The Margin Call Channel of Exchange Rate Determination*

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Abstract

This paper documents a novel channel of exchange rate determination by which foreign holders of U.S. equity futures scramble for dollars when facing margin calls from sufficiently large negative U.S. equity shocks, thereby causing significant dollar appreciation. We uncover this margin call channel in three stages. First, we establish that foreigners' aggregate margin-induced dollar demand function is very well approximated by a third-order polynomial in U.S. equity return, where this polynomial's quadratic coefficient quantifies the margin call channel. Second, employing unique granular data on Israeli institutional investors' (IIs') USD/ILS flows and prices, we find that a two standard deviation negative return shock significantly increases IIs' dollar demand, while a positive such shock does not induce any demand decrease; accordingly, the negative shock appreciates the dollar by more than twice than the corresponding dollar depreciation from the positive shock. Third, using unique granular data on IIs' synthetic exposure to U.S. equities, we establish that IIs' asymmetric dollar demand responses are increasing in their synthetic exposure, which is in line with our conceptual framework's prediction and validates the structural interpretation of our aggregate results. Importantly, when aggregated across IIs, the estimated micro-level margin call effect quantitatively accounts for virtually the entire asymmetry in aggregate spot flow response, providing strong support for the causal interpretation of the aggregate evidence.

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1 Introduction

We highlight a channel through which sufficiently large negative U.S. equity return shocks influence exchange rate variation: the scramble for dollars by institutional investors (IIs), such as pension and insurance funds, when faced with margin calls on their U.S. equity futures positions. This margin call channel of exchange rate determination is driven by the need for investors with foreign equity synthetic positions to obtain dollars following sharp declines in the value of these positions. They do this by buying dollars on the spot market to shore up their margin accounts. This in turn leads to a rise in the spot rate (dollar appreciation).

To causally identify the margin call channel of exchange rate determination, we turn to Israeli data, for which we have novel daily granular data on all FX flow types (spot, swaps, forwards) and prices for the universe of Israeli IIs along with their monthly granular U.S. equity synthetic exposures. Our dataset covers a recent 9-year sample period.

Empirical Approach. We identify and quantify the margin call channel in three stages. First, we formulate an institutionally-consistent margin-induced dollar demand function of local IIs holding U.S. equity futures that is dependent upon U.S. equity return. We establish via Monte Carlo evidence that, while each individual II's demand function is a piecewise linear function with discontinuity at the (unknown) margin-call-inducing return, the aggregate IIs' dollar demand function is very well approximated by a third-order polynomial in equity return. The quadratic coefficient of this polynomial, measuring the response asymmetry to equity return, serves to quantify the margin call channel. The smoothness of the aggregate demand function is institutionally rooted: investors differ in the loss thresholds at which margin calls are triggered due to heterogeneity in trade-entry timing and in margin buffers arising from internal liquidity management practices. Consequently, individual demand discontinuities occur at different loss levels and are smoothed out in the aggregate. Importantly, we do not claim that the true aggregate demand function is cubic; rather, the cubic polynomial serves as a reduced-form approximation that captures well the return shock effects' dominant sign- and size-dependencies of return shock effects generated by heterogeneous margin-call thresholds.

Second, utilizing unique granular daily data on the universe of Israeli IIs' transactions' FX flows (spot, swap, and forward flows) and prices (spot and forward exchange rates), we construct IIs' aggregate dollar FX flows and volume-weighted prices. We then run local projection third-

order polynomial regressions of these quantity and price variables on S&P 500 return shocks, focusing on four times the quadratic coefficient from these regressions, i.e., the difference between the dynamic effects of positive and negative two standard deviation return shocks.

Third, using unique granular data on IIs' synthetic exposures to U.S. equity futures, we run *panel* local projection third-order polynomial regressions of IIs' dollar spot flows on S&P 500 return shocks, interacting the latter with II-specific synthetic exposures. This specification serves to validate the structural, causal interpretation of our aggregate results from the second stage, as our conceptual framework establishes the intuitive prediction that the response asymmetry increases in synthetic exposure. Importantly, our panel regressions control for II-specific size and its interaction with return shocks. Consequently, identification comes from comparing IIs of similar size but differing synthetic exposure, thereby isolating the effect of synthetic exposure on spot flow response asymmetry and providing a causal test of the margin call channel.

Main Results. Our main findings can be summarized as follows. First, a negative two standard deviation return shock generates significant buying of spot dollars by IIs on impact, equal to 0.64 standard deviation units of spot flows, or $97.9 million, compared to an insignificant selling of $20.8 million in response to a positive two standard deviation return shock. This meaningfully asymmetric response represents a quantitatively important margin call channel. In accordance with this strong asymmetric quantity response, the spot rate also experiences significant response asymmetry with a negative two standard deviation return shock causing significant 0.37% dollar appreciation, equal to 0.43 standard deviation units of spot exchange rate return, nearly twice as much as the dollar depreciation of 0.19% caused by a positive two standard deviation return shock.

Second, we validate the causal margin-call-channel-based interpretation of the aggregate spot flows response asymmetries by showing via our panel local projections that they are significantly increasing in IIs' synthetic exposures. Specifically, exploiting both cross-sectional and time-series variation in IIs' synthetic exposures, we show that the response asymmetry rises by 186.6% for a one-standard-deviation increase in IIs' synthetic exposures. Intuitively, since we control for II-specific size, this result implies that among two IIs of identical size, response asymmetry is nearly three times larger for the II whose synthetic exposure is one standard deviation higher. Importantly, when aggregated across IIs, the panel-implied margin call effect quantitatively accounts

for effectively all of the asymmetry in the aggregate spot flow response, thereby closely linking the paper's micro-level and aggregate evidence and lending strong support to the causal interpretation of the latter.

Ruling Out Other Potential Mechanisms. Although the combination of daily IIs' spot flow and price data with monthly synthetic-exposure data gives us confidence in our identification strategy, we nevertheless take care throughout the paper to rule out alternative exchange-rate mechanisms that could account for the observed relationship between return shocks and spot rate movements. In doing so, we establish a causal link between the asymmetry in spot flow responses and that in spot rate responses. We pursue this objective in in a fourfold manner.

First, to ensure our estimated effects are not biased by non-return-shock impulses that nevertheless move FX markets, we control in both our aggregate and panel daily local projections for current and lagged third-order polynomials in U.S. interest rates, the broad dollar exchange rate, real U.S. (business cycle) shocks, Israeli interest rates, CDS prices of 5-year Israeli government dollar bonds, as well as lagged third-order polynomials in S&P 500 returns and the local projection's dependent variable.

