The Persistent Widening of Cross-Currency Basis: When Increased FX Swap Demand Meets Limits of Arbitrage*

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Abstract

This paper examines the demand-side factors that affect deviation from covered interest rate parity (CIP) with respect to the dollar (i.e., cross-currency basis), particularly when arbitrageurs are constrained. Using novel transaction-level data on the universe of Israeli institutional investors' (IIs') FX swaps, we employ a granular instrumental variable estimation to investigate how IIs' FX swap demand affects CIP deviation. Our findings demonstrate that a one standard deviation shock to IIs' FX swap demand when capital is more abundant has no economic and statistically significant impact on IIs' aggregate basis. However, when capital is scarce, the demand shock results in a significant and persistent reduction of 4.5-9 basis points in IIs' cross-currency basis, remaining significant for over 500 trading days. These results suggest that IIs' demand for dollar funding plays a crucial role in driving the CIP deviation.

JEL classification: E44,F3,G15,G23

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1 Introduction

The covered interest parity (CIP) condition is a cardinal no-arbitrage principle in international finance, asserting that the interest rate implied by the foreign exchange (FX) swap market equates to the interest rate in the cash market. CIP has held fairly well prior to the 2008-2009 global financial crisis (GFC), even for daily data, but has broken down since the onset of the GFC with the cash market dollar interest rate having been lower than the FX-swap-market-implied dollar interest rate for most currencies (Du et al. (2018), Avdjiev et al. (2019), Cerutti et al. (2021), and Du and Schreger (2022)).

FX swap trades constitute the most commonly traded FX instrument in the global FX market with 3.2 trillion dollars in average daily turnover in April 2019 (the date of the most recent BIS Triennial Survey) that represents a 48.6% share of global FX turnover (Schrimpf and Sushko (2019)).[1] The corresponding numbers for institutional investors (IIs), who use FX swaps to fund their FX investments in an FX-risk-free manner, are also significant at 776.9 billion dollars and 27.3%, respectively. This type of funding with FX swaps produces vast amounts of off-balance sheet debt, or 'missing dollar debt', with the off-balance sheet US dollar debt of non-banks outside the U.S. substantially exceeding their on-balance sheet debt and growing faster - being twice as much in June 2022 after being 1.6 times as much in 2016 (Borio et al. (2022)).

In this paper, we investigate the impact of IIs' demand on the deviations from CIP, given their considerable demand for FX swaps. Persistent CIP violations imply a potentially meaningful increase in a favored funding vehicle for local IIs, which can significantly curtail the long-term savings of the local economy. Therefore, a deeper understanding of the role of IIs in perpetuating the deviations from CIP is of great value.

A theoretically appealing explanation for CIP violations that may be related to the notable demand by local IIs is that periods of more significant limits of arbitrage (LOA) accompanied by rightward shifts in the demand for FX swaps of local IIs who wish to increase their exposure to foreign assets (without taking on FX risk) can lead to the persistent breakdown of CIP observed in the data since the GFC. This limits-of-arbitrage-dependent (LOA-dependent) FX swap demand

[1] The dollar's dominance in the global FX swap market is overwhelming, being one of the traded currencies in over 90% of FX swap trades.

channel builds on the idea that greater LOA imply a steepening of the FX swap supply curve, leading to a more significant widening of cross-currency basis in the presence of a rightward shift in the FX swap demand curve.

To achieve our research objectives, we utilize a unique dataset from the Bank of Israel (BOI) that provides detailed information on the universe of FX swap transactions of a panel of IIs over a 14-year period. The panel data enables us to use a granular instrumental variable (GIV) estimation approach, creating an IIs' demand shock as the sum of idiosyncratic IIs' shocks that are orthogonal to various supply- and demand-related FX swap market factors.

Summary of Main Results. Our results show that when there is a one standard deviation shock to IIs' aggregate FX swap demand in the LOA state, it leads to a significant and persistent reduction of 4.5-9 basis points in IIs' cross-currency basis. This effect remains significant for 528 trading days, and after 514 trading days, the FX swap demand shock accounts for 79% of the basis' variation. By contrast, in the linear (no LOA) case, the aggregate FX swap demand shock produces an economically and statistically insignificant change in IIs' aggregate basis, while moving IIs' aggregate open FX swap position in the initial horizons by significantly more than the corresponding effect in the LOA state. We interpret the latter results in the following manner. While initially IIs struggle to obtain funding in the FX swap market in the LOA state, at later horizons they are able to accumulate a significant amount of such funding. (Their aggregate open FX swap position significantly increases from the 65th through 419th horizon.) This delayed accumulation of open FX swap position can explain the persistence of the widening of the basis as pressure from IIs' gradual and persistent demand increase weighs materially on the FX swap market. Overall, these results support the presence of a meaningful LOA-dependent FX swap demand channel.

The paper unfolds in two parts. The first part lays out a simple conceptual framework that serves to fix ideas, motivate the aforementioned litmus test, and form a suitable conceptual base for this paper. The second part of this paper conducts the aforementioned litmus test. Before turning to discuss these two parts, we first briefly clarify some terminological issues so as to streamline this paper's exposition.

Terminology. We define cross-currency basis as the difference between the cash market dollar interest rate and the FX-swap-market-implied (CIP-implied) dollar interest rate. Hence, when the former is lower (higher) than the latter, we refer to the associated basis as being negative (positive). And a 'widening' of the basis refers to its *declining*.

FX Swap contracts are two-leg FX trades where the first leg is a spot transaction and the second leg is a forward transaction of an equivalent opposite amount. The most common use of FX swaps is for IIs to fund their FX balances and for CIP arbitragers to try to profit from CIP violations (Bergljot and Lian (2010)). 'FX swap demand' throughout this paper refers to demand of local IIs for the purchase spot dollars (i.e., the first leg) and selling of forward dollars (i.e., second leg) of the same amount. And 'FX swap supply' refers to the opposite end of this trade coming from arbitrageurs. In accordance with our focus on the *dollar* basis, we measure FX swap flows for the USD/NIS currency and ignore non-dollar related swap trades. (85.9% of our local IIs' FX swap volume is done in dollars, with the remaining small 14.1% share almost entirely done in euros (11.4%) and pounds (1.8%).)

Underlying Framework. This part lays out a simple structural partial equilibrium model of the FX swap market. The backbone of the model is a risk-averse local II that demands FX swaps to increase its (hedged) exposure to foreign assets, maximizing its profit in a mean-variance optimization setting, and a profit-maximizing risk-neutral arbitrageur with a pre-determined level of arbitrage capital that supplies FX swaps. We use this arbitrage capital variable to represent the notion of LOA. The two concepts are intrinsically related in that LOA implies that arbitrageurs are constrained in their ability to arbitrage away price anomalies and arbitrageurs' arbitrage capital is vital to the materialization of this ability. I.e., a constrained level of arbitrage capital is conceptually tantamount to LOA.

Our setting results in the following equilibrium result. Conditional on a positive FX swap demand white noise shock - represented by an exogenous decrease in the level of local II's risk aversion with respect to FX-swap-funded foreign investment,[2] the downward-sloping demand curve of FX swaps shifts rightward along the arbitrageur's upward-sloping supply curve with the steepness of the latter supply curve being shaped by the level of the arbitrageur's arbitrage capital. In particular, the lower this arbitrage capital is (i.e., the greater LOA), the steeper the arbitrageur's FX swap supply curve. Hence, the ability of the rightward shift in the FX swap demand curve to produce a negative cross-currency basis is increasing in LOA severity.

The second part of the paper tests the model's prediction, i.e., that an increase in local IIs' demand for FX swaps leads to greater widening of the basis when LOA is greater. This prediction is the essence of the LOA-dependent FX swap demand channel.

Econometric Model. The second part of the paper (whose results have already been summarized above) studies the LOA-dependent effect of increased IIs' FX swap demand on their USD/NIS cross-currency basis, where we construct the latter as the volume-weighted average of IIs' transaction-level bases. We use a GIV estimation procedure within a suitable Bayesian state-dependent local projection model which we present in Section 5.2.1. The technical details concerning this model's estimation and inference are given in Appendix A of the online appendix to this paper. Our Bayesian estimation and inference procedure provides a convenient numerical way to produce confidence intervals that account for estimation uncertainty in each of the two stages underlying our GIV estimation procedure. The Bayesian approach we take is in the spirit of a long tradition in the literature on impulse response estimation (see, e.g., Del Negro and Schorfheide (2011)) that has recently also caught on in the local projections literature (see, e.g, Miranda-Agrippino and Ricco (2021) and Ben Zeev (2023)). We view our dynamic modeling choice as one of the strengths of our paper as it allows for studying the rich dynamics that occur after the GIV-based FX swap demand shock. Our GIV estimation procedure succeeds in generating a panel of idiosyncratic demand shocks for our IIs whose sum serves as the effective IV in our setting. We control for a variety of aggregate supply- and demand-side factors in the estimation

[2] This demand shock can be viewed as an exogenous shift in the II's geographical preference for investment. E.g., an exogenous decision by a pension fund's investment committee to allocate more funds to foreign investment, with such decision reflecting the committee's perception of foreign investment being more appealing now.

of the idiosyncratic shocks so as to ensure the validity of our GIV approach.

Outline. The remainder of the paper is organized as follows. The next section provides a literature review. In the subsequent section the theoretical motivation for this paper is laid out. Section 4 provides institutional background for Israeli IIs' FX swap activity. Section 5 provides a description of the data and methodology used in this paper. Section 6 presents the baseline results and briefly discusses additional robustness checks (the results of which are shown in Appendix B of the online appendix to this paper). The final section concludes.

2 Related Literature

To the best of our knowledge, this paper constitutes the first empirical investigation of the LOA-dependent FX swap demand channel that uses transaction-level FX swap flow and price data along with a daily measure of LOA to quantify this channel. The granular dimension and daily frequency of our data allow us to quite cleanly identify this channel.

The persistent violations of CIP since the GFC have attracted significant research in recent years on the potential drivers of these violations,[3] focusing on the separate as well as joint role of FX swap supply and demand factors as potential drivers of these violations. Our work is motivated by this research and is a part of the burgeoning literature associated with it.

FX Swap Supply. Du et al. (2018) and Avdjiev et al. (2019) use aggregate data to provide evidence that regulatory balance sheet constraints are an important driver behind CIP violations through their adverse effects on global banks' capacity to supply FX forward and swap contracts. Puriya and Bräuning (2020) use novel contract-level data for German banks' forward contracts and exploit regulation-driven quarter-end window-dressing practices - intended to avoid regulatory capital charges on FX exposure from net on-balance-sheet dollar assets - to identify significant CIP violations driven by banks' dollar forward selling. Interpreted through the lens of the FX swap

[3] CIP deviations' implications, rather than drivers, are also an important avenue of research. E.g., Keller (2021) uses Peruvian data to show that positive cross-currency basis leads to a decline in local banks' local currency lending as they allocate funds away from local currency lending to fund their CIP arbitrage. The converse takes place when the basis is negative.

market, which the authors abstract from doing, this interesting forward market mechanism can be reasonably viewed as inducing a leftward shift to banks' FX swap supply in a setting where these banks have substitutability between conducting CIP arbitrage activity and conducting regulation-driven quarter-end window-dressing activity.

Cenedese et al. (2021) use micro (dealer-level) data to show that regulatory changes concerning U.K. banks' leverage ratios have increased CIP deviations for high-leverage U.K. dealers. And Anderson et al. (2021) provide evidence from micro data on global banks that the large negative wholesale funding shock from the 2016 U.S. money market mutual fund reform had a significant widening effect on USD/JPY cross-currency basis.

Fx Swap Demand. Liao (2020) use micro data to show that CIP deviations are mainly driven by differences between corporate credit spreads in different currencies, drawing attention to a mechanism where firms facing high dollar credit spreads can choose to issue non-dollar debt with lower corporate spreads and then swap the issuance's non-dollar proceeds into dollars through an FX swap - which in turn generates demand pressure for FX (dollar) swaps. And Syrstad and Viswanath-Natraj (2022) construct a daily measure of FX swap order flow - buyer initiated minus seller initiated trades - and show that the basis effect of a one standard deviation change in this measure has increased from less than one basis point prior to 2008 to about five basis points after 2008. (They look at three currency pairs: USD/EUR, USD/CHF, and USD/JPY.)

Papers Looking at Both FX Swap Supply and Demand Channels. Rime et al. (2022) use micro data to contribute to the understanding of the role of both FX swap supply and demand movements as drivers of persistent CIP violations. For the FX swap supply channel, Rime et al. (2022) provide evidence that meaningful risk-free CIP arbitrage opportunities are limited to only a narrow group of top-rated global banks whose balance sheet constraints prevent them from eliminating the associated CIP violations. For the FX swap demand channel, Rime et al. (2022) show that low-rated non-U.S. banks find it difficult to obtain dollar funding in the cash market and hence produce demand pressure for dollar funding via FX swaps. Cerutti et al. (2021) use aggregate data in a vast study of CIP violations' drivers and find evidence supporting meaningful roles for risk-taking capacity, FX market liquidity, unconventional monetary policy, and financial regulation, highlighting an intricate and time-varying role for both supply and demand shifts in the FX swap market as drivers of CIP violations.

The paper that is conceptually closest to ours is Sushko et al. (2016), which in turn builds and expands on ideas laid out in Borio et al. (2016). These ideas pertain to the combination of some form of LOA and hedging demand. Specifically, Sushko et al. (2016) estimate a state space model with a measurement equation linking an FX swap demand proxy to cross-currency basis and a state equation in the unobserved, time-varying elasticity of the basis with respect to hedging demand. They then show this elasticity to be closely correlated with the product of FX option-implied volatility and bank credit spreads, which can be interpreted as being consistent with the notion that the latter elasticity is higher when arbitrage limits are stricter.

