10)
$\Delta\text{VIX}_{t-5,t}$	0.011***	0.01***	0.01***
	(4.32)	(4.28)	(4.24)
IL_Monetary_Surprise$_t$	−3.35***	−3.45***	−3.42***
	(−4.70)	(−4.83)	(−4.75)
IL_CPI_Surprise$_t$	−0.53**	−0.54**	−0.54**
	(−2.00)	(−2.04)	(−2.03)
NS_FFR_Surprise$_t$	−5.95*	−5.80	−5.79
	(−1.73)	(−1.68)	(−1.67)
NS_Policy_Surprise$_t$	1.55	1.35	1.35
	(0.90)	(0.78)	(0.77)
CITI_Surprise_Index$_t$	−0.00006	−0.00010	−0.00009
	(−0.25)	(−0.42)	(−0.35)
Hansen J-statistic		0.23	
Hansen J-statistic p-value		0.97	

Notes: The dependent variable is the daily log return (in percent) of the USD/ILS spot rate (Panel A) and the nominal effective exchange rate ("NEER"; Panel B). Regressors include an intercept, the size of foreign exchange interventions ("FXI_t"; in USD billions), the daily log return of the EUR/USD spot rate ("$\text{EUR/USD}_{t-1,t}$"; in percent), the one-week change in the VIX ("$\Delta\text{VIX}_{t-5,t}$"; in percentage points), and five news indicators (variables ending with "Surprise$_t$"). Specification [1] employs standard OLS, [2] applies the continuously updated GMM estimator (CU-GMM), and [3] reports two-stage least squares (2SLS) estimates. For details on the CU-GMM instrument set, see Table F1. The Hansen J-test statistic evaluates the validity of the over-identifying restrictions in the GMM. The t-statistics (in parentheses) are Newey-West HAC corrected. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. The sample spans the period from January 1, 2013, to December 31, 2019, excluding the days of verbal intervention reported in Table H1.

I FXIS AND THE CROSS-CURRENCY BASIS: ACCOUNTING FOR TRANSACTION COSTS, MARKET CONVENTIONS, MARGINAL FUNDING COSTS, AND RISK-FREE INVESTMENT RATES

As emphasized by Rime, Schrimpf, and Syrstad (2022), CIP arbitrage opportunities may disappear once transaction costs – such as bid-ask spreads in spot, forward, or FX markets – and appropriate funding and investment rates are properly accounted for. To assess CIP deviations more realistically, we therefore incorporate these factors in our analysis.

To model the arbitrageur's funding costs, we use commercial paper (CP) rates issued by U.S. banks, which capture marginal short-term funding costs. For the investment leg, we use the yields of risk-free, short-term Israeli zero-coupon government securities (Makam yields). Since the Makam data are published with irregular, time-varying maturities, we interpolate the actual data using a cubic spline.[19]