Second, we consider the response of IIs' forward flows to rule out the competing equity hedging mechanism, where favorable (adverse) return shocks increase (decrease) the supply of IIs' supply of forwards, thus inducing dollar depreciation (appreciation) (Ben Zeev and Nathan (2024a)). Meaningful asymmetry of this mechanism would undermine the validity of our margin-call-channel-based interpretation of this paper's results. Encouragingly, we reject such asymmetry, thereby ensuring that our results are not driven by the equity hedging channel of exchange rate determination. More generally, because we difference out the effect of the positive return shock from that of the negative shock, any alternative exchange rate channels do not affect our identification so long that they are symmetric.

Third, we address the concern that our results are driven by the equity portfolio rebalancing channel studied by Hau and Rey (2004, 2006) and Camanho et al. (2022). Specifically, could it be that our results merely reflect that IIs rebalance more aggressively in response to negative return shocks than to positive ones, thus leading to greater buying of spot dollars from negative shocks than selling from positive shocks? While we lack the needed portfolio holding data to directly examine the validity of this concern, the sign-dependent nature of our aggregate spot flow responses

rules out the equity portfolio rebalancing channel by showing that positive return shocks lead to *insignificant* selling of spot dollars by IIs on impact. If such rebalancing channel were prominent in our data, we would observe significant such selling. That said, we do observe significant delayed spot dollar sales following positive shocks, indicating that portfolio rebalancing may still play a role at longer horizons. Such delayed responses—which are also present for forward flows—could, in principle, give rise to anticipatory trading by other market participants, a possibility that we examine next.

Finally, we rule out an expectations-based channel whereby market participants trade in anticipation of future exchange rate movements generated by IIs' delayed FX flows. Specifically, we show that no sector asymmetrically accumulates dollar positions in anticipation of the subsequent dollar appreciation associated with IIs' delayed flow responses. Thus, there is no evidence that other market participants strategically trade ahead of predictable exchange rate movements induced by IIs' trading activity. This exercise is particularly important because the delayed and persistent flow responses documented above are consistent with mechanisms such as equity portfolio rebalancing and equity hedging. To the extent that these flow dynamics generate predictable future exchange rate movements, they may attract anticipatory trading by other market participants. We therefore directly test for the presence of such trading and find no evidence of it.

Outline. The remainder of the paper is organized as follows. In the next section we provide a literature review. Section 3 provides institutional background of Israeli IIs' activity. The subsequent section provides the conceptual framework for this paper's empirical analysis. 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 online appendix A) as well as analyzes competing channels' roles. The final section concludes.

2 Related Literature

To the best of our knowledge, this paper constitutes the first empirical investigation of the margin call channel of exchange rate determination. Using granular daily FX spot flow and price data, along with granular monthly synthetic exposure data, we are able to validate and quantify this channel. We now turn to discuss the literatures that motivate our work.

Exchange Rate Determinants. The determinants of exchange rate behavior have long eluded researchers (Meese and Rogoff (1983)), with the data offering only a weak connection between exchange rates and macroeconomic aggregates, thus leading to the coining of the term 'exchange rate disconnect puzzle' by Obstfeld and Rogoff (2000). Understanding which forces drive exchange rates is crucial given their central role in global capital allocation (Maggiori et al. (2020)) and open economies' macroeconomic fluctuations (Schmitt-Grohé and Uribe (2016) and Na et al. (2018)).

Recently, meaningful advancement has been made in resolving the 'exchange rate disconnect puzzle' by three relevant literatures to our work. First, by turning to order flow data, a growing body of work has demonstrated that currency order flow can provide insight into explaining exchange rate excess returns. For example, Evans and Lyons (2002), Froot and Ramadorai (2005), and Menkhoff et al. (2016) have found that changes in currency order flow can help explain a significant amount of the fluctuations in the exchange rate.

Second, another body of literature has turned to investigating the relation between equity and credit markets and FX markets. Lustig et al. (2011) were the first to produce empirical evidence supporting a global-risk-based view of exchange rate determination. Offering a post-GFC resolution to the exchange rate disconnect puzzle, Lilley et al. (2019) shows that proxies for global risk appetite explain a significant share of currency returns after the GFC; the particular post-GFC element of Lilley et al. (2019)'s findings is possibly related to the findings from Avdjiev et al. (2019) which show that post-GFC CIP deviations are representative of risk-taking capacity in global capital markets and are accordingly systematically related to the dollar exchange rate. Hau and Rey (2004) (using a VAR) and Camanho et al. (2022) (exploiting fund-level international equity allocations) provide significant empirical evidence for an equity portfolio rebalancing channel (whose theoretical underpinning is from Hau and Rey (2006)), with a 7.1 billion dollars equity U.S. outflow (induced by foreign equity returns) resulting in a 1% dollar depreciation. Liao and Zhang (2020) studies a *debt* hedging channel of exchange rate determination, insightfully connecting country-level measures of net external financial imbalances to exchange rates.

While the equity portfolio rebalancing channel studied by Hau and Rey (2004, 2006) and Camanho et al. (2022) focuses on the relation between foreign equity markets and FX *spot* markets, Melvin and Prins (2015) and Ben Zeev and Nathan (2024a) study the equity hedging channel of exchange rate determination and therefore focuses on the relation between foreign equity markets

and FX *forward* markets, whereby local IIs sell dollar forwards (in turn depreciating the dollar) in response to favorable foreign equity return shocks. Like the equity hedging channel, our channel's impulse is also a foreign equity return shock, this in stark distinction from the underlying impulse of the portfolio rebalancing channel—a shock to the equity return *differential* between foreign and local equity markets. Unlike the equity hedging channel, our channel is spot-market-based, not forward-market-based. And, crucially, unlike both the latter competing channels, our channel is highly asymmetric, operating only in response to sufficiently large negative return shocks.