We differ from Sushko et al. (2016) along two main dimensions, which are also relevant for understanding the contribution of our paper to the broader literature. The first is our transaction-level data on IIs' FX swap flows and prices as well as our use of a daily measure of LOA based on the global financial institutions' market leverage measure from He et al. (2017), all of which allow us to identify the LOA-dependent FX swap demand channel quite cleanly.[4] Sushko et al. (2016) use a rough proxy for FX swap demand at a monthly frequency given by the implied cross-currency position of banks, IIs, and corporations, while also lacking a direct measure of these agents' basis. Second, our GIV-based local projection estimation approach allows us to study the LOA-dependent persistence of CIP violations conditional on an arguably exogenous FX swap demand shock that is in turn orthogonal to a rich array of other supply- and demand-related FX swap market factors. As such, it can be interpreted as a pure demand shock arising from IIs' idiosyncratic desire to increase their (hedged) exposure to foreign assets.

[4] The underlying motivation for our LOA measure choice comes from the intrinsic link between intermediaries' funding capacity and LOA (Shleifer and Vishny (1997)), as limits on the former prevent from arbitrageurs to obtain the capital they need to arbitrage away price anomalies. This notion is very well captured by He et al. (2017)'s global intermediaries' leverage measure as it reflects the soundness of the financial intermediary sector - representing in large part agency/contracting frictions' severity, regulation strictness, and intermediaries' portfolios' performance; hence, sharp increases in this measure capture well meaningful increases in LOA. (Another important paper emphasizing the intrinsic link between intermediaries' funding capacity and LOA is Anderson et al. (2021), whose data allows them to measure the CIP-relevant arbitrage capital from the amount of global banks' unsecured short-term borrowing that is funded at a lower rate than the CIP-implied one.)

3 Theoretical Motivation

In what follows we lay out a simple structural framework which is meant to fix ideas and form a suitable conceptual base for this paper's empirical analysis. Understanding the drivers of CIP deviations is tantamount to understanding the workings of the FX swap market (see Du and Schreger (2022) and references therein). Accordingly, the framework we use is a partial equilibrium of the FX swap market consisting of two time periods (t and $t+1$) and two agents. The first agent is a risk-neutral arbitrageur who supplies FX swaps. The second is a risk-averse local institutional investor (II) who demands FX swaps to obtain FX-risk-free foreign currency funding. The use of this foreign currency funding is for the local II to increase its (hedged) exposure to foreign assets.

We start our depiction of the model with a presentation of the supply side of the FX swap market by presenting the arbitrageur's supply of FX swaps. We then show demand for FX swaps by the local II. We end the section by defining equilibrium and presenting the model's main prediction.

3.1 Supply of FX Swaps

General Setting. There is a risk-neutral arbitrageur that represents the supply side of the FX swap market. The arbitrageur's aim is to profit from the local II by creating a synthetic forward rate that is cheaper than the market's observed forward rate. The arbitrageur's trade can be broken down into two parts. First, it buys spot $Q_{t,ARB}S_t$ local currency units and sells spot $Q_{t,ARB}$ foreign currency units in period t, conducting this trade entirely with the local II. Second, it sells forward $Q_{t,ARB}S_t(1+i_{t+1,L})$ local currency units at forward rate $F_{t,t+1}$, where $Q_{t,ARB}S_t$ is the local currency amount sold forward to the local II in the second leg of the associated arbitrageur-local II FX swap trade and $Q_{t,ARB}S_t i_{t+1,L}$ represents the interest related amount sold forward in an outright forward trade the arbitrageur conducts with some (unmodeled) broker-dealer institution.

The rationale for the second part of the trade can be explained as follows. Using its predetermined arbitrage capital, the arbitrageur conducts CIP arbitrage as well as other arbitrage trades (whose depiction is deferred for now). Given its role as arbitrageur, and since FX swaps trades do not perfectly align with CIP arbitrage as they exclude the interest proceeds element,[5] the arbitrageur additionally sells forward $Q_{t,ARB}S_t i_{t+1,L}$ local currency units, where $Q_{t,ARB}$ is the arbitrageur's FX swap supply (in foreign currency units) and $i_{t+1,L}$ is the local risk-free interest rates, respectively. (While left unmodeled, the counterparty to this interest proceeds forward trade can be thought of as a broker-dealer institution.)

The arbitrageur's level of predetermined arbitrage capital will be used below as the model's LOA measure in the sense that a lower such capital level implies greater LOA. While this LOA representation constitutes a reduced-form encapsulation of LOA, we view it as the most natural way to represent LOA in our structural setting.

We assume that the arbitrageur can borrow foreign currency frictionlessly in the cash market at interest rate $i_{t+1,W}$ and hence has no constraints on its funding of foreign currency. (I.e., $i_{t+1,W}$ represents the opportunity cost of arbitrageur's FX swap trade. In our setting it is viewed as the effective cost of the FX swap trade as we assume the arbitrageur funds this trade by borrowing the required funds in the cash market.) However, we assume that it faces frictions in the FX swap market, as we now turn to explain.

Haircut. Following Ivashina et al. (2015), we assume that a haircut (initial margin) is applied to the arbitrageur's FX swap trade in the amount of $\kappa Q_{t,ARB}$. That is, the arbitrageur's FX swap trade requires it to incur a linear haircut-induced cost through the depositing of share κ of its swap position to the local II.[6]

Arbitrageur's Alternative Arbitrage Activity. By allocating $\kappa Q_{t,ARB}$ for CIP arbitrage, the arbitrageur has to take these funds away from its pre-determined arbitrage capital A_t. In other words, $A_t - \kappa Q_{t,ARB}$ represents the arbitrageur's available capital for another (non-CIP) arbitrage activity (e.g., fixed income arbitrage). Following Ivashina et al. (2015), this other arbitrage activity has a net *concave* return given by $G(A_t - \kappa Q_{t,ARB})$, where $G(:) > 0$, $G'(:) > 0$, $G''(:) < 0$, and

[5]While this element is necessary for conducting CIP arbitrage, it is noteworthy that it is also very small (relative to the principal) given that FX swap trades' maturities are usually short (Schrimpf and Sushko (2019)).

[6]For simplicity, we abstract from the opposing haircut facing the local II.

$G'''(:) > 0$. [7]

These assumptions on $G(:)$ are met by standard production/revenue functions, including the logarithmic specification used in Ivashina et al. (2015). More generally, considering the commonly used positively homogenous production/revenue functions, it is straightforward to show that concavity ($G''(:) < 0$) in fact implies a positive third derivative ($G'''(:) > 0$) as the latter condition requires a returns to scale that is lower than 2 while the former implies a returns to scale that is lower than 1 (i.e., decreasing returns to scale). This is an important observation because evidence from the literature on bank investment returns (see Zhu (2008) and references therein) and the literature on mutual fund investment returns (McLemore (2019)) supports the notion of decreasing return to scale for financial institutions' investments.

Arbitrageur's Profit Maximization. We are now in position to write the arbitrageur's profit from its arbitrage activity as

$$Q_{t,ARB}\frac{S_t}{F_{t,t+1}}(1+i_{t+1,L}) - Q_{t,ARB}(1+i_{t+1,W}) + G(A_t - \kappa Q_{t,ARB}). \tag{1}$$

The FOC that results from maximizing the profit from Equation (1) with respect to $Q_{t,ARB}$ is

$$b_t \equiv 1 + i_{t+1,W} - \frac{S_t}{F_{t,t+1}}(1+i_{t+1,L}) = -\kappa G'(A_t - \kappa Q_{t,ARB}), \tag{2}$$

where b_t is the cross-currency basis (defined in accordance with the literature) and $\frac{S_t}{F_{t,t+1}}(1+i_{t+1,L})$ represents the synthetic, CIP-implied foreign (gross) risk-free interest rate which is clearly higher than the cash market one owing to the haircut-induced cost. In other words, Equation (2) implies a negative cross-currency basis b_t that is caused by the swap trade's haircut-induced friction.

Relation between $Q_{t,ARB}$ and $-b_t$. Minus of the cross-currency basis (i.e., $-b_t$) from FOC (2) is the arbitrageur's marginal profit from increasing its FX swap position. As such, the minus of the cross-currency basis can also be economically viewed as the price of the FX swap. Accordingly,

[7] The concavity of G is consistent with the limits-to-arbitrage notion from Shleifer and Vishny (1997). For internal consistency between such arbitrage limits existing across all of the arbitrageur's arbitrage activities, we could also have assumed a *convex* haircut-induced cost as in Liao and Zhang (2020) which seems more consistent with such limits than our linear haircut assumption. Such modeling choice does not change our model's main prediction and hence, for simplicity, we stick to the linear haircut modeling approach from Ivashina et al. (2015).

it is therefore reasonable to expect that the arbitrageur's supply of FX swaps increases in $-b_t$. To show this formally, we differentiate $-b_t$ from FOC (2) with respect to $Q_{t,ARB}$:

$$\frac{\partial(-b_t)}{\partial Q_{t,ARB}} = -\kappa^2 G''(A_t - \kappa Q_{t,ARB}) > 0, \tag{3}$$

where the positive sign of Equation (3) comes from the assumed concavity of net return function $G(A_t - \kappa Q_{t,ARB})$. Given the interpretation of $-b_t$ as FX swap price, Equation (3) delivers the standard result of an upward-sloping supply curve: higher price (marginal profit) of FX swaps induces the arbitrageur to supply more such swaps. Moreover, we can show that the slope of the arbitrageur's FX swap supply curve flattens (steepens) when initial arbitrage capital is higher (lower) by differentiating Equation (3) with respect to A_t:

$$\frac{\partial^2(-b_t)}{\partial Q_{t,ARB}\partial A_t} = -\kappa^2 G'''(A_t - \kappa Q_{t,ARB}) < 0. \tag{4}$$

This result clearly follows from the arguably weak assumption of $G(:)$'s positive third derivative (see related discussion on this assumption on Page 10). I.e., more (less) initial arbitrage capital induces less (more) rigidity in the willingness of the arbitrageur to supply FX swaps. Result (4) lies at the heart of our paper.

3.2 Demand for FX Swaps

General Setting. We assume a risk-averse local II that borrows in the swap market $Q_{t,II}$ foreign currency units for the purchase of foreign assets whose expected rate of return is denoted by $\mathbb{E}_t i_{t+1,FA}$, where $\mathbb{E}_t$ is the expectation operator conditional on period t information. (The $i_{t+1,FA}$ return variable can be thought of as some weighted average of returns of foreign stocks, bonds, and loans.) Specifically, the local II enters an FX swap with the arbitrageur of size $Q_{t,II}$. In the first leg of the trade the local II sells $Q_{t,II}S_t$ local currency spot units and buys $Q_{t,II}$ foreign currency units. And in the second leg, which takes place in period $t+1$, the local II buys $Q_{t,II}S_t$ local currency units at forward rate $F_{t,t+1}$ and sells $\frac{Q_{t,II}S_t}{F_{t,t+1}}$ foreign currency units. We abstract from the haircut that the local II realistically faces in this swap trade as well as from its non-swap-related investments. Adding these elements would complicate the exposition without affecting the main prediction of our model.

Expectation and Variance of Local II's Profit. We can write the local II's next period's expected profit (in foreign currency terms) from its swap-related foreign investment, which we assume to be positive and denote by $\mathbb{E}_t\Pi_{t+1,II}$, as

$$\mathbb{E}_t\Pi_{t+1,II} = Q_{t,II}(1+\mathbb{E}_t i_{t+1,FA}) - Q_{t,II}\frac{S_t}{F_{t,t+1}}. \tag{5}$$

We can use the definition of cross-currency basis from Equation (2) to write Equation (5) equivalently as

$$\mathbb{E}_t\Pi_{t+1,II} = Q_{t,II}(1+\mathbb{E}_t i_{t+1,FA}) - Q_{t,II}\left(\frac{1+i_{t+1,W}-b_t}{1+i_{t+1,L}}\right). \tag{6}$$

And the variance of local II's profit ($\mathbb{V}_t\Pi_{t+1,II}$) can be written as $\mathbb{V}_t\Pi_{t+1,II} = Q_{t,II}^2\mathbb{V}_t(1+i_{t+1,FA})$, where $\mathbb{V}_t$ is the variance operator conditional on period t information.

Mean-Variance Optimization Problem. We assume the local II chooses its demand for FX swaps $Q_{t,II}$ so as to maximize

$$\mathbb{E}_t\Pi_{t+1,II} - \frac{e^{\epsilon_t}}{2}\mathbb{V}_t\Pi_{t+1,II} = Q_{t,II}(1+\mathbb{E}_t i_{t+1,FA}) - Q_{t,II}\left(\frac{1+i_{t+1,W}-b_t}{1+i_{t+1,L}}\right) - \frac{e^{\epsilon_t}}{2}Q_{t,II}^2\mathbb{V}_t(1+i_{t+1,FA}), \tag{7}$$

where ϵ_t represents an FX swap demand white noise shock which in turn determines the level of local II's risk aversion with respect to swap-related foreign investment. Importantly, as formally shown below, a positive (negative) ϵ_t induces a leftward (rightward shift) in the demand for FX swaps. More generally, when one considers the alternative local investment opportunities facing the local II, such shocks essentially represent exogenous shifts in the local II's geographical investment preferences. In our empirical analysis we identify these shocks as the innovations in local IIs' FX swap flows that are orthogonal to a rich array of current and past values of variables that capture the other supply- and demand-side factors present in our model.

The FOC that results from maximizing the objective function from Equation (7) with respect to $Q_{t,II}$ is

$$Q_{t,II} = \frac{1+\mathbb{E}_t i_{t+1,FA}}{e^{\epsilon_t}\mathbb{V}_t(1+i_{t+1,FA})} - \frac{1+i_{t+1,W}-b_t}{(1+i_{t+1,L})e^{\epsilon_t}\mathbb{V}_t(1+i_{t+1,FA})}. \tag{8}$$

Equation (8) essentially represents local II's demand for FX swaps.