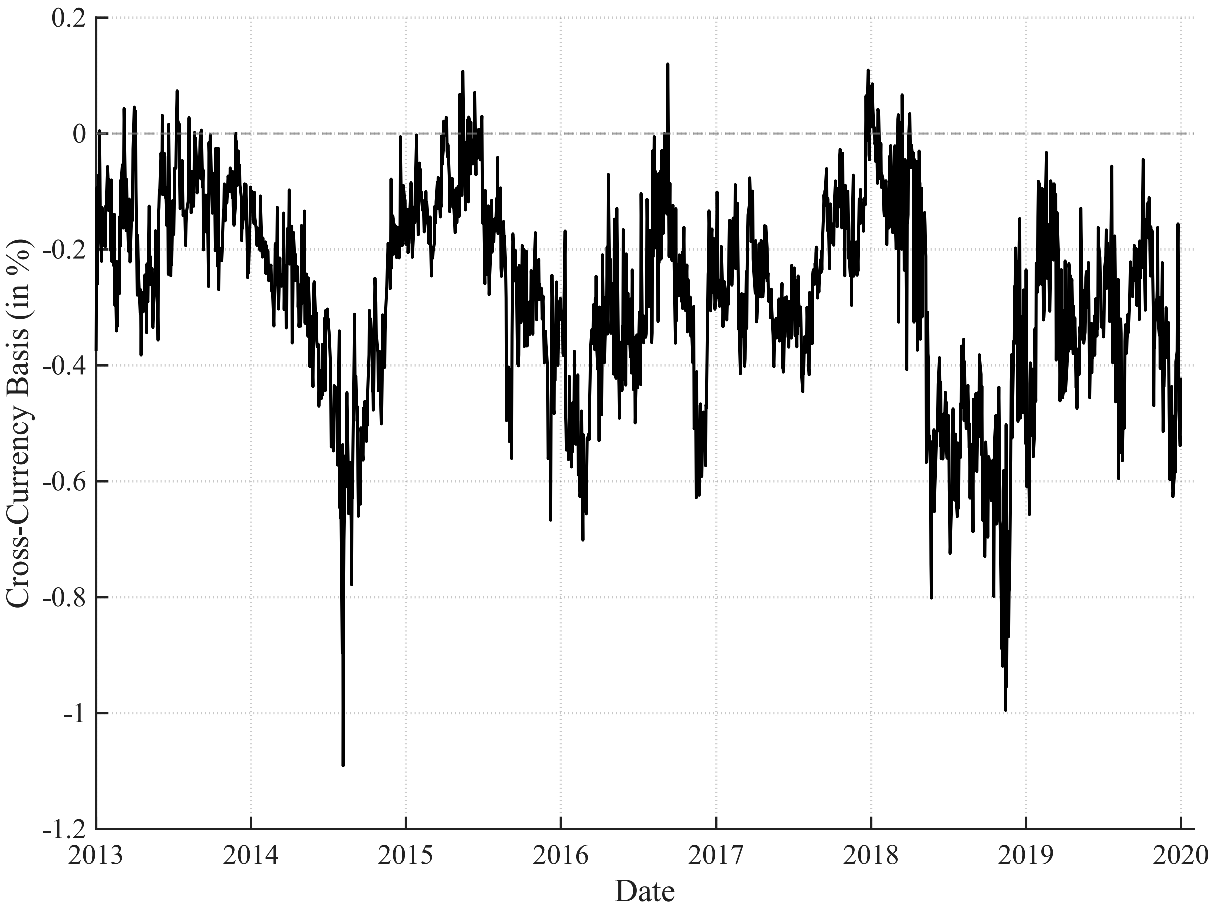
Following common market practice, we assume arbitrageurs implement CIP trades via FX swaps rather than separate spot and forward transactions (Rime et al., 2022). Incorporating bid-ask spreads and a settlement lag (see Du and Schreger (2022)), we derive the annualized cost-adjusted (denoted by "modified" in the following) cross-currency basis (CCB) as:

$$\widetilde{CCB} \equiv R_t^{US,ask}(\text{in }\%) - R_t^{IL,bid}(\text{in }\%) + \frac{100}{n}\ln\left[1 + \frac{\overline{F_{t,t_m}^{ask} - S_t^{bid}}}{S_t^{bid}}\right] < 0. \tag{I1}$$

where $R_t^{US,ask}$ and $R_t^{IL,bid}$ are the CP rate and Makam yield (in %; p.a.), $\overline{F_{t,t_m}^{ask} - S_t^{bid}}$ is the FX swap (in forward points), S_t^{bid} is the USD/ILS spot rate, $n = \frac{90-2}{360}$ is the effective three-month settlement lag.

The resulting CCB is shown in Figure I1. As shown, it is negative on approximately 97.2% of the trading days, consistent with persistent CIP violations.

FIGURE I1
CROSS-CURRENCY BASIS (IN %; P.A.), REFLECTING COMMON MARKET PRACTICE, TRANSACTION COSTS, AND MARGINAL FUNDING COSTS FOR THE ARBITRAGEUR



Notes: The figure shows the cross-currency basis (in percent p.a.) that accounts for the common market practice of using FX swaps instead of separate spot and forward transactions, transaction costs, marginal funding costs, and risk-free investment rates. The data span the period from January 1, 2013, to December, 31, 2019.