Third, a related strand of literature and the closest to our paper among the three, emphasizes the role of international dollar liquidity demand in exchange rate determination. Gabaix and Maggiori (2015) show that exchange rates depend on the risk-bearing capacity of financial intermediaries, implying that financial-sector balance sheets can become a key driver of currency values. Itskhoki and Mukhin (2021) show how shocks to international dollar liquidity and the balance-sheet needs of financial intermediaries can generate exchange-rate fluctuations. Together, these papers highlight how balance-sheet-driven demand for dollar liquidity, rather than traditional macroeconomic fundamentals alone, can become an important determinant of exchange rates. Bianchi et al. (2021) develop a theory in which funding uncertainty in interbank markets induces financial institutions to scramble for dollars, generating dollar appreciation. Our mechanism is closely related: margin calls on U.S. equity futures positions induce non-U.S. IIs to scramble for dollar liquidity, thereby appreciating the dollar exchange rate.

Margin Calls. While, to our knowledge, there have not been papers directly connecting margin calls on U.S. equity futures to exchange rate determination, vast work has been done on margin-induced determination of financial asset price and liquidity. The core mechanism across this literature is that declines in asset prices tighten borrowing constraints, forcing deleveraging and triggering further price movements. This literature can be traced back to Kiyotaki and Moore (1997), who provides the canonical framework linking asset prices to borrowing capacity. Brunnermeier and Pedersen (2009) later formalized the link between collateral constraints, market liquidity, and funding liquidity: when funding conditions deteriorate due to margin tightening, market liquidity worsens, amplifying price volatility. In the open economy context, Caballero and Krishnamurthy (2001) and Mendoza (2010) show how in countries facing limited access to international collateral, negative shocks can trigger binding external constraints, leading to capital outflows, asset price

collapses, and exchange rate depreciations; and Bianchi (2011) demonstrates how collateral constraints can generate systemic, welfare-reducing deleveraging dynamics, as private agents fail to internalize the effect of their borrowing and asset sales on aggregate collateral values and future borrowing capacity. Finally, Jansen et al. (2026) and Pinter et al. (2026) show how margin calls on pension funds interest rate swap positions can lead to fire-sale-induced declines in government bond prices.[1]

Intermediaries and Asset Pricing. Last, we also contribute to the extant literature investigating the many ways in which intermediaries affect financial markets (Greenwood and Vayanos (2010), Ellul et al. (2011), He and Krishnamurthy (2013), He et al. (2017), O' Hara et al. (2018), He and Krishnamurthy (2018), Klingler and Sundaresan (2019), Hendershott et al. (2020), Jiang et al. (2021), Koijen and Yogo (2022), Greenwood et al. (2023), and Ben Zeev and Nathan (2024b) among others). We add to this literature by showing how margin-call-induced spot dollar demand by IIs (an important form of intermediaries) affects exchange rates.

3 Institutional Background

This section lays out information about the IIs in Israel and the environment in which they operate. We first start with a description of the liquidity in the Israeli FX market.

Liquidity of the Israeli FX Market. According to the latest BIS triennial survey of 51 countries, as of April 2025, Israel's daily average turnover for the USD/ILS currency pair in the spot market was $1,842 million, 116% higher than the size of the forward market's daily average turnover of $853 million and 15.7% of total volume (11,757 millions dollars).

The most traded instrument in the USD/ILS currency market is FX swaps, possessing a volume of $7,837 million. While USD/ILS FX swaps act mainly as a hedged dollar funding device for IIs' foreign investment (Ben Zeev and Nathan (2024b)), they are not suitable as a dollar funding device for U.S. equity futures margin calls because their use would go in the wrong logical

[1]Online appendix D shows that no such fire-sale-based mechanism holds for our setting. Specifically, while IIs scramble for spot dollars to meet their margin calls, there is no corresponding distressed scrambling for ILS through local asset sales. Rather, IIs' abundant ILS cash assets allow them to sell local government bonds in a very delayed manner and without meaningful price declines, as they do this against liquidity-abundant and undistressed local banks.

direction in the stress-ridden times of margin calls, locking up additional collateral and risking additional margin calls, this time on the FX swaps themselves, in the case of dollar appreciation. By contrast, tapping into the spot market is free from these issues and addresses the core issue introduced by the margin call which is fundamentally a liquidity problem.

Notwithstanding Israel's small open economy status, its spot trading volume sits more advanced than its sheer economy size, landing in the second quartile of the 51 countries, standing higher than other notable small open economies' spot market volumes such as the Netherlands, New Zealand, Norway, and Finland. Overall, the data suggests that Israel's spot FX market is vibrant and liquid.

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 daily 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,[2] and life insurance policies.[3] IIs are important players in the Israeli financial market, managing 1,039.4 billion dollars on behalf of the public as of December 2025, which is 44% of the public's entire financial asset portfolio and 150% 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% (and in October 2022 to 0%), 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

[2]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.

[3]Mutual 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 excluded from the list of entities that comprises our sample.

pushing them to seek alternatives to their investments in Israel.[4]

It was only by the end of 2009 that Israeli IIs reached a double-digit level of foreign asset holdings as a share of their total assets. In tandem with this landmark, they began to steadily increase their foreign asset exposure, reaching a peak share of such exposure relative to total asset holdings of 43.9% in July 2024, alongside increasing their foreign equity synthetic exposure as well. As of December 2025, the share of total foreign asset exposure relative to total assets is 40.9%, with foreign equity synthetic exposure comprising a peak 37.1% share of total foreign exposure. Figure 1 shows the underlying dynamics of these ratios, along with other relevant variables, depicting the billions of dollars values of IIs' foreign equity holdings, foreign equity synthetic exposure, the sum of the latter two variables—i.e., total foreign equity exposure, foreign asset exposure, FX exposure, and total assets; for completeness, Figure 1 also shows the evolution of IIs' aggregate (transactions-based, volume-weighted average) spot rate, where the underlying daily values were averaged within each month to create a monthly spot rate series.[5]

Synthetic Exposure Through U.S. Equity Futures. The vast majority of Israeli IIs' foreign equity synthetic exposure is through E-mini S&P 500 futures (ES).[6] Introduced in September 1997, ES contracts are the most popular U.S. equity future contracts, trading almost around clock on the Chicago Mercantile Exchange (CME) with average daily volumes and open interest in the order of 338 and 490 billion dollars over our sample (2017–2025), and offering 3-, 6-, 9-, and 12-month maturities. ES is a smaller-sized contract relative to the (discontinued) regular S&P 500 futures contracts, whose trading began in January 1982 and discontinued in May 2017, because ES is valued at only 50 times the level of the S&P 500 index as opposed to 250 times for the regular futures

[4]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.