Relation between $Q_{t,II}$ and $-b_t$. In the previous section we interpreted $-b_t$ as the price of FX swaps. As such, we should expect to have a negative relation between this price and demand for FX swaps. To show this negative relation (i.e., a downward sloping FX swap demand curve), let us differentiate Equation (8) with respect to $-b_t$:

$$\frac{\partial Q_{t,II}}{\partial(-b_t)} = -\frac{1}{(1+i_{t+1,L})e^{\epsilon_t}\mathbb{V}_t(1+i_{t+1,FA})} < 0. \tag{9}$$

Relation between $Q_{t,II}$ and ϵ_t. We argued above that a positive (negative) realization for ϵ_t represents a leftward (rightward) shift in local II's FX swap demand. To show this formally, let us differentiate Equation (8) with respect to e^{ϵ_t}:

$$\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}} = -\frac{1+\mathbb{E}_t i_{t+1,FA}}{e^{2\epsilon_t}[\mathbb{V}_t(1+i_{t+1,FA})]^2} + \frac{1+i_{t+1,W}-b_t}{e^{2\epsilon_t}[\mathbb{V}_t(1+i_{t+1,FA})]^2(1+i_{t+1,L})} < 0, \tag{10}$$

where the negative sign of Equation (10) comes from the fact that local II's expected profit, $1 + \mathbb{E}_t i_{t+1,FA} - \left(\frac{1+i_{t+1,W}-b_t}{1+i_{t+1,L}}\right)$, is assumed to be positive.

3.3 Model Equilibrium

We define equilibrium in the FX swap market as the equality $Q_{t,II} = Q_{t,ARB} = Q_t$, where Q_t denotes the equilibrium level of FX swap flows. The latter equilibrium equation, when substituted into FOCs (2) and (8) produce two equations in two unknowns b_t and Q_t. (A proof that relies on a fixed-point argument for the existence and uniqueness of a solution to this demand-supply equation system is available upon request from the authors.) We can use our previous results on the nature of the FX swap supply and demand curves to deduce the main prediction of our model.

The A_t-Dependent Relation Between ϵ_t and b_t. Consider our model's FX demand-supply framework in the space of $-b_t$ and Q_t. Equation (2) defines an upward-sloping FX swap supply curve whose slope becomes steeper with a lower A_t. Equation (8) defines a downward-sloping FX swap demand curve which shifts rightward in response to a negative realization of swap demand shock ϵ_t. In equilibrium, such favorable swap demand shock is predicted to produce an increase in $-b_t$ (i.e., a widening of the basis) which depends on the level of the arbitrageur's initial arbitrage capital A_t: the lower (higher) this capital is, the stronger (weaker) the widening effect of the demand shock.

To see this relation formally, we take three steps. First, we substitute Equation (8) into Equation (2) (after substituting into both equations the equilibrium condition $Q_{t,II} = Q_{t,ARB} = Q_t$) to obtain the following equilibrium equation for b_t:

$$b_t = -\kappa G'\left(A_t - \kappa\left(\frac{1+\mathbb{E}_t i_{t+1,FA}}{e^{\epsilon_t}\mathbb{V}_t(1+i_{t+1,FA})} - \frac{1+i_{t+1,W}-b_t}{(1+i_{t+1,L})e^{\epsilon_t}\mathbb{V}_t(1+i_{t+1,FA})}\right)\right). \tag{11}$$

Second, we implicitly differentiate Equation (11) with respect to e^{ϵ_t} to obtain the effect of the latter on b_t:[8]

$$\frac{\partial b_t}{\partial e^{\epsilon_t}} = \frac{\kappa^2 G''(:)\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}}}{1-\kappa G''(:)\frac{\partial Q_{t,II}}{\partial b_t}} > 0. \tag{12}$$

The positive sign of Equation (12) relies on the assumed concavity of G and the derived negative and positive signs of $\frac{\partial Q_{t,II}}{\partial(-b_t)}$ and $\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}}$ from Equations (9) and (10), respectively. Third, we differentiate Equation (12) with respect to A_t:

$$\frac{\partial^2 b_t}{\partial e^{\epsilon_t}\partial A_t} = \frac{\kappa^2 G'''(:)\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}}(1-\kappa G''(:)\frac{\partial Q_{t,II}}{\partial b_t}) + \kappa^2 G''(:)\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}} G'''(:)\frac{\partial Q_{t,II}}{\partial b_t}}{\left(1-\kappa G''(:)\frac{\partial Q_{t,II}}{\partial b_t}\right)^2} = \tag{13}$$

$$\frac{\kappa^2 G'''(:)\frac{\partial^2 b_t}{\partial e^{\epsilon_t}}\left(1-G''(:)\frac{\partial Q_{t,II}}{\partial b_t}(\kappa^2-\kappa)\right)}{\left(1-\kappa G''(:)\frac{\partial Q_{t,II}}{\partial b_t}\right)^2} < 0.$$

The negative sign of Equation (13) relies on the assumed concavity of G, its assumed positive third derivative, the fact that $\kappa < 1$, and the derived negative and positive signs of $\frac{\partial Q_{t,II}}{\partial(-b_t)}$ and $\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}}$ from Equations (9) and (10), respectively. Equations (12) and (13) formally demonstrate that a negative realization for ϵ_t (i.e., a rightward shift in FX swap demand) is predicted to generate a stronger widening of the basis (i.e., a larger decline in b_t) if the initial value of A_t is lower (i.e., if LOA are greater).

[8] To streamline the remaining two derivations' exposition, which is otherwise quite cumbersome, we avoid writing out the argument in G as well as the explicit expressions from $\frac{\partial Q_{t,II}}{\partial(-b_t)}$ and $\frac{\partial Q_{t,II}}{\partial e^{\epsilon_t}}$ from Equations (9) and (10). The signs of these expressions are sufficient for our purposes in these two derivations.

This prediction has strong economic intuition given that lower A_t, by limiting the availability of funds for arbitrageurs' arbitrage activity and thus inducing greater LOA, should make their FX swap supply more rigid and hence less responsive to a rightward shift in FX swap demand. The A_t-dependent FX swap demand channel embodied by Equation (13) can also be equivalently referred to as the LOA-dependent FX swap demand channel (as done in the previous sections as well as hereafter), which is the central object of study of this paper.

Figure 1 qualitatively depicts the LOA-dependent FX swap demand channel. There are two noteworthy facts from this figure. First, to most vividly convey the crux of the LOA-dependent FX swap demand channel, we focus on the two extreme cases of perfectly *elastic* FX swap supply (leftward panel of the figure, i.e., LOA state) and perfectly *inelastic* FX swap supply (rightward panel of the figure, i.e., No LOA state). While the precise manifestation of these cases in our model depends on what is assumed about the asymptotic behavior of $G''(:)$, one can view these cases as reasonable proxies for states of abundant versus scarce levels of initial arbitrage capital.

Second, Figure 1 reflects the fact that an LOA state corresponds to both a steeper and a more leftward FX swap supply curve in our model. That is, having an initially lower arbitrage capital implies not only a steeper FX swap supply curve but also a lesser quantity of FX swaps and wider basis. Hence, while the core of our demand channel lies in the effect of A_t on the slope of the FX swap supply curve, for completeness we also reflect A_t's shifting effect on this curve in Figure 1.

4 Institutional Background

This section lays out information about the IIs in Israel and the environment in which they operate in the context of their FX swap activity.

Definition of IIs. IIs are broadly defined as financial intermediaries who pool funds from numerous investors and invest these funds in various financial assets on behalf of these investors. The BOI's definition of IIs in Israel that guides its collection of the transaction-level II FX flow data treats IIs as the universe of entities that manage the public's long-term savings in Israel. Such entities include pension funds, provident funds, severance pay funds, advanced training funds,[9] and life insurance policies.[10] IIs are important players in the Israeli financial market, managing 770.81 billion dollars on behalf of the public as of December 2021, which is 47% of the public's entire financial asset portfolio and 160% of GDP.

Regulatory Background. Until 2003, 70% of pension funds' investments, which comprise roughly 50% of total IIs' investment, were allocated to earmarked government bonds. In a watershed regulatory change, that occurred in 2003, the Israeli government lowered this 70% threshold to 30%, thereby triggering a gradual increase in IIs' investment in foreign assets as a share of total assets. Moreover, in 2008 the Israeli government enacted compulsory pension arrangements for all workers, further increasing the portfolio managed by IIs while pushing them to seek alternatives to their investments in Israel.[11] Against this regulatory backdrop, IIs' have already allocated roughly 10% of their assets to foreign ones in the beginning of our sample (which starts in 2008) and have steadily raised this share to over 29% at the end of our sample (2021).

IIs' FX Swap and Spot Trading. To fund their foreign investments, IIs can either do spot trades where they sell NIS and buy USD or FX swap trades where they do opposing spot and forward trades. To gain an understanding about which one of these two options is favored by them, Figure 2 shows the evolution of accumulated daily FX swap (solid line) and spot (dashed line) flows for 1/7/2008-3/31/2022. (This sample is chosen to accord with our empirical analysis's baseline sample.) Negative accumulated swap and spot flows' values represent the accumulated

[9] The name 'advanced training fund' is somewhat misleading. In its inception, this fund was designed to be a tax-deductible saving vehicle to further one's education. Nowadays, it serves as a means to invest long-term.

[10] Mutual funds and exchange traded funds, whose investment is mostly for short- and medium-term purposes, are not included in the BOI's definition of IIs. In terms of the type of financial firms (rather than types of funds) which comprise our sample, the universe of investment banks and insurance companies are the entities managing the public's long-term savings in Israel for our sample (i.e., they are the owners of the funds that manage the public's long-term savings). Commercial banks, who have been banned in 2004 from managing the public's long-term savings in Israel, are thus excluded from the list of entities that comprises our sample.

[11] These regulatory changes have taken place against the backdrop of a 2001 regulatory shift from defined benefit to defined contribution pension plans, which is yet another historical regulation-driven growth source for Israeli IIs' portfolios.

spot selling of foreign currency; positive values represent the accumulated buying of foreign currency. In accordance with the literature, this paper's focus is on the *dollar* basis; hence, the FX flows shown in Figure 2 represent only trades in the currency pair USD/NIS.[12]

The FX swap flow series takes into account the offsetting forward flows from the associated second leg of each trade. As such, in accordance with our structural model and the literature's interpretation of the FX swap market as a vehicle for obtaining FX-risk-free collateralized dollar funding, the accumulated flow series represents IIs' FX-swap-market-implied dollar loan balance. Equivalently, this accumulated series can also be interpreted as IIs' FX-swap-induced open position on the dollar, where positive values represent a short such position.[13]

There are two noteworthy facts that are borne out by Figure 2. First, for most of the sample, Israeli IIs have obtained dollar funding through spot trades moderately more than through swap trades. But the two alternatives are quite comparable. And towards the end of the sample the FX-risk-free funding alternative of FX swaps surpasses the spot based alternative, with the accumulation of swaps reaching a peak of 80.1 Billion dollars on 1/25/2022 compared to a corresponding accumulated spot value of 49.9 Billion dollars.[14]

Sectoral Comparison of FX Swap Flows. Figure 3 shows the evolution of accumulated daily aggregate FX swap flows for 1/7/2008-3/31/2022 for three additional sectors on top of the IIs sector (which, for completeness, is also included in the figure): real sector, which represents the net FX flows from swap transactions involving Israeli exporters and importers; local arbitrageurs

[12]85.9% of IIs' FX swap flow volume is in dollars. The remaining share is almost entirely in euros (11.4%) and pounds (1.8%). 87.8% of IIs' FX spot volume is done in dollars, with the remaining share also almost entirely done in euros (9.7%) and pounds (1.6%).

[13]While we do not have the starting level of IIs' open position prior to our sample's inception, and hence the accumulated swap flows are only a proxy for the associated open position, FX swap flow activity was quite modest prior to 2008 thereby implying that the latter proxy should be quite accurate. In any case, since we are interested in the *changes* in IIs' open FX swap position (rather than their level) for this paper's purposes, this issue is of null importance to our analysis.

[14]Outright forwards constitute an additional FX trade category that IIs use and is not shown here due to its irrelevance to this paper's analysis. This irrelevance is rooted in cross-currency basis being the price of FX swaps, thus rendering the understanding of the drivers of CIP deviations tantamount to the understanding of the workings of the FX swap market (see Du and Schreger (2022) and references therein). IIs use outright forwards to hedge against the FX risk from increases in their foreign stocks portfolio, an hedging mechanism that underlies the equity hedging channel of exchange rate determination (Nathan and Ben Zeev (2022)).

sector, which includes Israeli commercial banks, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms; and foreign arbitrageurs sector, which includes all foreign firms engaged in financial activity (i.e., foreign commercial and investment banks, pension and insurance funds, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms).[15]

Our sectoral decomposition follows our structural model from the previous section which underscores arbitrageurs as IIs' central counterparty in their FX swap trades. Although our model does not differentiate between local and foreign arbitrageurs, we present local and foreign arbitrageurs separately in Figure 3 to be consistent with our separate consideration of them in our empirical analysis. This consideration is motivated by the fact that foreign arbitrageurs' global nature and size advantage arguably render them to be the potentially more relevant counterparties conditional on an aggregate demand shock to IIs' FX swap demand in the LOA state.

Figure 3 demonstrates that the sole effective buyers of dollar swaps among market participants are IIs, against which the two sellers of dollar swaps are the foreign and local arbitrageurs sectors. The real sector is a net buyer of dollar swaps but its activity is negligible. That the foreign and local arbitrageurs sectors act as sellers of dollar swap is consistent with the modeling approach taken in the previous section which assumes that arbitrageurs are IIs' counterparties, supplying IIs' their demanded FX swaps.

IIs' Aggregate Cross-Currency Basis. We end this section with an exposition of the aggregate cost of IIs' FX swaps, as measured by cross-currency basis and defined in the usual way as the difference between the dollar Libor rate and CIP-implied rate, facing IIs over our sample. The availability of both spot and forward rates in our transaction-level dataset allows us to construct this IIs-specific basis as the volume-weighted average of the associated transaction-level bases. Figure 4 shows the evolution of the latter measure of IIs' aggregate basis. For comparison purposes we also depict in this figure the market-wide 1-, 3-, and 6-month USD/NIS cross currency market-wide bases constructed from spot and forward rate data from Thomson Reuters.