Table I1 reports the second-stage estimates from regressing the modified CCB on the BOI's sterilized FX intervention volumes, while controlling for transaction costs, marginal funding costs, and risk-free investment rates. The results confirm that the BOI's FXIs widen CIP deviations:

TABLE I1
EFFECT OF INTERVENTIONS ON THE MODIFIED CROSS-CURRENCY BASIS

	Dependent variable: Δ Modified 3M Basis$_t$ (in %)
Intercept	0.37*
	(1.65)
FXI$_t$	−15.82**
	(−1.98)
ΔEUR/USD$_{t-1,t}$	0.34
	(0.86)
ΔVIX$_{t-5,t}$	−0.11**
	(−2.06)
IL_Monetary_Surprise$_t$	26.57
	(1.60)
IL_CPI_Surprise$_t$	13.419**
	(1.96)
NS_FFR_Surprise$_t$	−83.97
	(−1.26)
NS_Policy_Surprise$_t$	22.50
	(0.50)
CITI_Surprise_Index$_t$	0.003
	(0.87)
Hansen J-statistic	2.149
Hansen J-statistic p-value	0.542

Notes: The daily change of the modified three-month USD/ILS basis (in percentage points, annualized) is regressed on an intercept, the size of interventions ("FXI$_t$"; in USD billions), the daily log return of the EUR/USD spot rate ("EUR/USD$_{t-1,t}$"; in percent), the one-week change in the VIX ("ΔVIX$_{t-5,t}$"; in percentage points) and the one-week change of the USD LIBOR rate ("ΔLIBOR$_{t-5,t}$"; in percentage points). The continuously updated GMM estimator (CU-GMM) is used. For details about the set of instruments that are included in the CU-GMM, see Table F1. To assess whether the data in the CU-GMM is consistent with the imposed moment conditions, the Hansen J-test statistic of over-identifying restrictions is included. The t-statistics (in parentheses below the coefficients) are the Newey-West HAC corrected t-statistics. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample spans the period from January 1, 2013, to December 31, 2019.

Proof of modified CCB equation. CIP deviations allow for profitable arbitrage opportunities when using the US money market for funding, if

$$
\begin{aligned}
\left(1+R_t^{US,ask}\right)^n &< \left(1+R_t^{IL,bid}\right)^n \frac{S_t^{bid}}{F_{t,t_m}^{ask}}, \\
\left(\frac{1+R_t^{US,ask}}{1+R_t^{IL,bid}}\right)^n &< \frac{S_t^{bid}}{F_{t,t_m}^{ask}}, \\
n\left[\ln\left(1+R_t^{US,ask}\right)-\ln\left(1+R_t^{IL,bid}\right)\right] &\approx n\left(R_t^{US,ask}-R_t^{IL,bid}\right) < \ln\left[\frac{S_t^{bid}}{F_{t,t_m}^{ask}}\right], \\
R_t^{US,ask}-R_t^{IL,bid}-\frac{1}{n}\ln\left[\frac{S_t^{bid}}{F_{t,t_m}^{ask}}\right] &< 0.
\end{aligned}
$$

Since interest rates are typically quoted in percent, we write this condition:

$$
\begin{aligned}
R_t^{US,ask}(\text{in }\%) - R_t^{IL,bid}(\text{in }\%) - \frac{100}{n}\ln\left[\frac{S_t^{bid}}{F_{t,t_m}^{ask}}\right] &< 0. \\
R_t^{US,ask}(\text{in }\%) - R_t^{IL,bid}(\text{in }\%) + \frac{100}{n}\ln\left[\frac{F_{t,t_m}^{ask}}{S_t^{bid}} \pm 1\right] &< 0. \\
R_t^{US,ask}(\text{in }\%) - R_t^{IL,bid}(\text{in }\%) + \frac{100}{n}\ln\left[1 + \frac{F_{t,t_m}^{ask} - S_t^{bid}}{S_t^{bid}}\right] &< 0.
\end{aligned}
$$