[5]The underlying granular exposure data runs from December 2016–December 2025, thus dictating the starting and ending dates in Figure 1. Note that FX exposure is significantly lower than foreign asset exposure due to IIs' considerable FX hedging practices.

[6]Using the BOI's breakdown of IIs' foreign equity synthetic positions' fair value by exchange-traded and over the counter (OTC) instruments, we have found that about 90% of IIs' such synthetic activity originates in exchange-traded instruments. The remaining 10% comes from equity swaps, which are economically equivalent to ES but are traded OTC. Based on conversations with market participants, IIs do more than 90% of their foreign equity synthetic exposure activity in the U.S. Hence, the S&P 500 index, from which we extract our return shocks, can be viewed as an accurate base asset representative for IIs' foreign equity synthetic exposure. (While our synthetic exposure data does not separate between options and futures, it is well known that IIs' foreign equity options activity is negligible.)

contracts. ESs' high liquidity, standardization, and central clearing make them highly attractive instruments for obtaining exposure to their underlying asset—the S&P 500 stock price index. This attractiveness is reflected in Figure 1, which shows that IIs' foreign equity synthetic exposure has grown substantially over the sample period, at an average monthly rate of 2.3%, compared to a corresponding growth rate of 1.5% for foreign equity holdings (i.e., physical exposure). Synthetic exposure first surpassed foreign equity holdings in January 2023 and continued to expand thereafter, reaching 157.6 billion dollars in December 2025, significantly exceeding the 127.4 billion dollars held in physical exposure.

IIs obtain this exposure by committing to buy the S&P 500 index at a specified future date at a pre-determined and known futures price, transacting against some broker. Any profit or loss—computed as the daily change in the futures price times the number of contract units—is paid from or to the broker on a daily basis, as part of the ES mark-to-market settlement framework. As time advances from the contract initiation, in accordance with the no-arbitrage futures pricing framework where the risk-free-discounted futures price equals the base asset's spot price net of dividend payments, and assuming that expected profits are being invested by the II at the risk-free rate, the II is expected to earn the S&P 500 total return (capital gain plus dividend yield) net of potentially foregone interest on posted margin (discussed below).[7]

Importantly, the II needs to post dollar cash collateral as initial margin for the ES position. The CME requires a minimal such margin in the order of 5–10% of the notional exposure amount (as of June 2026, it is 10%). As explained in the previous section, various factors—including internal risk management practices interacted with previous profits and losses on the position—can alter the effective initial margin posted by the II. The CME also determines a maintenance margin, in the order of 90% of the initial margin, where any losses pushing the effective initial margin below the maintenance margin trigger a margin call, i.e., a formal request from the broker to post additional cash to prevent the effective margin account from falling below the maintenance margin. Hence, IIs' obtaining of leveraged exposure to the S&P 500 index is not a free lunch: its main cost, in addition to the margin itself (leverage is finite) and position loss risk, is the liquidity risk of receiving margin calls which can generate severe and abrupt dollar liquidity needs.

[7] In practice, IIs usually earn the risk-free interest rate on the margin they hold with their brokers, effectively eliminating the opportunity cost of posted margin.

4 Conceptual Framework

Institutional Setting and True Aggregate Margin-Induced Dollar Demand. This section lays out a simple conceptual framework meant to fix ideas and provide a suitable foundation for the empirical analysis. Consider a local investment fund, indexed by i ($i = 1, 2, \ldots, I$), who obtains exposure to a foreign equity index synthetically by holding a futures contract obligating it to buy the equity index at a future date at price P. The fund transacts in Q_i contracts such that $Q_i P$ is the notional amount of the position. For simplicity, we assume the contract has zero basis, i.e., the spot price equals P, so there is a one-to-one relation between changes in the spot price and changes in the contract value and resulting profits and losses.

The contract is transacted through a broker who maintains mark-to-market accounting. The fund posts an initial margin IM_i at the initiation of the contract. As the price evolves, mark-to-market losses may necessitate additional funding. Specifically, when cumulative losses exceed a threshold $TL_i > 0$—corresponding to the difference between initial and maintenance margin where the latter is the margin the broker does not allow the fund's margin account to go below—the broker issues a margin call requiring additional cash. We therefore model total margin-induced dollar demand as:

$$M_i = IM_i + \max(-Q_i \Delta P - TL_i, 0). \tag{1}$$

Dividing and multiplying the right-hand side of Equation (1) by $Q_i P$ yields:

$$M_i = Q_i P \left(im_i + \max(-r - tl_i, 0) \right), \tag{2}$$

where $im_i \equiv IM_i/(Q_i P)$ and $tl_i \equiv TL_i/(Q_i P)$ denote the initial margin and threshold loss as shares of notional exposure, and $r \equiv \Delta P/P$ is the return on the equity index. M_i is an explicit, nonlinear function of r, characterized by a kink at the margin-call threshold $-tl_i$ for each fund.

Our interest lies in the aggregate margin-induced dollar demand, given by

$$M(r) = \sum_i M_i. \tag{3}$$

Third-Order Polynomial Approximation. For a margin call to occur, a sufficiently *large* and *negative* return is required, implying both sign- and size-dependence in the function $M(r)$. At the individual level, $M_i(r)$ is kinked at $r = -tl_i$. Aggregating across funds smooths these discontinuities provided there is sufficient heterogeneity in tl_i across funds.

From our conversations with market participants, although margin requirements for our funds' U.S. equity futures contracts are largely similar, whether standardized at the exchange level (E-mini S&P 500 futures) or traded OTC via equity swaps, the effective distance to margin calls (i.e., tl_i) varies significantly across funds. This heterogeneity arises from differences in the amount of excess collateral held relative to minimum requirements, caused in turn by heterogeneity in the timing of position initiation, which determines accumulated mark-to-market gains or losses, and internal risk management practices governing recapitalization and leverage.

We proxy this heterogeneity using the ratio of total cash held to total assets (both covering both foreign and local currency), which measures internal liquidity management practices and policies. This measure should in turn should be meaningfully related to the unobserved dispersion in distance-to-margin-call across funds. (We elaborate on this measurement below when we discuss the fit of our third-order polynomial approximation.)

Accordingly, we approximate the aggregate demand function $M(r)$ with a third-order polynomial, with the quadratic and cubic terms capturing sign- and size-dependence, respectively:

$$M(r) = \alpha + \beta r + \gamma r^2 + \delta r^3 + \epsilon, \tag{4}$$

where ϵ is the approximation error.