It is clear that Israeli IIs, as did many of their international counterparts, faced a meaningful

[15]The foreign *real* sector's FX swap volume is negligible and is therefore excluded from Figure 3.

cost of obtaining dollar funding from the FX swap market for our considered sample period. The mean of IIs' aggregate basis is -43.3 basis points. This meaningful average also embodies significant volatility, with the basis actually being positive early on in the sample but then starting to become negative in early 2009 and remaining in this negative territory pretty throughout the vast majority of the sample. Encouragingly, our transaction-level based IIs' basis is very similar to the market-wide Thomson Reuters based ones, with correlations between our basis and the 1-, 3-, and 6-month bases standing at 85.1%, 93.9%, and 90.5%, respectively. (The means of the Thomson Reuters based bases are -44.1, -44.2, and -37.2 basis points.)

5 Methodology

This section elucidates the methodology used in the empirical analysis undertaken in this paper. We first describe the data used in the estimation after which we turn to present the general lines of the estimation. Further technical details of our estimation approach are shown in Appendix A of the online appendix to this paper.

5.1 Data

Our data is daily and covers the period 1/7/2008-3/31/2022. The specific starting and ending points of this approximate 14-year period are dictated by the availability of the Bank of Israel (BOI) proprietary FX swap data.

5.1.1 FX Swap Flows and Prices Data

We have proprietary transaction-level data covering both quantities and prices (spot and forward rates) for Israeli IIs as well as local (Israeli commercial banks, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms) and foreign arbitrageurs (represented by all types of foreign financial firms and institutions). We also have such data for the local and foreign real sectors but in our empirical analysis we abstract from these additional sectors because they are insignificant players in the FX swap market.

FX Swap Flows. We construct from our micro data aggregate FX swap flow series for IIs and local and foreign arbitrageurs sectors. The aggregate FX swap flow variable for a specific sector measures (in dollars) the daily net change in the corresponding sector's open swap position. This position is calculated from the net transaction flows from the sector's buying and selling of U.S. dollars on the FX swap market, while accounting for such flows from both legs of the swap trades. A positive (negative) value for this variable for a given observation when the sector was a net buyer (seller) of swap-linked dollars on the corresponding day. While we do not have the starting level of the sectors' open position prior to our sample's inception, and hence the accumulated swap flows are only a proxy for the associated sectoral open position, FX swap flow activity was quite modest prior to 2008 for USD/NIS thereby implying that the latter proxy should be quite accurate. In any case, since we are interested in the *changes* in a sector's open FX swap position (rather than their level) for this paper's purposes, this issue is of null importance to our analysis.

Table 1 presents the maturity distribution in the FX swap market by sector. (For completeness - in addition to the central II and local and foreign arbitrageurs sectors - we also include the local real sector in this table.) The median maturity of IIs' FX swap trades is 54 days where as that for local and foreign arbitrageurs are 7 and 3 days, respectively, highlighting an interesting maturity gap between the major short and long dollar swap position holders. Local banks, who in addition to their local arbitraging role are also the main market makers in the USD/NIS FX swap market against which IIs conduct the majority of their swap trades (roughly 83% - with the remaining share being conducted against foreign financial firms), face the task of managing the risk from this maturity mismatch.

We restrict attention to USD/NIS trades given our literature-consistent focus on the *dollar* basis. (85.9% of our local IIs' FX swap volume is done in dollars, with the remaining small 14.1% share almost entirely done in euros (11.4%) and pounds (1.8%).)

II-Level FX Swap Flows. Our GIV-based identification comes from our ability to observe transaction-level FX swap flows for individual IIs. There is a total of 14 such IIs on which we base our GIV-based identification procedure. These IIs are the universe of asset managers in Israel managing its public's long-term savings and comprise of investment banks and insurance companies. The long-term savings industry in Israel is quite concentrated, as reflected by an average Herfindahl-Hirschman Index of 0.26 for IIs' (absolute) open FX swap positions.[16]

It reasonable to expect only modest correlation among our 14 IIs' FX swap flows given the high-frequency (daily) nature of our data. This expectation is borne out by the data with an average absolute pairwise correlation among the 14 IIs of 12.6% and a corresponding standard deviation of 8.9%. Importantly, by removing the effects on these flows of various common drivers, our estimation procedure is capable of materially reducing these numbers to 3.1% and 2.5%, respectively. I.e., the high-frequency nature of our data along with the suitability of our estimation procedure facilitate the extraction of daily idiosyncratic II-level FX swap demand shocks whose sum provides a valid IV for the testing and quantification of our LOA-dependent FX swap demand channel.

IIs' FX Swap Prices. We construct a direct measure of IIs' aggregate basis by computing a volume-weighted average of their associated transaction-level bases. This is made possible for us by the availability of the spot and forward rates underlying each transaction in our dataset. Transactions' bases are computed the standard way as the difference between the cash market risk-free dollar interest rate at the corresponding maturity and the CIP-implied dollar interest rate (i.e., forward premium multiplied by gross local risk-free rate). Note that these transaction-level bases represent the *actual* price incurred by IIs from tapping into the FX swap market for FX funding; hence, the aggregate basis variable at our disposal measures the actual cost of FX swaps facing the IIs sector.

The dollar risk-free interest rate is measured by Libor. To construct the CIP-implied dollar rate, we use the Tel Aviv Inter-Bank Offered Rate (Telbor) as our measure of the Israeli cash market risk-free interest rates. (Telbor is based on interest rate quotes by a number of commercial banks in the Israeli inter-bank market.) As IIs' swap transactions' maturity distribution is fairly continuous, we use linearly interpolated interest rates from the 1-, 3-, 6- and 12-month maturities' Thomson Reuters interest rate values to computes the transaction-specific interest rates.

[16]Only one II in our sample consistently holds long, rather than short, open FX swap positions. All other IIs consistently hold short such positions.

5.1.2 Market-Wide USD/NIS Cross-Currency Bases

To provide external validity for our sample of contracts, we also construct the USD/NIS cross-currency bases for the 1-, 3-, and 6-month maturities in the standard way, i.e., as the difference between the cash market risk-free dollar interest rate at the corresponding maturity and the CIP-implied dollar interest rate (i.e., forward premium multiplied by gross local risk-free rate). To construct these bases, we use the Thomson Reuters 4:00 PM London time spot and forward rate data as well as Thomson Reuters end-of-day quotes for USD and NIS interest rates (Libor and Telbor).

5.1.3 Additional Macro-Financial Data

We use several daily frequency macro-financial variables in our analysis, all of which cover the baseline empirical sample of 1/7/2008-3/31/2022. These variables are taken from Bloomberg and their values are end-of-day quotes.

LOA Measure. Building on the intrinsic link between intermediaries' funding capacity and LOA (Shleifer and Vishny (1997)) (also see discussion from Footnote 4), we measure LOA with the daily market leverage series from He et al. (2017).[17] This variable is an aggregate capital ratio for the intermediary sector, which is defined as set of primary dealers - a select group of financial intermediaries that serve as trading counterparties to the Federal Reserve Bank of New York in its implementation of monetary policy, and is computed as the ratio between the sum of this sector's market equity and the sum of its market equity and book debt value (i.e., a value-weighted average of intermediaries' capital ratios).

He et al. (2017) experiment with both the raw intermediary capital ratio and the squared intermediary capital ratio to capture intermediary sector soundness. As our baseline measure of LOA, we use the squared version of their measure since it is likely that this measure better captures non-linearities in this sector's soundness. Nevertheless, we demonstrate the robustness of our results to using the raw intermediary capital ration in Appendix B.1 of the online appendix to this paper.

[17] This data is available at https://voices.uchicago.edu/zhiguohe/data-and-empirical-patterns/intermediary-capital-ratio-and-risk-factor/.

VIX. The VIX is a volatility index measures the near-term expected volatility of the S&P 500 Index and is calculated from real-time S&P 500 Index European options with an average expiration of 30 days. We use its log-first-differences (in lagged and current form) in the micro-level regressions that identifies the idiosyncratic FX swap demand shocks to control for global uncertainty shocks.

Broad Dollar Index. The broad dollar index is a trade-weighted U.S. dollar index measuring the value of the dollar relative to other world currencies while updating the weights yearly. We use its log-first-differences (in lagged and current form) in the micro-level regressions that identifies the idiosyncratic FX swap demand shocks to control for global risk appetite shocks (Avdjiev et al. (2019)).

S&P 500 and TA-35 Indices. The commonly used S&P 500 is our measure of global stock prices while the TA-35 index is our measure of local stock prices, with the two indices listing the largest 500 and 35 companies in U.S. and Tel-Aviv Stock Exchanges, respectively. We include current and lagged values of the log-first-differences of these two indices in the micro-level regressions that identify the idiosyncratic FX swap demand shocks so as to ensure that these shocks do not capture endogenous demand variation due to variation in stock market performance in the U.S. and Israeli stock markets. Notably, the inclusion of the local stock market return variable also serves to ensure that shocks specific to the Israeli economy are not contaminating our identification.

USD/EUR Cross-Currency Bases. To ensure that our FX swap demand shock is unrelated to variation in frictions in the global FX swap market, we control for current and lagged values of the first-differences of the 1- and 12-month USD/EUR cross-currency bases in the regression that identifies the FX swap demand shock. We compute these bases correspondingly to how we compute the USD/NIS ones, taking the 1- and 12-month Euribor rates as the risk-free rates for the Euro. As explained in Footnote 19, these two maturities are sufficient for our purposes given the high correlations between the first differences of the 1- and 3-month bases and the 6- and 12-month bases.

5.2 Estimation

We estimate a daily frequency Bayesian state-dependent local projection model whose core lies in the granular instrumental variable (GIV) approach from Gabaix and Koijen (2020). The estimation proceeds in two steps. In the first, we identify idiosyncratic FX swap demand shocks from 14 micro-level regressions of our IIs' swap flows on their own raw lags, the interactions of their current and lagged values with the one-day lagged value of the funding index, and a rich array of controls which capture FX swap supply- and demand-side factors.

This rich specification ensures that the micro-level innovations to the IIs' FX swap series from the micro-level regressions represent well idiosyncratic FX swap demand shocks. We think about these idiosyncratic shocks in terms of our structural model from Section 3, i.e., as representing idiosyncratic changes in IIs' geographical portfolio preferences. (Also see related discussion in Footnote 2.) In the second step, we run local projection regressions of IIs' cross-currency basis on the sum of the 14 idiosyncratic micro-level FX swap demand shocks from the first estimation step as well as on the interaction between this sum and the one-day lagged LOA measure. This allows us to estimate the LOA-dependent dynamic effect of the FX swap demand shock on the basis.

The sum of the 14 idiosyncratic micro-level FX swap demand shocks provides an aggregate shock to IIs' FX swap demand in the spirit of Gabaix and Koijen (2020). In particular, each of the idiosyncratic demand shocks represents an exogenous shift to the corresponding II's FX swap demand curve. Hence, summing these shocks produces a shock (shifter) to IIs' aggregate FX swap demand. Note that we can not use Gabaix and Koijen (2020)'s suggestion to construct the aggregate demand shock as the difference between size- and equal-weighted averages of the idiosyncratic shocks because our FX swap flow variables takes on negative values in addition to positive values thus devoiding the meaningfulness of any attempt to form a size-weighted mean of the idiosyncratic shocks. Taking the sum of the idiosyncratic shocks to be the aggregate demand shocks circumvents this issue and, importantly, echoes the powerful insight from Gabaix and Koijen (2020) on the benefit from using granular exogenous demand shocks for the identification of aggregate demand shifters.

5.2.1 Econometric Model

Specification. We estimate the following two-stage model:

$$\Delta SP_{i,t} = \alpha_{i,0,L} + \alpha_{i,1,L}\mathbb{T}_t + \Gamma_i \mathbb{D}_t + \beta_{i,1,L}\Delta SP_{i,t-1} + \cdots + \beta_{i,p_i,L}\Delta SP_{i,t-p_i} \tag{14}$$
$$+ LOA_{t-1}\Big(\alpha_{i,0,I} + \alpha_{i,1,I}\mathbb{T}_t + \beta_{i,0,I}\Delta SP_{i,t} + \cdots + \beta_{i,p_i,I}\Delta SP_{i,t-p_i}\Big)$$
$$+ A_{i,1}\Delta b_{t-1} + ... + A_{i,p_i}\Delta b_{t-p} + C_{i,0}Z_t + ... + C_{i,p_i}Z_{t-p_i} + \epsilon_{i,t},$$
$$b_{t+h} - b_{t-1} = \alpha_{2,L,h} + \Xi_{L,h}\hat{\varepsilon}_t + LOA_{t-1}\Big(\alpha_{2,I,h} + \Xi_{I,h}\hat{\varepsilon}_t\Big) + u_{t+h}, \tag{15}$$

where i and t index IIs and time at daily frequency; $\alpha_{i,0,L}$ is the fixed effect, $\mathbb{T}_t$ is a time trend, and $\mathbb{D}_t$ is a day-dummy matrix containing binary variables for Monday through Thursday with corresponding matrix coefficient Γ_i; $\Delta SP_{i,t}$ is II i's FX swap flows (i.e., the first-difference of this II's open FX swap position); LOA_{t-1} is the deviation of the He et al. (2017)'s squared intermediary capital ratio variable at $t-1$ from its mean divided by this variable's standard deviation; p_i denotes the number of lags for II i's equation;[18] $A_{i,j}$ ($j = 1, ..., p_i$) are coefficient scalars and Δb_{t-j} is lagged aggregate IIs' cross-currency basis; $C_{i,s}$ ($s = 0, ..., p_i$) are 1×8 coefficient vectors and Z_{t-s} are 8×1 variable vectors whose components are detailed below; $\epsilon_{i,t} \sim i.i.d.\ N(\mathbf{0}, \sigma^2_{i,\epsilon})$ is Equation (14)'s residual (i.e., true idiosyncratic FX swap demand shock for II i) where $\sigma_{i,\epsilon}$ is its standard deviation; b_t is IIs' cross-currency basis; h is Regression (15)'s rolling horizon ($h = 0, ..., H$); $\hat{\varepsilon}_t = \sum_{i=1}^{14} \hat{\epsilon}_{i,t}$ is the sum of estimated residuals from Equation (14) (this sum is normalized to have unit standard deviation), i.e., the estimated aggregate IIs' FX swap demand shock; and $u_{t+h} \sim i.i.d.\ N(\mathbf{0}, \sigma^2_{u,h})$ is Equation (15)'s residual where $\sigma_{u,h}$ is its standard deviation.