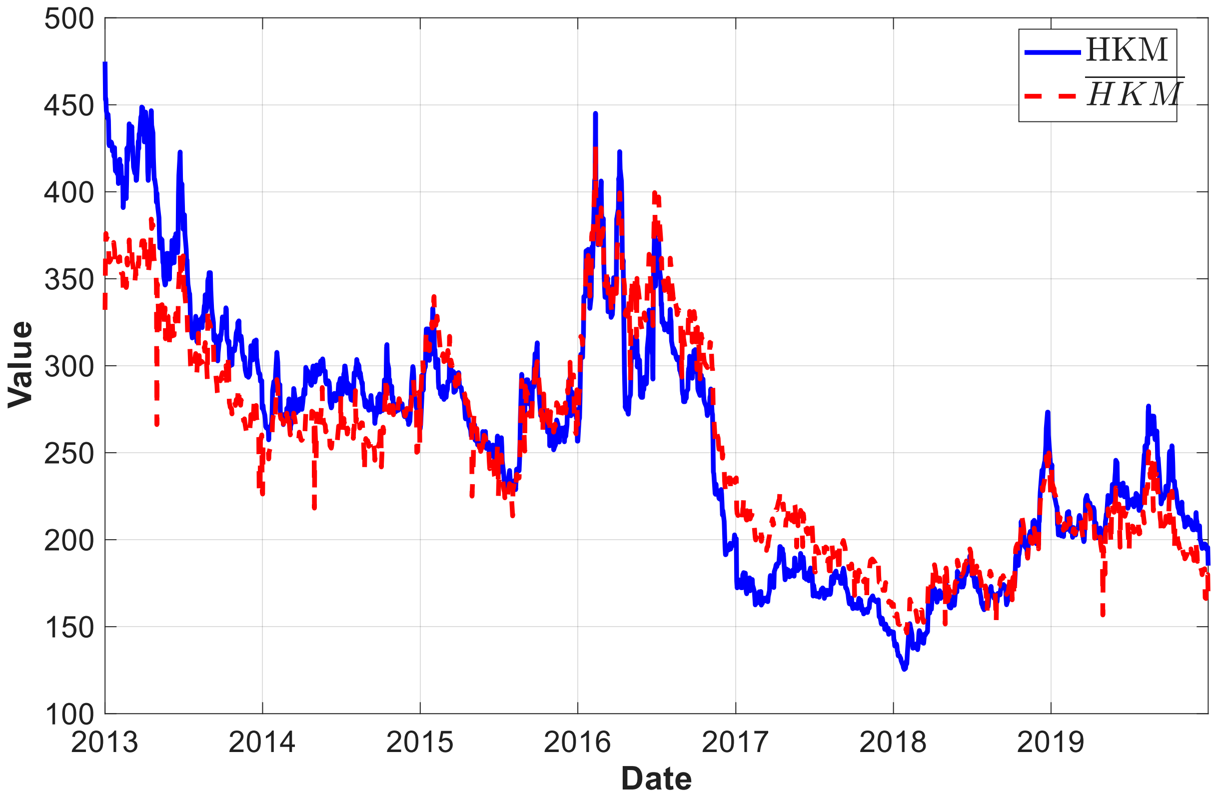
Moreover, as explained in Appendix A in Du and Schreger (2022), spot market transactions are typically settled two business days after the trade date. Consequently, we set $n = \frac{90-2}{360}$ for the three-month USD/ILS forward rate.

J THE EFFECTIVENESS OF INTERVENTIONS WITH THE ISRAELI HKM

The Israeli HKM, which we denote as $\overline{HKM}$, is based on the leverage ratios of banks that are active participants in the USD/ILS market. These include major global banks that largely coincide with the primary dealers serving as trading counterparties with the New York Fed in its implementation of monetary policy,[20] as well as all major Israeli banks that engage in USD/ILS transactions. We believe this targeted $\overline{HKM}$ measure provides a more appropriate reflection of the financial constraints relevant to USD/ILS market dynamics.