Fit of Third-Order Polynomial Approximation. How good is *reduced-form* Approximation (4)? To adequately answer this question, we compute the fit (R^2) of this approximation as follows. First, to measure the said vast heterogeneity, we proxy for the *effective* im_is ($\tilde{im}_i$) with $\tilde{im}_i = im_i + \epsilon_i$ where $im_i = 0.1$ according to the industry-consistent approximate minimal 10% initial margin baseline and ϵ_i is a Pearson-family distributed random variable with mean, standard deviation, skewness, and kurtosis of 3.9%, 3.3%, 1.9, and 18.5, respectively, all taken from the empirical cross-sectional distribution of the average share of total cash held in total assets across our 82 pension and insurance entities.[8] Then, using the industry-consistent approximate 1% benchmark for tl_i, we compute the effective tl_i as $\tilde{tl}_i = 0.01 + \tilde{im}_i - im_i = 0.01 + \epsilon_i$; and, accordingly, we use the

[8]This dataset covers 75 pension funds and 7 insurance companies. The latter encompass 23 insurance policy funds for which only company-level, rather than fund-level, observations are available. Accordingly, these 23 insurance policy funds are aggregated to the parent-company level, yielding 7 *aggregated* insurance entities. Because this aggregation is limited in scope, and to maintain consistency between the sample used in the Monte Carlo exercise and that used in the empirical analysis, we retain these aggregated entities in the exercise. Results are very similar when they are excluded.

time-series-averages from our empirical samples of the fund-specific notional exposure amounts as the measure of $Q_i P$ which appears separately in Equation (2). Second, for each value of r from our empirical sample of the S&P 500 return series, and values of $i\tilde{m}_i$ and $\tilde{tl}_i$, we compute M_i from Equation (2), resulting in a sample of M_i which we regress on the raw, squared, and cubed values of r.

Table 1 shows the average and standard deviation of R^2s and coefficient values for this regression across 2,000 Monte Carlo simulations obtained from drawing 2,000 values for ϵ_i for each $i = 1, 2, ..., 82$. (Coefficients are in terms of millions of dollars units with respect to unit standard deviation return shock.) Our experiment clearly demonstrates that our polynomial specification does an excellent job of fitting the aggregate margin-induced dollar demand function, with mean R^2 at 95.3% and very tightly so with a very low standard deviation of 0.9%. The estimated coefficients reveal substantial nonlinearity. While the linear coefficient is statistically indistinguishable from zero, both the quadratic and cubic coefficients are highly significant. The average quadratic coefficient is 540% larger than the corresponding linear coefficient, indicating a pronounced sign-dependence of return shock effects. Moreover, despite capturing a substantially higher-order effect, the average cubic coefficient is only 14% smaller than the average linear coefficient, pointing to strong size-dependence.[9]

We also report in the additional rows of Table 1 results from applying second- and first-order polynomial regression estimations to the simulated samples. These additional results stress the importance of using the third-order polynomial specification, as the mean R^2 materially drops to 67.1% with a 2.3% standard deviation when abstracting from the third-order polynomial dimension; as expected, results are even more materially worsened when also ignoring the second-order dimension, with the linear specification yielding only a 18.8% mean R^2 with 1.8% standard deviation.

Notwithstanding the high R^2 from Table 1 for the third-order polynomial specification, attention must be drawn to the fact that this section abstracts from various other exchange rate channels that will likely sully our identification when estimating reduced form Approximation (4). This issue is rooted in our modeling of IIs' demand very partially, focusing only on the margin-induced

[9]Recall that coefficient estimates measure the effects of a one-standard-deviation return shock. Accordingly, one would expect the cubic coefficient, δ, to be relatively small, as it captures the effect of a shock of magnitude 0.0117^3. Analogously, the quadratic coefficient, γ, captures the effect of a shock of magnitude 0.0117^2. The fact that both higher-order coefficients remain economically meaningful despite this scaling provides further evidence of the strong sign- and size-dependence of return shock effects.

portion of this demand. Hence, in our empirical estimation, to alleviate this sullying concern, we control for alternative exchange rate channels related to interest rates, risk factors, and the real economy.

Margin Call Channel Quantification. The central message of this section is that a sufficiently large and negative decrease in the value of local IIs' synthetic foreign (U.S.) equity position causes a margin-call-induced increase in IIs' demand for spot dollars; this demand shift, taking place along a standard upward sloping spot supply curve, would appreciate the dollar against the local currency. To capture this margin-call-induced mechanism, as this section establishes, we can use a third-order polynomial in the return shock as such specification approximates well IIs' margin-induced dollar demand. In particular, the quadratic coefficient is the measure of the margin call channel of exchange rate determination because it precisely quantifies the differential effect of the return shock resulting from the margin call.

Formally, we seek to uncover the difference between the effect of a margin-call-inducing (i.e., adverse) *large* (two standard deviation) return shock and the effect of a non-margin-call-inducing (i.e., favorable) *large* (two standard deviation) return shock. This difference, which we denote by $\mathbb{M}$ and is equal to 8γ, captures our sought-after margin call channel:

$$\begin{aligned} &\mathbb{M} = (\mathbb{E}[M|r=-2] - \mathbb{E}[M|r=0]) - (\mathbb{E}[M|r=0] - \mathbb{E}[M|r=2]) = \\ &(\alpha - 2\beta + 4\gamma - 8\delta - \alpha) - (\alpha - (\alpha + 2\beta + 4\gamma + 8\delta)) = 8\gamma. \end{aligned} \tag{5}$$