Identification. To be internally consistent, we identify the idiosyncratic FX swap demand shocks from Equation (14) by regressing IIs' swap flows on both their raw lags, whose associated coefficients are with index L as they represent the *linear* part of that equation, as well as on the interactions between the one-day lagged LOA variable and current and lagged IIs' swap flows, whose

[18] We compute the AIC, corrected AIC, BIC, and HQIC lag length criteria tests for each II i's regression. For the baseline case, we take the average lag specification across the latter four considered tests for each II-level regression. The average lag across the different II-level specifications is 13.3 with a standard deviation of 5.5. We show the robustness of our results to alternative lag specifications in online appendix's Section B.3.

associated coefficients are with index I as they represent the nonlinear (interaction-terms) part of Equation (14). The inclusion of the interaction between the one-day LOA variable and the current value of IIs' swap flows ensures that the identified idiosyncratic shock do not erroneously capture the interaction of the true shock with the one-day lagged LOA variable. And we separately control for the one-day lagged LOA variable to ensure that our identified idiosyncratic shocks do not erroneously pick up the effects of greater/lesser LOA.

Disciplined by our structural model, we also project onto a rich array of additional variables in Equation (14) to ensure the validity of our identification. The inclusion of lagged first-differences of IIs' aggregate cross-currency basis purge from our identified idiosyncratic shocks any variation related to the past dynamics of aggregate FX swap prices. And variable vector Z_{t-s} includes the following variables: log-first-differences of S&P 500 and TA-35 indices and first-difference of the spread between the 3-month Libor and Telbor rates, the inclusion of which ensures that foreign and local equity price and interest rate spread changes are not driving our results; log-first-difference of VIX and broad dollar index, the controlling of which ensures our identified idiosyncratic shocks are unrelated to global uncertainty and risk appetite shocks, respectively; first-differences of USD/EUR 1- and 12-month cross-currency bases,[19] the controlling of which removes the possibility that our identified idiosyncratic shocks capture shocks to frictions in the global FX swap market; and first-differences of the LOA variable, whose inclusion assures our identified idiosyncratic shocks are not picking up *changes* in LOA.[20]

A crucial element of our econometric model is that we allow for all of the coefficients in Equation (14) to vary with i. Technically, this implies that we separately estimate this equation for each of our 14 IIs. Substantively, this heterogenous coefficient setting allows us to remove common variation in IIs' FX swap demand arising not only from the common variables in Equation (14) but also from the *way* by which IIs' respond to these variables. This is important because in addition to time-invariant differences across IIs' swap demand (captured by fixed effect $\alpha_{i,0,L}$) there are

[19]While results are robust to including the first-differences of the 3- and 6-month EUR/USD bases, the former has a 70% correlation with the 1-month basis and the latter has an 85% correlation with the 12-month basis. Hence, the 1- and 12-month bases appear to be sufficient for capturing the frictions present in the global FX swap market. (The correlation between these two variables is 41%.)

[20]The merit of Specification (14) is borne out by its high average R^2 of 84.8% across the 14 II-level regressions.

also time-varying such differences stemming from heterogenous sensitivities of IIs' to both lagged II-specific FX swap flows and common FX swap market drivers. The latter heterogeneity is what our heterogenous coefficient setting precisely accounts for, resulting in a panel of 14 idiosyncratic demand shocks that exhibit a mere average absolute pairwise correlation of 3.1% with a standard deviation of 2.5%.

The coefficients of interest are $\Xi_{L,h}$ and $\Xi_{I,h}$ from Equation (15), whose central explanatory variable is the aggregate FX swap demand shock constructed as the sum of the estimated 14 idiosyncratic demand shocks from Equation (14). Building on the conceptual base provided by our structural model, we construct the effects of a one standard deviation aggregate FX swap demand shock (sum of 14 estimated idiosyncratic demand shocks) in the LOA state on cross-currency basis at horizon h as $\Xi_{L,h} + 2\Xi_{I,h}$, i.e., the LOA state is defined by the LOA variable being 2 standard deviations higher than its mean. The 2 value corresponds to the 96th percentile of the LOA variable's distribution. Interpreted through the lens of our model's conceptual framework, $\Xi_{L,h} + 2\Xi_{I,h}$ captures the effects of an FX swap demand shock conditional on the supply curve of FX swaps being significantly rigid. For comparison purposes, we will also show the linear responses (i.e., $\Xi_{L,h}$) which give the effects of the aggregate FX swap demand shock when LOA variable is at its mean value; hence, these responses will inform us about the effects of the aggregate FX swap demand shock when there are no meaningful LOA.

Let the stacked K_ix1 $B_i = [\alpha_{i,0,L}, ..., C_{i,p_i}]'$ (K_i is the number of parameters for the RHS of Equation (14)) and 5x1 $Q_h = [\alpha_{2,L,h}, ..., \gamma_h]'$ matrices represent the coefficient matrices from Equations (14) and (15), respectively. I.e., the parameters to be estimated from these two equations can be summarized by coefficient matrices B_is and residual variance $\sigma^2_{i,\epsilon}$ for Equation (14) and coefficient matrix Q_h and residual variance $\sigma^2_{u,h}$ for Equation (15). (These nomenclatures will be used in Appendix A of the online appendix to this paper to facilitate this appendix's detailed depiction of the inference and estimation procedure for Equations (14) and (15).)

Impulse Response Estimation Method. We estimate Equations (14) and (15) jointly by applying the Bayesian estimation algorithm for strong block-recursive structure put forward by Zha (1999) for block-recursive VARs, where the likelihood function is broken into the different recursive blocks. In our case, we only have two blocks, where the first consists of Equation (14) and the second contains Equation (15). As shown in Zha (1999), this kind of block separation along with the standard assumption of a normal-inverse Wishart conjugate prior structure leads to a normal-inverse Wishart posterior distribution for the block-recursive equation parameters.

To account for temporal correlations of the error term in Equation (15), we apply a Newey-West correction to the standard errors within our Bayesian estimation procedure. In doing so we accord with the reasoning from Miranda-Agrippino and Ricco (2021), who estimate a hybrid VAR-local-projections model and follow the suggestion from Müller (2013) to increase estimation precision in the presence of a misspecified likelihood function (as in our and their setting) by replacing the original posterior's covariance matrix with an appropriately modified one. Moreover, given the high-frequency nature of our data and the general tendency of impulse responses from local projections to exhibit jaggedness, we apply the smoothing procedure from Plagborg-Møller (2016) to our estimated raw impulse responses. (Details on this smoothing procedure are provided in Appendix A of the online appendix to this paper.)

FEV Estimation Method. For the forecast error variance (FEV) decomposition estimation, we utilize the estimated (smoothed) GAC-dependent impulse responses to compute the GAC-dependent FEV contributions of our swap demand shock as follows:

$$\mathbb{C}_{LOA,h} = \frac{\mathbb{V}(\hat{\epsilon}_t \mid LOA)\left(\hat{\Xi}_{L,0} + 2\hat{\Xi}_{I,0}\right)^2 + ... + \left(\hat{\Xi}_{L,h} + 2\hat{\Xi}_{I,h}\right)^2}{\mathbb{V}(b_{t+h} - b_{t-1} \mid LOA)}, \tag{16}$$

$$\mathbb{C}_{NLOA,h} = \frac{\hat{\Xi}^2_{L,0} + ... + \hat{\Xi}^2_{L,h}}{\mathbb{V}(b_{t+h} - b_{t-1})}, \tag{17}$$

where $\hat{\Xi}_{L,h}$ and $\hat{\Xi}_{I,h}$ are the estimated linear and nonlinear (interaction-term) impulse response coefficients from Equation (15); LOA and $NLOA$ correspond to the LOA state and non-LOA (linear) state, respectively; $\mathbb{V}(b_{t+h} - b_{t-1} \mid LOA)$ represents the variance of IIs' cross-currency basis' accumulated differences conditional on the LOA state and $\mathbb{V}(b_{t+h} - b_{t-1})$ is the unconditional variance of this variable; and, similarly, $\mathbb{V}(\hat{\epsilon}_t \mid LOA)$ is the estimated aggregate FX swap demand shocks' variance conditional on the LOA state, respectively.

Operationally, we define the LOA state as the group of observations where the LOA series values are above or equal to the funding index series's 92nd percentile. The rationale for this definition is based on the fact that the LOA state is defined by the LOA variable being equal to its 96th percentile value. (The funding index's 2 standard deviation value corresponds to its 96th percentile.) Hence, we define the variance conditional on this states as the variance that results from considering observations that closely and symmetrically surround the LOA state value but at the same time delivers a sufficient number of observations for FEV estimation. The non-LOA state, because it corresponds to the linear effect of the aggregate FX swap demand shock, is defined in an unconditional sense on the basis of all observations - i.e., the variance of both the aggregate FX swap demand and IIs' cross-currency basis' accumulated differences conditional on this state are simply the *unconditional* variances.[21] (Recall that the unconditional variance of the aggregate FX swap demand shock is unit and hence does not appear in Equation (17).)

6 Empirical Evidence

This section presents the main results of the paper. In all considered figures, solid lines represent the median LOA-dependent responses of the corresponding variable to a one standard deviation shock to aggregate IIs' FX swap demand while dashed lines depict 95% posterior confidence bands; 600 daily horizons are considered. Note that these 600 horizons represent IIs' FX swap active trading days. After accounting for non-swap-activity days on the part of IIs, these 600 horizons roughly reflect 3 calendar years. To further our understanding of the quantitative importance of the LOA-dependent FX swap demand channel, we also present forecast error variance (FEV) decomposition results for our cross-currency basis variables. After showing the results for currency bases, we turn to the results for the IIs' open FX swap position variable.

[21] In the spirit of Gorodnichenko and Lee (2020)'s FEV method for local projections (termed LP-B in their paper) which ensures that the computed FEV share does not exceed one, we compute the denominator in Equations (16) and (17) as the sum of the corresponding numerator and the variance (conditional one for Equation (16) and unconditional one for Equation (17)) of the residual from Equation (15)'s implied moving average decomposition. (As in the empirical results whose presentation follows next, this moving average decomposition is based on estimated impulse responses up to the 600th horizon, which covers roughly 3 years of calendar years after accounting for non-swap-activity days on the part of IIs.) While asymptotically this alternative way of computing the variance in the denominator is equivalent to computing it from the actual data, the latter computation in finite samples can lead to estimated FEV shares that exceed one.

6.1 IIs' Cross-Currency Basis' Impulse Responses

Figure 5 shows the LOA-dependent effects of a one standard deviation aggregate FX swap demand shock on the aggregate (volume-weighted) IIs' basis. The first two columns of the figure present the effects of the shocks in the LOA state and the linear (no LOA) case, respectively. The third column of the figure shows the difference between the impulse responses in the LOA state and linear case.

The results demonstrate a significant and persistent widening of the basis in response to the aggregate FX swap demand shock in the LOA state. There is a significant widening of the basis on impact of 4.5 basis points with the dynamics of this effect exhibiting a hump-shaped pattern, peaking at 9 basis points after 373 trading days. Notably, the effect maintains its significance for 528 trading days.

In contrast to the LOA-state-dependent responses, the linear (no LOA) response is both economically and statistically insignificant for all considered horizons. Therefore, the magnitude and the persistence of the differences between the responses in the LOA state and linear case are similar to those observed for the LOA-state-dependent responses. Response differences across the LOA state and linear case remains significant for 541 trading days.

In sum, the results from Figure 5 support the story from our structural model. When LOA are meaningful, FX swap supply is sufficiently rigid such that a favorable aggregate FX swap demand shock causes a significant widening of the basis. And our dynamic framework allows us to uncover a significant persistence to this LOA-dependent mechanism. By contrast, when LOA are not meaningful (the linear case), FX swap supply is sufficiently elastic so as to prevent from the favorable aggregate FX swap demand shock to widen the basis. We now turn to the FEV results.

6.2 IIs' Cross-Currency Basis' FEV

Figure 6 shows the LOA-dependent contributions of the aggregate FX swap demand shock to the FEV of IIs' basis. The FX swap demand shock's peak contribution is 79%, taking place at the 514th horizon. That the swap demand shock accounts for such a meaningful FEV share indicates that the LOA-dependent FX swap demand channel we uncover in this paper is quantitatively important for explaining IIs' cross-currency basis' variation. Specifically, the dynamic nature of our analysis, by capturing the persistence of the basis' response, is the crucial element in allowing the estimation of this quantitative importance.

In contrast to the LOA state, the second column of Figure 6 shows that FEV contributions in the linear (no LOA) case are negligible, peaking at 2.4% (600th horizon). These unimportant FEV shares are consistent with the view that our linear case captures an elastic FX swap supply curve. The third column of Figure 6 confirms that the economically large differences between the FEV shares across the LOA state and the linear case are also statistically significant, showing significant differences for all 600 considered horizons.

6.3 IIs' Aggregate Open FX Swap Position

To further bolster confidence in the interpretation of our results as evidence for a meaningful LOA-dependent FX swap demand channel, it is important to confirm that IIs' aggregate open FX swap position's differential response across the LOA state and the linear case accords with the latter channel. Specifically, if this channel is truly driving our results for the currency bases, then we should expect to see IIs' aggregate open FX swap position *initially* respond more strongly to the aggregate FX swap demand shock in the linear case than in the LOA state.

Figure 7 shows the LOA-dependent impulse responses of IIs' aggregate open FX swap position along with the corresponding responses for the local and foreign arbitrageurs sectors. These responses are obtained from replacing IIs' cross-currency basis' accumulated difference outcome variable in Equation (15) with the accumulated difference in each sector's aggregate open FX swap position (i.e., $SP_{t+h,j} - SP_{t-1,j}$ where $j = [IIs, LAs, FAs]$).[22] The results from Figure 7 accord well with those from Figure 5: IIs' aggregate open FX swap position increases significantly more initially in the linear case than in the LOA state, reaching a significantly greater impact response of 303.1 million dollars in the former compared to an effectively null response in the latter. This materially greater impact response in the linear (no LOA) case supports the interpretation of our results as being driven by an LOA-dependent FX swap demand channel where the linear case

[22] We also add to the RHS of Equation (15) a time trend, both separately as well as interacted with LOA_{t-1}, so as to control for possible trending behavior of IIs' and local foreign arbitrageurs' accumulated FX swap flows.