Specifically, we calculate the HKM measure for each bank active in the USD/ILS market and then aggregate these individual measures. This process involves retrieving quarterly assets for each bank as well as their daily market equity values, then calculating the leverage ratio as the ratio of assets to market equity. Figure J1 presents a comparison between the original HKM measure and our new market-specific $\overline{HKM}$ measure.

FIGURE J1
FINANCIAL FRICTIONS INDICATORS: THE ORIGINAL HKM VS. THE ISRAELI HKM



Notes: The figure shows the financial frictions indicator that is constructed following the approach in He, Kelly, and Manela (2017). The blue line plots the original HKM series computed using capital ratios of the primary dealers, denoted by "HKM". The red line shows the HKM series computed using capital ratios of the banks actively trading in the USD/ILS spot market.

As shown in the figure, while the two measures exhibit similar temporal patterns, the $\overline{HKM}$ measure captures the specific leverage constraints of institutions most relevant for our analysis. The correlation between the two measures is 0.9433, indicating a strong relationship while confirming that the $\overline{HKM}$ measure is more appropriately tailored to our specific research context.

The $\overline{HKM}$ measure is now used to better capture the specific leverage constraints of institutions most relevant for our study of BOI interventions. As evidenced by the estimates in Table J1, our results in the paper (see Table 6) are robust to the sample of banks used to construct this financial frictions proxy.

TABLE J1
DETERMINANTS OF THE EFFECTIVENESS OF INTERVENTIONS: ISRAELI HKM

Controls	Dependent variable: $\Delta \ln(\text{USD/ILS}_t)$ (in %)
Intercept	−0.03*
	(−1.87)
FXI_t	0.83*
	(1.74)
$\Delta\overline{\text{HKM}}_{t-5,t}$	0.006**
	(2.09)
$\Delta\overline{\text{HKM}}_{t-5,t} \times \text{FXI}_t$	0.33***
	(2.60)
$\Delta\text{EUR/USD}_{t-1,t}$	−0.39***
	(−22.05)
$\Delta\text{VIX}_{t-5,t}$	0.005
	(1.62)
$\text{IL\_Monetary\_Surprise}_t$	−3.02***
	(−4.57)
IL_CPI_Surprise_t	−0.59**
	(−2.06)
NS_FFR_Surprise_t	−2.67
	(−0.78)
$\text{NS\_Policy\_Surprise}_t$	3.13
	(1.28)
$\text{CITI\_Surprise\_Index}_t$	−0.00002
	(−0.08)
Hansen J-statistic	13.48
Hansen J-statistic p-value	0.14

Notes: The daily log return of the USD/ILS spot rate (in percent) is regressed on an intercept, the size of interventions ("FXI_t"; in USD billions), the one-week change in the Israeli HKM indicator ("$\Delta\overline{\text{HKM}}_{t-5,t}$"), the interaction between FXI_t and $\Delta\overline{\text{HKM}}_{t-5,t}$, the daily log return of the EUR/USD spot rate ("$\text{EUR/USD}_{t-1,t}$"; in percent), the one-week change in the VIX ("$\Delta\text{VIX}_{t-5,t}$"; in percentage points) and the five news indicators (variable names ending with "Surprise_t"), using the continuously updated GMM estimator (CU-GMM). The set of instruments used in the CU-GMM is detailed in Table F1. We report the Hansen J-test statistic of over-identifying restrictions to assess the consistency of the data with the imposed moment conditions. The t-statistics are Newey-West HAC corrected and reported in parentheses. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. The sample period is January 1, 2013, to December 31, 2019.

K THE HIGHER MOMENTS OF THE RISK-NEUTRAL DENSITY

Using option price quotes – such as RRs and BF spreads – instead of estimating higher-order moments from the full RND reduces model dependency. In this section, we demonstrate that RR and BF price quotes approximate the implied skewness and kurtosis of the RND when they are scaled by the level of ATMV.