Importantly, as detailed in the next section, our granular fund-level synthetic exposure data will allow us to additionally identify the margin call channel along the exposure intensity dimension ($Q_i P$), comparing quadratic coefficients across high- and low-synthetically-exposed funds. This approach is rooted in the fact that the coefficients from Equation (4) are scaled by the scalers of Equation (2), i.e., $Q_i P$. Specifically, as confirmed by unreported experimentation for ease of exposition, scaling up the distribution of $Q_i P$ by some factor X also scales up Equation (4)'s coefficients by the same factor. Accordingly, we introduce an additional, granular-based, quantifying

object for the margin call channel:

$$\begin{aligned}\widetilde{\mathbb{M}} = &\left(\mathbb{E}\left[M|r=-2, Q_iP_i = \mathbb{SD}(Q_iP_i)\right] - \mathbb{E}\left[M|r=0, Q_iP_i = \mathbb{SD}(Q_iP_i)\right]\right) - \\ &\left(\mathbb{E}\left[M|r=0, Q_iP_i = \mathbb{SD}(Q_iP_i)\right] - \mathbb{E}\left[M|r=2, Q_iP_i = \mathbb{SD}(Q_iP_i)\right]\right) - \\ &\left(\mathbb{E}\left[M|r=-2, Q_iP_i = \mathbb{E}(Q_iP_i)\right] - \mathbb{E}\left[M|r=0, Q_iP_i = \mathbb{E}(Q_iP_i)\right]\right) - \\ &\left(\mathbb{E}\left[M|r=0, Q_iP_i = \mathbb{E}(Q_iP_i)\right] - \mathbb{E}\left[M|r=2, Q_iP_i = \mathbb{E}(Q_iP_i)\right]\right) = \\ &(\alpha_1 - 2\beta_1 + 4\gamma_1 - 8\delta_1 - \alpha_1) - (\alpha_1 - (\alpha_1 + 2\beta_1 + 4\gamma_1 + 8\delta_1)) - \\ &(\alpha_2 - 2\beta_2 + 4\gamma_2 - 8\delta_2 - \alpha_2) - (\alpha_2 - (\alpha_2 + 2\beta_2 + 4\gamma_2 + 8\delta_2)) = 8(\gamma_1 - \gamma_2),\end{aligned} \tag{6}$$

where $\mathbb{SD}(Q_iP_i)$ is the standard deviation of our IIs' notional synthetic exposures. Coefficients indexed by 1 correspond to effects when the notional exposure amount is higher than the mean by one standard deviation while those indexed by 2 correspond to effects when this amount is equal to mean exposure. Granular-based $\widetilde{\mathbb{M}}$ reinforces aggregate-based $\mathbb{M}$ by showing that the margin call channel's strength is scaled by notional exposure amount level, i.e., that the aggregate effects captured by $\mathbb{M}$ are indeed rooted in synthetic exposure intensity. As we detail in the next section, we estimate $\widetilde{\mathbb{M}}$ via panel third-order polynomial local projection regressions interacted with lagged notional exposure amounts, with $\gamma_1 - \gamma_2$ simply captured by the coefficient on the interaction between the squared return and lagged exposure.

It is noteworthy that we have a total of 75 pension funds and 7 insurance companies with granular exposure data, where the latter encompass 23 insurance policy funds. These 98 pension and insurance policy funds ultimately belong to a total of 18 fund families (IIs), representing the universe of investment banks and insurance companies in Israel. Hence, in our empirical estimation, we aggregate within each II which serves the important purpose highlighted in this section of smoothing out the fund-level discontinuities at the margin call threshold losses.

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.

5.1 Data

Our data is daily and covers the period 1/3/2017-12/31/2025. The specific starting and ending points of this 9-year period are dictated by the availability of the Bank of Israel (BOI) proprietary data we have on the monthly granular synthetic exposure of Israeli IIs which we integrate with the daily FX flow and price data. We begin our data description by providing details on IIs' data after which we turn to discuss the other variables we utilize in our empirical analysis.

5.1.1 IIs' FX Flows and Prices Data

We have proprietary granular daily data collected by the Bank of Israel (BOI) for Israeli IIs on FX flows and prices by type (spot, forward, swap, and option) for the USD/ILS currency pair. We have a total of 75 pension funds and 23 insurance policy funds that are owned by 18 IIs fund families—i.e., about 5.4 funds per II; these 18 IIs correspond to the universe of investment banks and insurance companies that manage the public's long-term savings. Our obvious focus is on spot flows and prices given their focal role in the margin call channel of exchange rate determination but we also look at forward flows to rule out the competing equity hedging channel as well as forward prices to confirm that our spot rate response also translates to a similar forward rate response.

Spot and Forward Flows and Rates. The spot flows variable measures (in dollars) the daily net transaction flow from IIs' buying and selling of U.S. dollars on the USD/ILS spot market. There is a negative (positive) value for this variable for a given observation when an II was a net seller (buyer) of spot dollars on the corresponding day. The aggregate IIs' daily spot flows variable is simply the sum of the individual 18 IIs' daily spot flows. We construct aggregate daily IIs' spot rates as the volume-weighted average of spot rates computed from all daily IIs' spot transactions.

The forwards flows variable measures (in dollars) the daily net change in IIs' open forward position.[10] This position is calculated from the net transaction flows from IIs' buying and selling of U.S. dollars on the USD/ILS forward market, while accounting for flows from the expiring maturity of contracts. A positive (negative) value for this variable for a given observation takes place

[10]Our starting date for the open position calculation is the beginning of 2016, i.e., a year before the beginning of our regressions' sample. Since we are interested in the changes in IIs' open forward position (rather than their level) for this paper's purposes, this initial date for computing the open position serves our purposes well given that the volume-weighted average maturity of IIs' forwards over 2016-2015 is, on average, 95.2 days, thus effectively nullifying the importance of pre-2016 forward trades for our purposes.

when IIs were a net buyer (seller) of forward dollars on the corresponding day. The aggregate IIs' daily forward flows variable is simply the sum of the individual 18 IIs' daily forward flows. We construct aggregate daily IIs' forward rates as the volume-weighted average of forward rates computed from all daily IIs' forward transactions.

Descriptive statistics (mean and standard deviation) for IIs' spot and forward flows and rates are shown in Table 2; for completeness, this table also shows the corresponding statistics for S&P 500 return.

5.1.2 Other Sectors' Spot Flows Data

We also exploit spot and forward flow data for four additional sectors: the foreign sector, which comprises all foreign financial entities (including foreign banks, institutional investors, mutual funds, exchange traded funds, hedge funds, and proprietary trading firms); the local banking sector, consisting of Israeli commercial banks; the local financial sector, consisting of Israeli mutual funds, exchange-traded funds, hedge funds, and proprietary trading firms; and the real sector, consisting of Israeli exporters and importers. This dataset serves two purposes.

First, it allows us to identify the counterparties to IIs' FX transactions and, more generally, to characterize the supply and demand sides of the USD/ILS market following return shocks. Figure 2, which reports accumulated spot flows by sector, shows that the *unconditional* counterpart to IIs' cumulative spot dollar purchases of $85.5 billion over our sample period is primarily foreign sector selling, which accumulates to $79.4 billion. The local banking sector also contributes materially to spot dollar demand, accumulating purchases of $46.3 billion, while the real sector contributes to supply, cumulatively selling a similar amount of spot dollars ($43.2 billion).