(LOA state) identifies an elastic (inelastic) FX swap supply curve.

Notwithstanding the initial response differences (in the direction of linear case response), which are significant for a total of 117 trading days, in later horizons we observe a strong persistence in the swap position's response in the LOA state which renders a significant rise in the swap position in this state for the 65th-419th horizons. In other words, while initially IIs' face difficulty obtaining funding in the FX swap market, their efforts to do so ultimately bear fruit at later horizons. This persistent effort in turn clearly places a heavy burden on the FX market, inducing significant upward pressure on FX swap prices. Hence, our results uncover an interesting propagation mechanism for the aggregate FX swap demand shock in the LOA state which rests on the persistent nature of this shock and the associated perseverant IIs' effort to ultimately obtain the funding they had set out to procure to begin with.

Who provides FX swaps to IIs following their demand shock? Figure 7 shows that in the linear case both local and foreign arbitrageurs serve as suppliers of FX swap dollars to IIs. However, in the LOA state, foreign arbitrageurs are the sole such suppliers. This finding likely stems from these institutions' greater capacity to obtain arbitrage capital in times of distress relative to local arbitrageurs.

6.4 Market-Wide Cross-Currency Basis

To externally validate our results, it is useful to also consider the response of market-wide cross-currency basis in addition to our baseline aggregate (volume-weighted) IIs' basis. Toward this end, we again estimate Equations (14) and (15) but now instead of using the aggregate IIs' basis as outcome variable in Equation (15) we use the 1-, 3-, and 6-month market-wide bases constructed from Thomson Reuters spot and forward rate data. (See Section 5.1.2 for further details on this data.)

The impulse responses and FEV results from this exercise are presented in Figures 8a and 8b, respectively. Encouragingly, results for market-wide bases are both quantitatively and qualitatively similar to the baseline ones, with the 1-, 3-, and 6-month bases exhibiting significant and persistent responses which reach peak widening of 7.3, 8.3, and 9.2 basis points after 324, 361, and 350 trading days, respectively. The corresponding peak FEV shares are 80.4%, 78.8%, and 76.9%

(at the 489th, 506th, and 515th horizons), respectively.

6.5 Robustness Checks

Appendix B of the online appendix to this paper examines the robustness of the baseline results from the previous three sections along three dimensions. The first uses He et al. (2017)'s *raw* intermediary capital ratio variable as our LOA measure instead of the squared one. The second excludes the COVID-ridden period by truncating the sample at February 28, 2020. And the last robustness check examines results' sensitivity to different lag choices in Equation (14). The results from these three robustness checks are similar to the baseline ones, bolstering confidence in this paper's message about a meaningful LOA-dependent FX swap demand channel.

7 Conclusion

The evidence provided in this paper supports a meaningful LOA-dependent FX swap demand channel. In particular, the effect of an FX swap demand shock that shifts IIs' aggregate demand for swaps rightward meaningfully depends on the initial LOA state: when LOA are meaningful, the FX supply curve is rigid thereby resulting in a significant and persistent widening of IIs' cross-currency basis; by contrast, when LOA are immaterial, the FX supply curve is elastic thereby preventing a widening of the basis.

We have obtained these results by using a bottom-up, GIV-based econometric approach that constructs the aggregate FX swap demand shock as the sum of estimated idiosyncratic demand shocks of individual IIs. And our IIs' basis measure is also based on micro data, constructed as the volume-weighted average of the *actual* basis incurred by individual IIs. That both our daily shock and outcome variables are founded on our unique transaction-level FX swap data strengthens our confidence in the validity of this paper's results.

We hope this paper's results can advance our understanding of how cross-currency basis can persistently widen in the presence of favorable FX swap demand shocks. While our results are based on Israeli data, our view is that they can be externally valid for a much broader sample of economies which posses a developed FX swap market in which local IIs are central demanders for dollars.

Finally, this paper's results have potentially meaningful policy implications. A quantitatively important LOA-dependent channel may render it optimal for policymakers looking to combat a swap-demand-driven basis widening to consider policy tools (e.g., taxation on dollar-denominated asset returns or quantity restrictions on dollar-denominated asset investments) that constrain local IIs' dollar swap demand. Studying the normative aspect of the employment of such policy tools in the presence of a meaningful LOA-dependent FX swap demand channel is a potentially fruitful avenue for future research.

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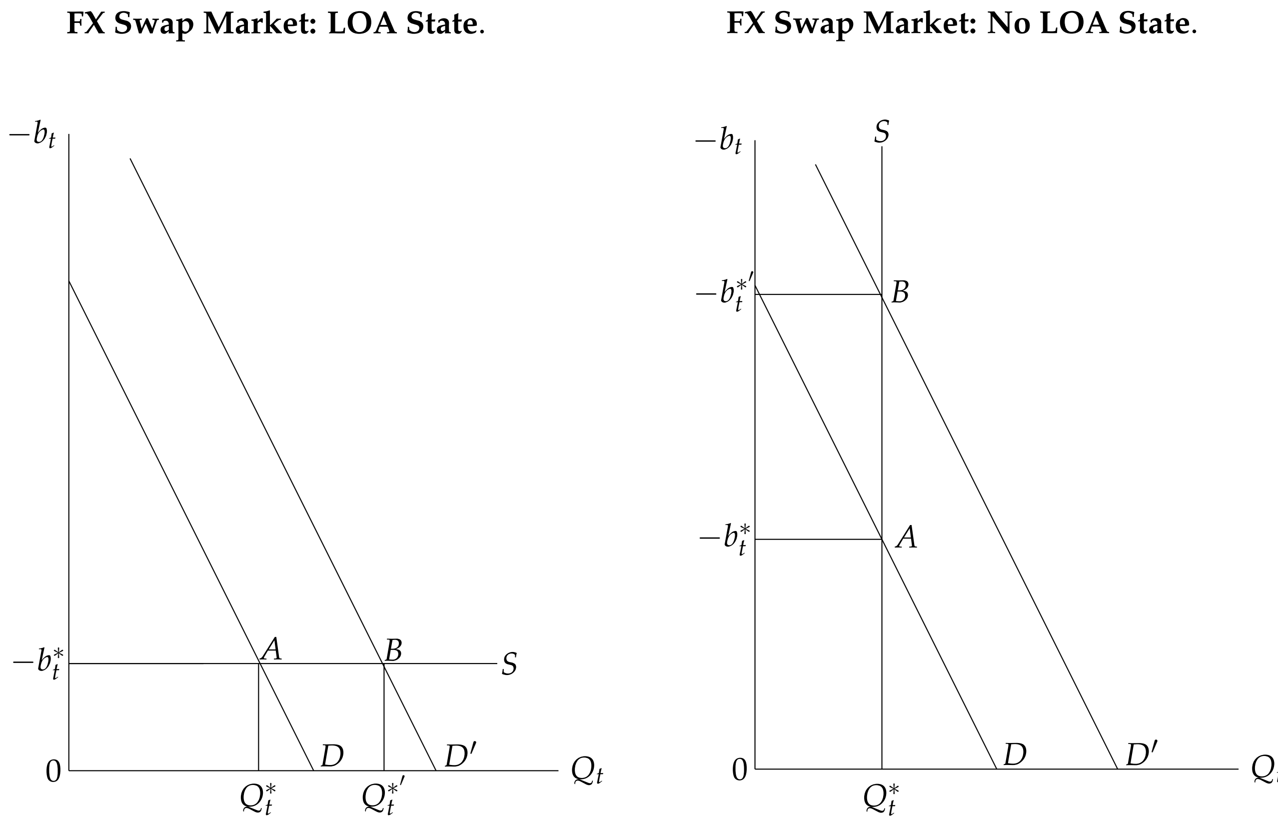
Table 1: **FX Swap Market Transactions' Maturity Distribution by Sector.**

	5th Percentile	25th Percentile	Median	75th Percentile	95th Percentile
IIs	3	21	54	84	198
Real	2	4	10	24	124
LAs	1	3	7	41	147
FAs	1	2	3	22	70
All	1	2	6	32	128

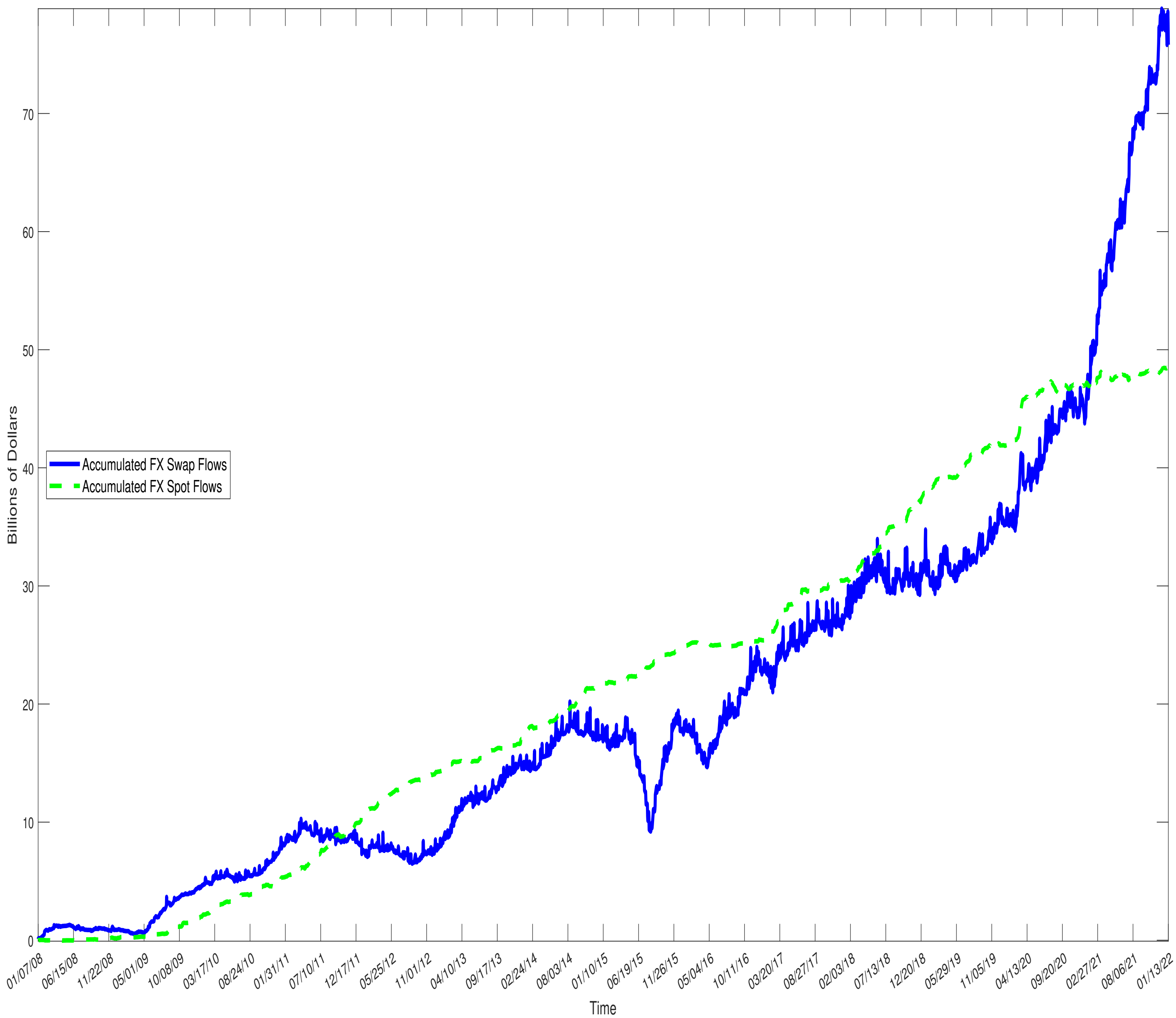
Notes: This figure presents the maturity distribution (5th, 25th, 50th, 75th, and 95th percentiles) for FX swap transactions in our transaction-level dataset broken down by sector. On top of the IIs sector, this table includes three additional sectors: real sector, which represents the FX swap transactions involving Israeli exporters and importers; local arbitrageurs (LAs) sector, which includes Israeli commercial banks, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms; and foreign arbitrageurs (FAs) sector, which includes all foreign firms engaged in financial activity (i.e., foreign commercial and investment banks, pension and insurance funds, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms). Data are from the BOI and cover 1/7/2008-3/31/2022. Maturity distributions' percentiles are in terms of days.

Figure 1: **Diagrammatic Depiction of GAC-Dependent FX Swap Demand Channel**.