K.1 Option-Implied Volatility Curve

Backus et al. (2004) show that the option-implied smile[21] is approximately equal to:[22]

$$IV_{t,T}(d) \approx ATMV_{t,T}\left[1 - \frac{1}{6}s_{t,T}d - \frac{1}{24}k_{t,T}(1-d^2)\right], \tag{K1}$$

where $IV_{t,T}$ and $ATMV_{t,T}$ are the implied volatility and an estimate of the price quote of the ATMV at time t maturing at time T. It is common market practice to replace the ATMV metric by a constant value (Carr and Wu, 2003)[23] to make quotes comparable across assets:[24]

$$ATMV_{t,T} = \sigma.$$

The remaining expressions in Equation (K1) correspond to the skewness ($s_{t,T}$), excess kurtosis ($k_{t,T}$), and the standardized z-value (d), calculated from the daily log return of the spot exchange rate, r_t, which is assumed to be normally distributed:

$$\begin{aligned} s_{t,T} &= \frac{E(r_t-\mu)^3}{\sigma^3}, \\ k_{t,T} &= \frac{E(r_t-\mu)^4}{\sigma^4} - 3, \\ &\text{and} \\ d &= \frac{\ln(\frac{F}{X})}{IV\sqrt{T-t}} + \frac{1}{2}IV\sqrt{T-t}. \end{aligned}$$

The skewness and excess kurtosis[25] are both centred at the mean μ and scaled by the third and fourth power, respectively, of the volatility σ of the underlying spot exchange rate.

Note that the skewness $s_{t,T}$ and excess kurtosis $k_{t,T}$ are location invariant statistics – so-called normalized central measures – that measure asymmetry and dispersion, respectively. Because both are centered at the mean μ, changes in μ do not affect their values.

K.2 *Moneyness*

We follow Backus et al. (2004) in using d as a measure of moneyness for mathematical convenience. This deviates from industry convention, where only the negative of the first summand of d is typically used to quantify option moneyness.[26,27] As a result, the sign of d differs from standard quoting conventions – yielding an IV smile that is, broadly speaking, a mirror image of the conventional IV smile.[28]

Note that d is typically negative under realistic market conditions – i.e., moderate (here: foreign) interest rates for and maturities not exceeding two years (Bisesti, Castagna, and Mercurio, 2005):

1. For instance, for a 25-Δ call option, the option spot delta $\Delta_C = \exp\left(-r^f \tau\right) \Phi\left(d(25c)\right)$ equals 0.25 under the GK framework.[29]
2. After re-arranging and inverting this equation, we get $d(25c) = \Phi^{-1}\left(0.25 \cdot \exp\left(r^f \tau\right)\right)$.[30]
3. For representative parameters and maturities, we see that $0.25 \cdot \exp\left(r^f \tau\right) \overset{!}{<} 0.5$, as otherwise r^f would have to be larger than $\ln(2)/\tau$ ($\approx$ 34.7% for a period of $\tau = 2$ years).[31]
4. Hence, $d(25c)$ will be negative in standard applications.[32]
5. Also note that $d(25c) > d(10c)$, unless $r^f = 0$.[33]

K.3 Link Between the Three Option Strategies and the Higher Moments of the Risk-Neutral Density

Substituting the IV smile (Equation (K1)) in Equations (C5), (C6) and (C7), we get

$$
\begin{aligned}
ATMV &= ATMV_{t,T} (= \sigma \text{ by market convention}), && \text{(K2)}\\
BF25 &= \frac{-ATMV_{t,T}}{24} k_{t,T} \left(1 - \left[d(25c)^2\right]\right), && \text{(K3)}\\
&\begin{cases} \geq 0 & k_{t,T} \leq 0, \\ < 0 & k_{t,T} > 0. \end{cases} && \text{(K4)}\\
RR25 &= \frac{-ATMV_{t,T}}{6} s_{t,T} \left(d(25c) - d(25p)\right), \\
&= \frac{-ATMV_{t,T}}{3} s_{t,T} d(25c), && \text{(K5)}\\
&\begin{cases} \geq 0 & s_{t,T} > 0, \\ < 0 & s_{t,T} < 0. \end{cases} && \text{(K6)}
\end{aligned}
$$

From Table B3, we observe that the minima and maxima are, in most cases, more than two standard deviations away from the mean. This implies negative excess kurtosis of the RND. According to Equation (K4), such kurtosis is associated with a non-negative BF spread, consistent with the descriptive statistics presented in Table B3.