Second, these data allow us to evaluate the relevance of the competing expectations-based channel discussed in Section 6.4.3. Specifically, by examining the impact responses of spot and forward flows for sectors containing potential arbitrageurs, we can assess whether market participants trade in anticipation of future II FX activity and the associated exchange rate pressure.

5.1.3 Monthly Synthetic Exposure Data

To operationalize this paper's granular identification approach, which serves to validate the causal interpretation of our aggregate results, we use BOI-collected fund-level notional synthetic exposure amounts to U.S. equities. While this data is unavailable by financial instrument, we have

confirmed from conversations with market participants that effectively all of this exposure is from S&P 500.

Our granular exposure data covers both pension funds (75 in number) and insurance policy funds (23 in number). While the former is available by fund, the latter is available at the insurance parent company level. All pension and insurance funds ultimately belong to 18 fund families (IIs), representing the universe of investment banks and insurance companies in Israel. we convert the monthly frequency of the exposure data to daily by assuming constant within-the-month values—results are robust to interpolation-based alternatives. The granular exposure data runs from December 2016–December 2025, and is used in lagged interactive form in our panel local projection third-order polynomial regressions, thus dictating the 9-year sample we use for the FX-related dataset.

5.1.4 Macro-Financial Data

We use several aggregate daily frequency macro-financial variables in our analysis, all of which cover the IIs' FX flows' sample (1/3/2017-12/30/2025). All of these variables are taken from Bloomberg and their values are end-of-day quotes.

S&P 500 Index. The impulse underlying our margin call channel is the daily return on the S&P 500 Index, a capitalization-weighted stock market index tracking the stock performance of 500 leading public companies listed on stock exchanges in the U.S.

Interest Rates. To control for the interest channel of exchange rate determination, we control for current and lagged third-order polynomials in the first-difference of U.S. and Israeli 1-year risk-free rates foreign risk-free interest rates in our estimation, measured by the 1-year treasury bill rate and 1-year MAKAM rate, respectively. The MAKAM is a bond issued by the BOI and is thus devoid of sovereign risk.

U.S. Business Cycles. To ensure our results are not coming from the relation between the real economy and the dollar exchange rate, we control for high-frequency real effects with the Aruoba et al. (2009) daily U.S. business cycle index (ADS) provided by the Philadelphia Fed.

Broad Dollar Index. The broad dollar index (BDI) 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 control for current and lagged third-order polynomials in BDI return to purge our estimation of both global risk appetite shocks (Avdjiev et al. (2019)) as well as any non-USD/ILS exchange rate variation coming from the global FX markets.

Israeli CDS. To control for Israeli risk shocks, we include in our estimations current and lagged third-order polynomials in the first-difference of the CDS prices of 5-year Israeli government dollar bonds.

5.2 Estimation

We estimate two daily frequency nonlinear econometric models. The first uses aggregate data, running local projection third-order polynomial regressions of accumulated IIs' dollar spot flows and USD/ILS spot exchange rate returns on raw, quadratic, and cubic values of the S&P 500 return. The second exploits the granular synthetic exposure data to validate the causal margin-call-channel-based interpretation of the aggregate results from the first model, running *panel* local projection third-order polynomial regressions of II-specific accumulated dollar spot flows on raw, quadratic, and cubic values of the S&P 500 return. Throughout the estimation we control for current and lagged third-order polynomials in the first-differences of local and U.S. interest rates, BDI return, first difference of ADS index, first difference of Israeli CDS price, as well as lagged third-order polynomials in the outcome variable of interest.

5.2.1 Econometric Model

Aggregate Model. We estimate *reduced-form* local projection regressions given by

$$accum_spot_flows_{t+h} - accum_spot_flows_{t-1} = \alpha_{h,q} + \beta_{h,q} S\&P_500_return_t + \gamma_{h,q} S\&P_500_return_t^2 \quad (7)$$
$$+ \delta_{h,q} S\&P_500_return_t^3 + \mathbb{C}'_{t,q}\Xi_{h,q} + u_{t+h,q},$$
$$(spot_rate_{t+h} - spot_rate_{t-1})/spot_rate_{t-1} = \alpha_{h,p} + \beta_{h,p} S\&P_500_return_t + \gamma_{h,p} S\&P_500_return_t^2 \quad (8)$$
$$+ \delta_{h,p} S\&P_500_return_t^3 + \mathbb{C}'_{t,p}\Xi_{h,p} + u_{t+h,p},$$

where $h = 0, 1, ..., 10$ is the local projection horizon; $accum_spot_flows_t = \sum_{i=0}^{t} spot_flows_i$ is IIs' aggregate accumulated net spot flows (dollar buying minus dollar selling) ($i = 0$ represents the

beginning of our sample), in millions of dollars;[11] and $spot_rate_t$ is the volume-weighted average (transactions-based) IIs' USD/ILS spot rate; $S\&P_500_return_t$ is the standardized daily return on the S&P 500 index; $\mathbb{C}_{t,q}$ includes current and lagged third-order polynomials in the first-differences of local and U.S. interest rates, BDI return, first difference of ADS index, first difference of Israeli CDS price, as well as lagged third-order polynomials in $spot_flows_t$; $\mathbb{C}_{t,p}$ is identical to $\mathbb{C}_{t,q}$ except that lagged third-order polynomials in the spot rate return replace spot flows.[12] (See Section 6 for extensions of the analysis, where we also consider as outcome variables various additional variables of interest.)

As explained in Section 4, our coefficient of interest is γ_h. Specifically, for $i = q, p$, we shall consider the impulse responses to a two standard deviation negative return shock, $-2\beta_{h,i} + 4\gamma_{h,i} - 8\delta_{h,i}$, impulse responses to a two standard deviation positive return shock, $2\beta_{h,i} + 4\gamma_{h,i} + 8\delta_{h,i}$, and the difference between these two objects (where positive shock effect is multiplied by -1) which captures the margin call channel, $8\gamma_{h,i}$.