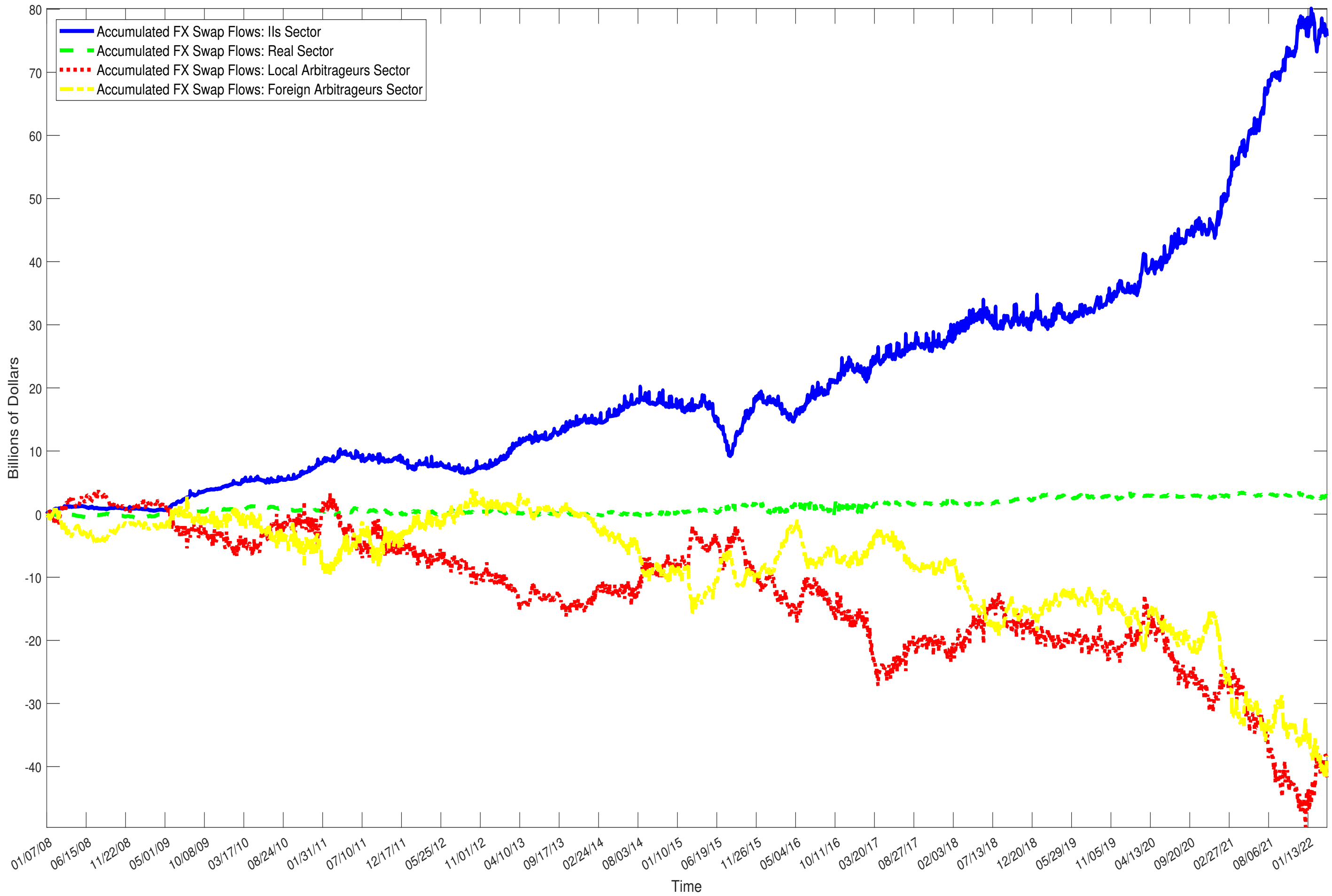
Notes: This figure provides a qualitative depiction of the LOA-dependent FX swap demand channel underlying the structural model from Section 3. The LOA (No LOA) state represents the state in which the level of A_t, i.e., the arbitrageur's arbitrage capital, is limited (adequate). b_t is cross-currency basis defined in the usual way as the difference between the cash dollar interest rate and the CIP-implied dollar interest rate. These states are assumed to correspond to the extreme cases of perfectly *elastic* FX swap supply (leftward panel of the figure, i.e., LOA state) and perfectly *inelastic* FX swap supply (rightward panel of the figure, i.e., No LOA state). The core of this demand channel lies in how the responsiveness of the basis varies across the two states in the presence of a rightward shift in FX swap demand. $-b_t$ (which is on the y-axis) represents the marginal profit that arbitrageurs make from CIP arbitrage, which can in turn be interpreted as the price of FX swaps. The quantity of FX swaps, in dollar terms, is on the x-axis.

Figure 2: **Time Series of IIs' Accumulated FX Swap and Spot Flows.**



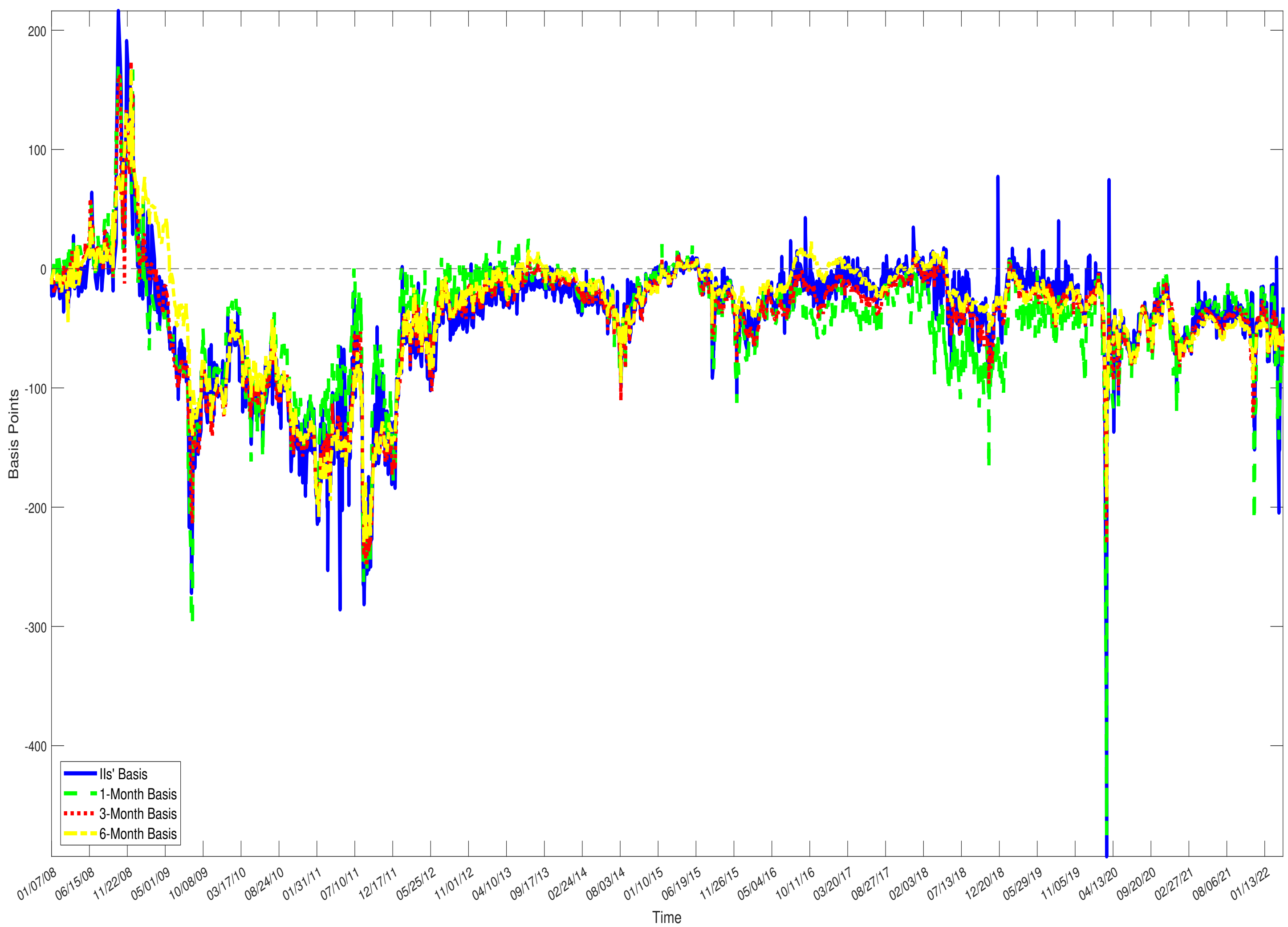
Notes: This figure presents the time series of the accumulated daily flows of IIs' FX swap (solid line) and spot (dashed line) trades in the USD/NIS currency pair. Since FX swap flows are changes in IIs' open FX swap position, their shown accumulated series can be viewed as IIs' open FX swap position. Hence, a positive (negative) value for the latter series represents an open short (long) FX swap position. Positive values for the accumulated spot flow series represent the accumulated buying of spot dollars. Data are from the BOI and cover 01/07/2008-3/31/2022. Time (in daily frequency) is on the x-axis. Values are in billions of dollars.

Figure 3: **Time Series of Accumulated FX Swap Flows by Sector.**



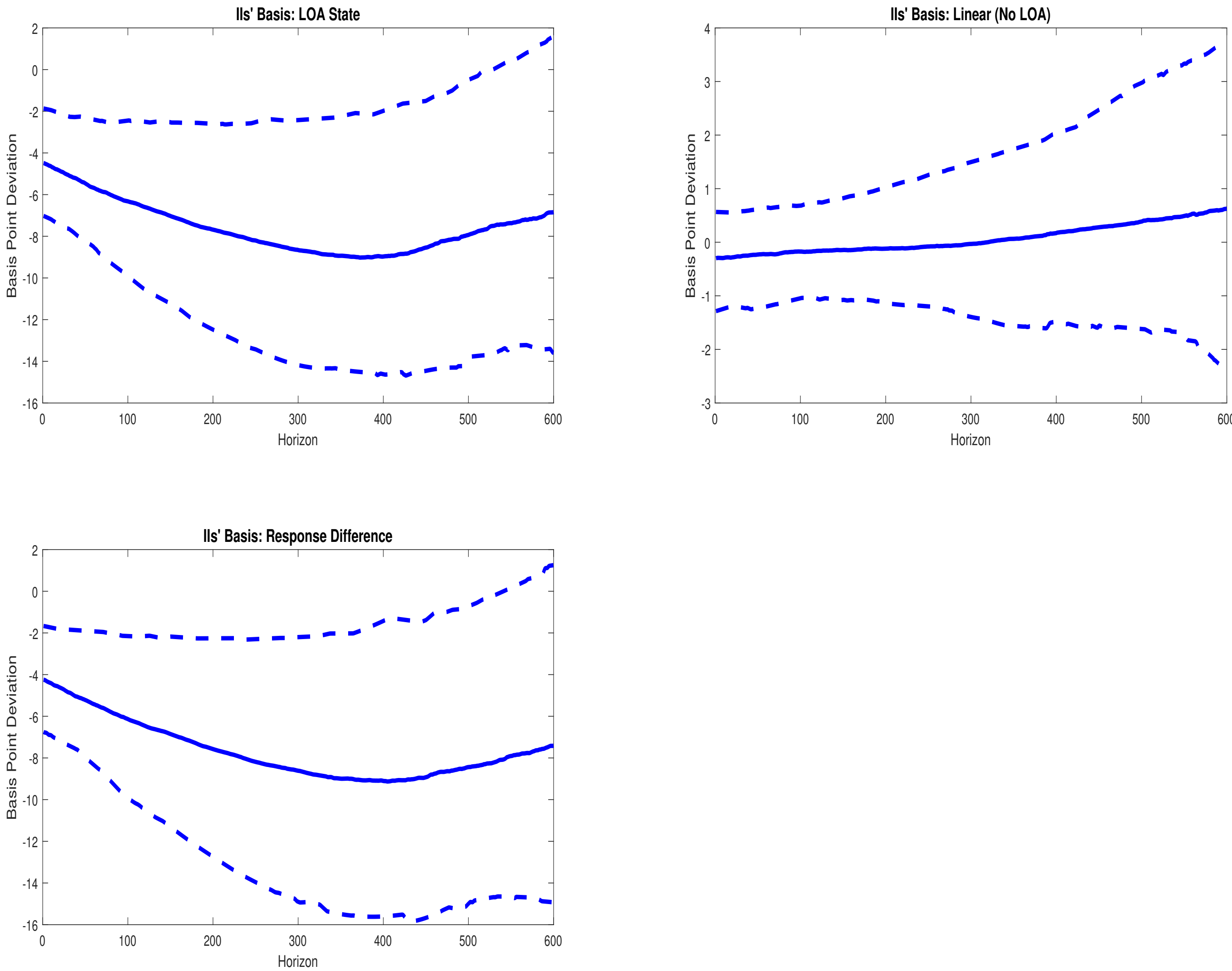
Notes: This figure presents the time series of accumulated daily FX swap flows by sector. Since FX swap flows are changes in the corresponding sector's open FX swap position, their shown accumulated series can be viewed as the corresponding sector's open FX swap position with positive (negative) values representing an open FX swap short (long) position. On top of the IIs sector (which, for completeness, is also included in the figure and is represented by the solid line), this figure includes three additional sectors: real sector (dashed line), which represents the net FX flows from swap transactions involving Israeli exporters and importers; local arbitrageurs sector (dotted line), which includes Israeli commercial banks, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms; and foreign sector (dash-dotted line), which includes all foreign firms engaged in financial activity (i.e., foreign commercial and investment banks, pension and insurance funds, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms). Data are from the BOI and cover 1/7/2008-3/31/2022. Time (daily dates) is on the x-axis. Values are in billions of dollars.