Similarly, the fact that the mean consistently exceeds the median for all RRs under consideration suggests that the RND exhibits right skewness – that is, it has positive skew. This is further supported by the predominance of positive RR quotes throughout the sample period. These empirical findings align with the theoretical inequality in Equation (K6), which implies that positive skewness results in non-negative RR price quotes.

If we scale $BF25$ and $RR25$ by $ATMV$ and re-arrange both expressions, we get:[34]

$$
\begin{aligned}
\widetilde{BF25} &\equiv \frac{-24}{(1 - [d(25c)^2])} \frac{BF25}{ATMV}, \\
&= k_t, && \text{(K7)}\\
\widetilde{RR25} &\equiv \frac{-3}{d(25c)} \frac{RR25}{ATMV}, \\
&= s_t. && \text{(K8)}
\end{aligned}
$$

As noted in Section K.1, skewness and excess kurtosis are theoretically unaffected by shifts in the mean of the RND. Accordingly, neither the scaled BF spread nor the scaled

RR should respond to FX interventions that influence the expected future spot rate. This prediction, however, stands in contrast to the empirical evidence, which reveals a positive correlation between RR quotes and spot rates in FX option markets, as emphasized in the paper. This suggests that RR pricing must be influenced by additional market factors beyond statistical moments, such as hedging demand, quote conventions, or strategic behavior in anticipation of central bank interventions.

K.4 Sensitivities of the Butterfly Spread and the Risk Reversal

K.4.1 Butterfly Spread

For typical out-of-the-money options – such as 25-Δ contracts – differentiating the BF spread with respect to the skewness and excess kurtosis of the RND yields the following sensitivities:

$$\begin{aligned} \left.\frac{\partial BF}{\partial s_{t,T}}\right|_{-1<d<1} &= 0, \\ \left.\frac{\partial BF}{\partial k_{t,T}}\right|_{-1<d<1} &= \frac{-ATMV_{t,T}}{24}\left(1 - [d(25c)]^2\right), \\ &< 0. \end{aligned}$$

Hence, the BF spread widens as excess kurtosis declines – indicating that extreme exchange rate movements in either directions become less probable over the spread's lifetime. The BF spread remains insensitive to changes in skewness of the RND, or expected future spot rate distribution.

K.4.2 Risk Reversal

We proceed similarly for the change in the price quote of the RR:

$$\begin{aligned} \left.\frac{\partial RR}{\partial s_{t,T}}\right|_{-1<d<1} &= -\frac{ATMV_{t,T}}{3} d(25c), \\ &> 0, \\ \left.\frac{\partial RR}{\partial k_{t,T}}\right|_{-1<d<1} &= 0. \end{aligned}$$

Hence, the RR increases as the skewness of the RND becomes more pronounced, while it remains unaffected by changes in excess kurtosis in the expected future spot rate distribution.