Figure 4: **Time Series of USD/NIS Cross Currency Basis.**



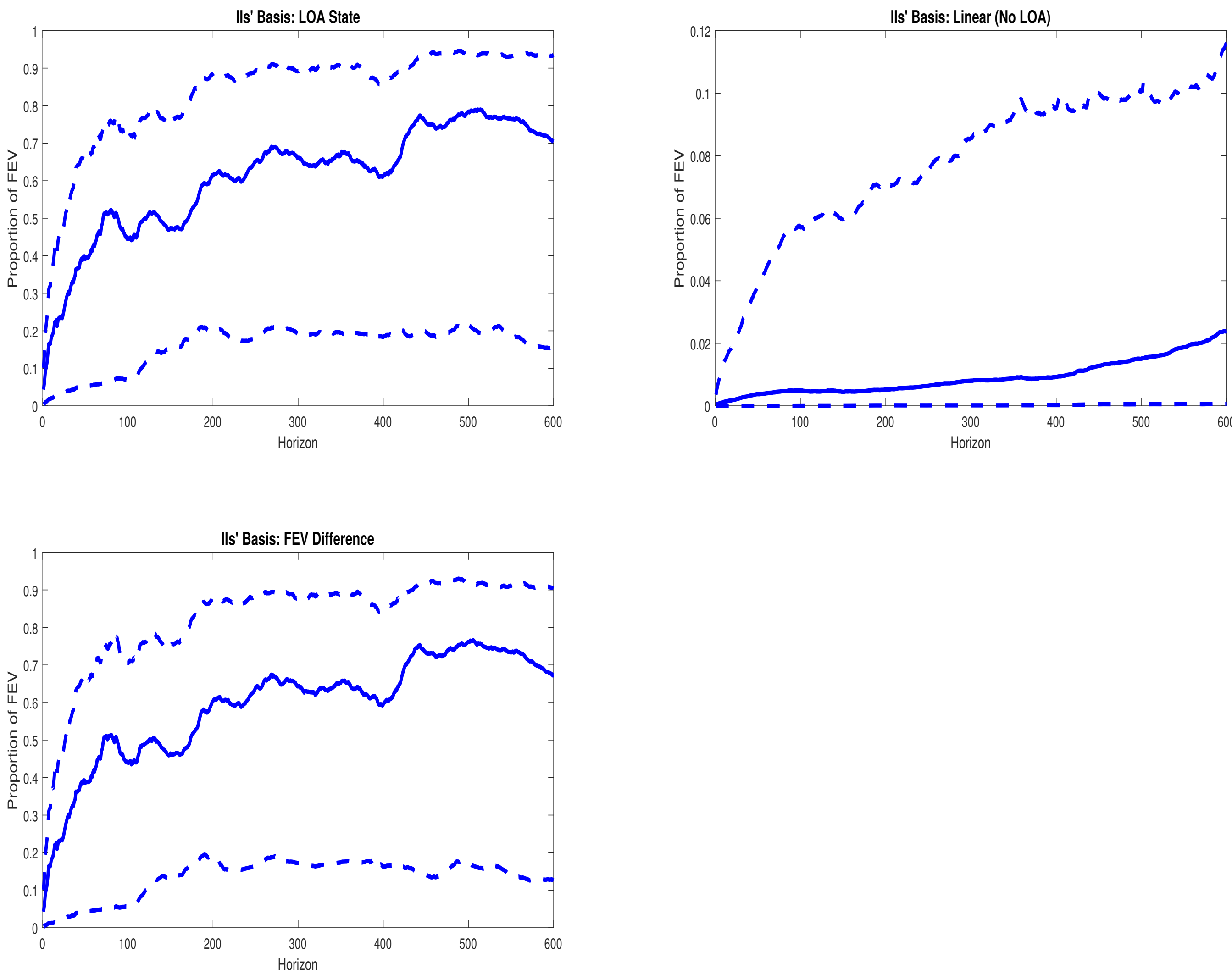
Notes: This figure presents the time series of daily USD/NIS cross currency basis for IIs (constructed from our transaction-level FX swap dataset as the volume-weighted average of the transaction-level bases) (solid line) and the 1- (dashed line), 3- (dotted line), and 6-month (dash-dotted line) bases constructed from Thomson Reuters spot and forward rate data. The bases are computed as the difference between Libor dollar rates and CIP-implied dollar rates. The data cover 1/7/2008-31/3/2021. Time (daily dates) is on the x-axis. Values are in basis point terms.

Figure 5: **LOA-Dependent Impulse Responses of IIs' Aggregate Cross-Currency Basis to a One Standard Deviation Aggregate FX Swap Demand Shock**.



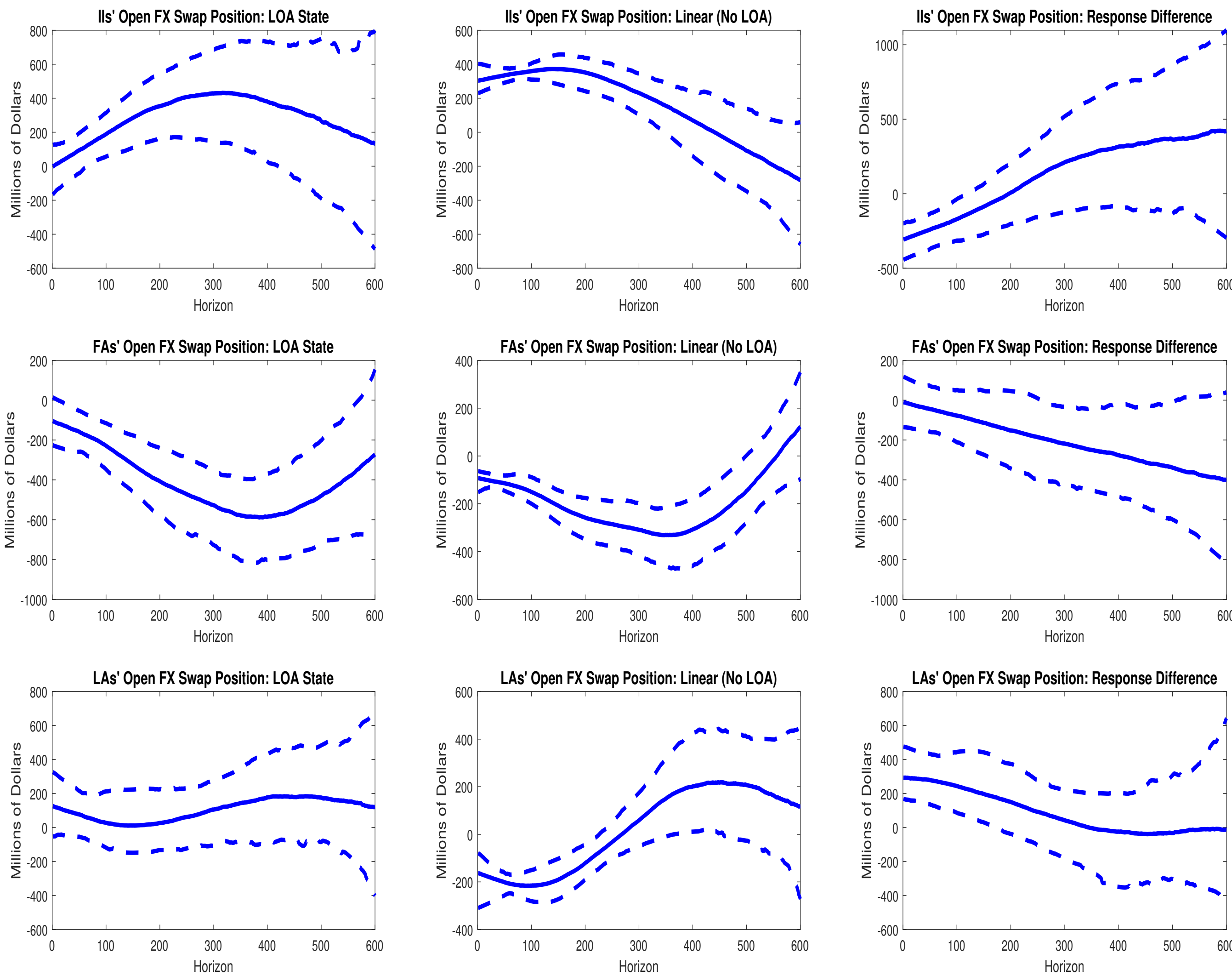
Notes: This figure presents the LOA-dependent impulse responses of IIs' aggregate cross currency basis to a one standard deviation aggregate FX swap demand shock from the model described by Equations (14) and (15). The first and second columns show the responses in the LOA state and linear (no LOA) case, respectively; and the third column shows the response differences across these two cases. Responses are in terms of deviations from pre-shock values (basis point deviations). Horizon (on x-axis) is in days.

Figure 6: **LOA-Dependent FEV Shares of IIs′ Aggregate Cross-Currency Basis Attributable to the Aggregate FX Swap Demand Shock**.



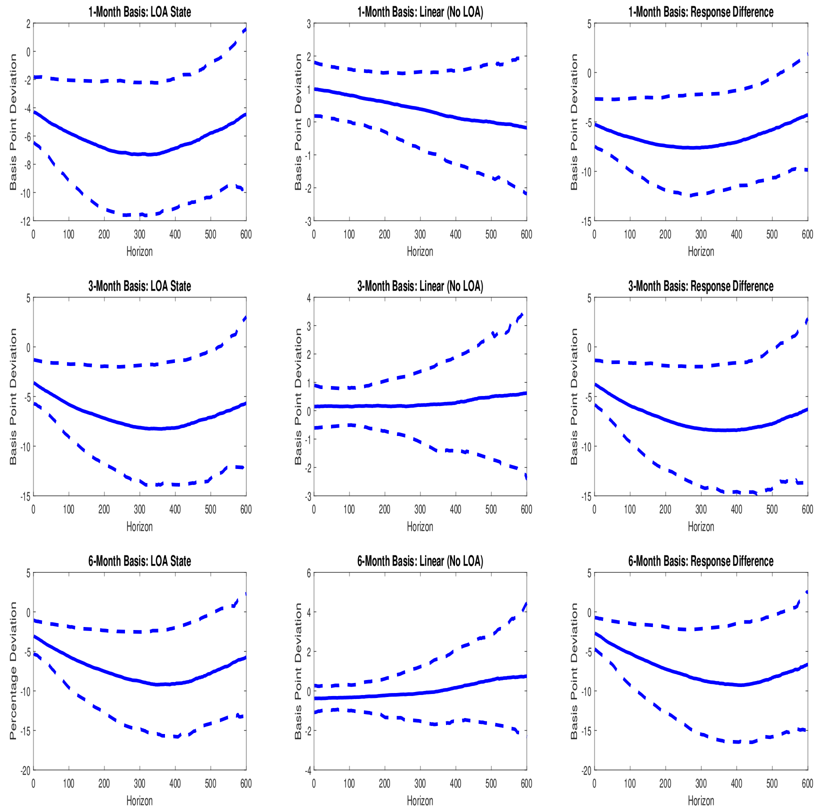
Notes: This figure presents the FEV share of IIs′ aggregate cross-currency basis that is attributable to the aggregate FX swap demand shock from the model described by Equations (14) and (15). The first and second columns show the FEV contributions in the LOA state and linear (no LOA) case, respectively; and the third column shows the FEV contribution differences across these two cases. Horizon (on the x-axis) is in days and the FEV share is on the y-axis.

Figure 7: **LOA-Dependent Impulse Responses of IIs' Aggregate Open FX Swap Position to a One Standard Deviation Aggregate FX Swap Demand Shock**.

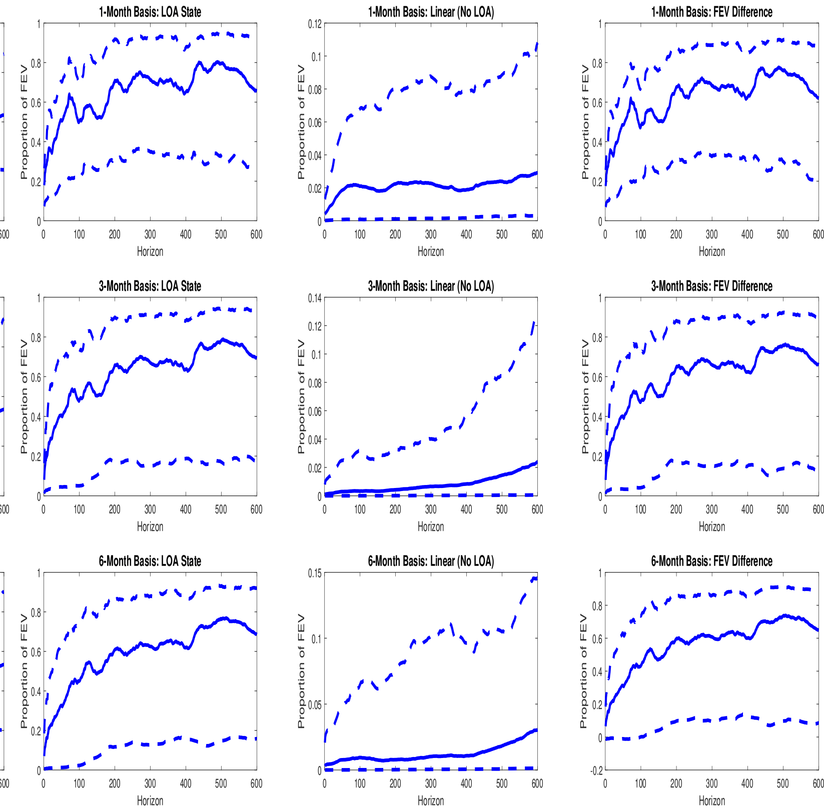


Notes: This figure presents the LOA-dependent impulse responses of IIs', local arbitrageurs' (LAs'), and foreign arbitrageurs' (FAs') aggregate open swap positions to a one standard deviation aggregate FX swap demand shock from the model described by Equations (14) and (15) where the outcome variable in the latter equation (accumulated difference in IIs' basis) is now replaced by the accumulated difference in the corresponding sector's open FX swap position (i.e., $SP_{t+h,j} - SP_{t-1,j}$, where $j = [IIs, LAs, FAs]$). The first and second columns show the responses in the LOA state and linear (no LOA) case, respectively; and the third column shows the response differences across these two cases. Responses are in terms of deviations from pre-shock values (in millions of dollars terms). Horizon (on x-axis) is in days.

Figure 8: **Market-Wide Cross-Currency Bases: (a) LOA-Dependent Impulse Responses; (b) LOA-Dependent FEVs**.



(a) LOA-Dependent Impulse Responses of Cross-Currency Bases to a One Standard Deviation FX Swap Demand Shock.



(b) LOA-Dependent FEV Shares of Cross-Currency Bases Attributable to FX Swap Demand Shock.

Notes: Panel (a): This figure presents the LOA-dependent impulse responses of the 1-, 3-, and 6-month market-wide cross currency bases to a one standard deviation aggregate FX swap demand shock from the model described by Equations (14) and (15). These bases are constructed from Thomson Reuters spot and forward rate data. (See Section 5.1.2 for further details on this data.) The first and second columns show the responses in the LOA and no LOA states, respectively; and the third column shows the response differences across the two states. Responses are in terms of deviations from pre-shock values (basis point deviations). Horizon (on x-axis) is in days. Panel (b): This figure presents the FEV share of the cross-currency bases that is attributable to the FX swap demand shock from the model described by Equations (14) and (15). This figure shares the same expositional structure as 5. Horizon (on the x-axis) is in days and the FEV share is on the y-axis.