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NOTES

1. See Flug and Shpitzer (2013) for details.
2. As identified by many more market indicators.
3. The Tamar field was discovered in 2009 in deep water off the coast of Haifa. For background on Israel's gas sector, see the Wikipedia entry "Natural gas in Israel" (Wikipedia, 2020).
4. See `https://www.boi.org.il/en/NewsAndPublications/PressReleases/Pages/14-1-21.aspx`.
5. The updated series is available on Miguel Acosta's website at `https://www.acostamiguel.com/replication/MPshocksAcosta.xlsx`.
6. The updated series is available on Miguel Acosta's website at `https://www.acostamiguel.com/replication/MPshocksAcosta.xlsx`.
7. To test statistical significance, we formulate our scientific hypothesis as the alternative hypothesis, denoted by H_a.
8. FX options are conventionally quoted in implied volatilities, while equity options are quoted in currency units.
9. That is, when $\Delta_C = -\Delta_P = 0.5 \exp^{-r^f \tau}$.
10. The strike of this straddle equals $K_{ATM} = F_t \exp\left[1/2\sigma^2(T-t)\right]$.
11. This is also the convention used by Bloomberg; see, for example, Olijslagers, Petersen, de Vette, and van Wijnbergen (2019).
12. See Chapter 10 in Hull (2006). Hence, $K_1 < K_2 < K_3$.
13. The payoff of this strategy is maximized if the spot exchange rate at the expiration date equals K_2.

14. That is, their prices should increase.
15. See the success criteria in the FX intervention strand of literature, for instance, Humpage (1999); Fatum and Hutchison (2003); Fratzscher (2005); Fatum and Hutchison (2006); Galati et al. (2007); Fatum (2008); Fratzscher (2008); Fratzscher, Gloede, Menkhoff, Sarno, and Stöhr (2019).
16. See Section 2 in Carr and Wu (2007). The time index is suppressed throughout this appendix for expositional clarity.
17. This reflects a market tilt toward USD appreciation. As shown in Table B3, RR values were predominantly positive over the sample period, indicating persistent asymmetric sentiment.
18. Following, e.g., Baillie and Osterberg (1997); Galati et al. (2005); Disyatat and Galati (2007); Galati et al. (2007); Ito (2007); Ito and Yabu (2007); Nedeljkovic and Saborowski (2019); Naef and Weber (2023), drawing on early insights from Goodhart and Hesse (1993) and Lewis (1995).
19. These interpolated estimates closely match those obtained via arbitrage-free Nelson-Siegel curve fitting (Christensen, Diebold, and Rudebusch, 2009, 2011).
20. See `https://www.newyorkfed.org/markets/primarydealers` for the complete list.
21. Or option-implied volatility curve, i.e., a plot of the implied volatility-moneyness function.
22. See their Equation (16). They use a Gram-Charlier expansion to allow the density of the logarithm of the spot exchange rate to exhibit non-zero skewness and excess kurtosis, and therefore deviate from a normal density. A similar approach has been advanced by Zhang and Xiang (2008) to model the implied volatility smirk for equity index options. They propose a second-order polynomial that leads to a similar formula; see their Equations (2) and (7)-(9).
23. For instance, the average historical (or realized) volatility of the underlying over a specific period.
24. Subsequent papers also impose this calibration, see for instance Zhang and Xiang (2008).
25. Capturing the slope and curvature of the IV smile.
26. See, e.g., Carr and Wu (2003, 2007); Zhang and Xiang (2008).
27. Moneyness can alternatively be expressed in terms of strike price or any transformation thereof, including forward moneyness, log moneyness, or option delta; see Reiswich and Wystup (2010).
28. For example, most traded call options will be associated with negative values of d, in contrast to the positive d typically assigned under market quoting standards.
29. Similarly, for a put option, we get: $\Delta_P = \Delta_C - \exp\left(-r^f \tau\right)$ (hint: simply take the derivative of the put-call parity with respect to the underlying).
30. For a put option: $d(25p) = -d(25c) = -\Phi^{-1}\left(0.25 \cdot \exp\left(r^f \tau\right)\right)$.
31. Similarly, $0.75 \cdot \exp\left(r^f \tau\right) 0.5$, as otherwise r^f would have to be smaller than $\ln(2/3)/\tau$ ($\approx -20.3\%$ for a period of $\tau = 2$ years).
32. Similarly, $d(25p)$ will be positive in standard applications.
33. As a result, the IV smile curve exhibits a steeper slope on the wings, reinforcing the sensitivity of the BF spread to kurtosis effects.
34. Olijslagers et al. (2019) similarly divide the price of both option strategies by the ATMV.