Panel Model. We estimate *reduced-form panel* local projection regressions given by

$$\begin{aligned} &accum_spot_flows_{i,t+h} - accum_spot_flows_{i,t-1} = \mu_{i,h} + \beta_{h,lin} S\&P_500_return_t \\ &+ \gamma_{h,lin} S\&P_500_return_t^2 + \delta_{h,lin} S\&P_500_return_t^3 + \mathbb{C}'_{i,t}\Xi_{h,lin} \\ &+ synthetic_exposure_{i,t-1}\Big[\beta_{h,int} S\&P_500_return_t + \gamma_{h,int} S\&P_500_return_t^2 \\ &+ \delta_{h,int} S\&P_500_return_t^3 + \mathbb{C}'_{i,t}\Xi_{h,int}\Big] + v_{t+h}, \end{aligned} \tag{9}$$

where $\mu_{i,h}$ are fixed effects ($i = 1, 2, .., I$); $h = 0, 1, ..., 10$ is the local projection horizon; $accum_spot_flows_{i,t}$ is the ith II's accumulated net spot flows (dollar purchases minus dollar selling), in millions of dollars; and $synthetic_exposure_{i,t-1}$ is lagged notional synthetic exposure of the ith II, interacted with all of the regression's variables and measured, for each day, in terms of deviations from the mean, normalized by the standard deviation.[13,14] Control vector $\mathbb{C}_{i,t}$ is identical to $\mathbb{C}_{t,q}$ from the aggregate

[11] Given the market-making nature of the USD/ILS spot market, it is essential to use accumulated spot flows to capture the inventory-based pricing pressure from margin calls.

[12] We specify a lag length of 20 days for the controls in $\mathbb{C}_{t,p}$, which corresponds to the average of the optimally chosen lag specifications from the AIC, corrected AIC, BIC, HQIC, and adjusted R^2 lag length criteria tests. We consistently also specify 20 lags for the controls in $\mathbb{C}_{t,q}$ and demonstrate robustness of our results to alternative lag specifications in online appendix A.

[13] Exposure mean and standard deviation are computed from the pooled exposure distribution, thus resulting in $synthetic_exposure_{i,t-1}$ reflecting both cross-sectional and time-series variation in exposures.

[14] It is noteworthy that all variables in Regression (9), including all interaction terms, were found to be stationary. Hence, standard inference procedures can be applied when estimating this regression.

model's Equation (7) except that the former, in accordance with the panel specification, includes II-specific lagged spot flows instead of aggregate spot flows.[15], and $synthetic_exposure_{i,t-1}$.

We have a total of 18 IIs ($I = 18$), with these fund families owning 98 funds (75 pension funds and 23 insurance policy funds). Hence, as explained in the previous section, aggregating within each II serves the important purpose highlighted in that section of smoothing out the fund-level discontinuities at the margin call threshold losses.

As explained in Section 4, our coefficient of interest is the interactive coefficient $\gamma_{h,int}$. Specifically, we shall consider three objects. First, the impulse responses to a two standard deviation negative (positive) return shock conditional on lagged exposure being at the mean, $-2\beta_{h,lin} + 4\gamma_{h,lin} - 8\delta_{h,lin}$ ($2\beta_{h,lin} + 4\gamma_{h,lin} + 8\delta_{h,lin}$), while focusing the difference between the negative and positive shock effects, $8\gamma_{h,lin}$. Second, the impulse responses to a two standard deviation negative (positive) return shock conditional on lagged exposure being one standard deviation above the mean, $-2\beta_{h,lin} + 4\gamma_{h,lin} - 8\delta_{h,lin} - 2\beta_{h,int} + 4\gamma_{h,int} - 8\delta_{h,int}$ ($2\beta_{h,lin} + 4\gamma_{h,lin} + 8\delta_{h,lin} + 2\beta_{h,int} + 4\gamma_{h,int} + 8\delta_{h,int}$), while focusing on the difference between the negative and positive shock effects, $8\gamma_{h,lin} + 8\gamma_{h,int}$. And, last, the difference between these two objects which serves as a litmus test for the aggregate results' causal interpretation, $8\gamma_{h,int}$.

6 Empirical Evidence

This section presents the main results of the paper. We begin with the baseline results from the aggregate model, followed by a validation of their causal interpretation via the presentation of the results for the panel (granular) model. We then consider additional analysis for our aggregate model that concerns the responses of IIs' forward flows and prices This is followed by a discussion of an array of robustness checks (the robustness analysis' results are only discussed in the text and fully shown in online appendix A). We end the section with an analysis that rules out a meaningful role for other exchange rate channels in driving our results.

[15]To ensure that our panel results are not driven by II-level size differences, we also control for size as measured by IIs' total asset holdings. Specifically, we include this variable precisely as we include the exposure variable, i.e., in lagged form at the II-level, interacted with all of the regression's variables, and measured, for each day, in terms of deviations from the mean, normalized by the standard deviation. For expositional purposes, this inclusion is not shown in Equation (9)

6.1 Aggregate Model: Baseline Results

Spot Quantities. Figure 3 shows impulse responses of IIs' accumulated spot flows to a two standard deviation negative and positive return shock as well as the difference between these two objects. Responses to the positive shock are multiplied by -1 for comparability with respect to those to the negative shock. Impulse responses horizons are from impact day ($h = 0$) through 10th day after shock ($h = 10$). For completeness, we also show the linear response, which ignores the higher order coefficients, i.e., $2 * \beta_h, q$.

The margin call channel is nicely captured by Figure 3: While the positive shock generates insignificant dollar selling by IIs on impact, the negative shock induces IIs to buy 97.9 million spot dollars on impact, or 0.64 standard deviations of IIs' spot flows. The stark difference between the two responses of $76.8 million is also very significant, with a t-stat of 3.1. This significance persists for all of the considered horizons, as IIs continue to buy spot dollars in response to the negative shock: 10 days after shock, IIs accumulate a significant $502.1 million of spot buying in response to the negative shock, compared to a much lesser corresponding selling of 159.9 million spot dollars following the positive shock. While the asymmetry remains significant at longer horizons, our interpretation places greatest weight on the impact horizon. Relative to delayed responses, impact responses are less likely to be influenced by mechanisms other than margin calls and therefore provide the cleanest evidence on the causal effect of interest. We revisit the interpretation of longer horizon asymmetries in Section 6.2.

IIs begin to significantly sell spot dollars in response to the positive return shock only on the 4th horizon, consistent with delayed portfolio rebalancing that could potentially also be present following the negative shock. In Section 6.4.3, using other sectors' daily spot flow data, we rule out an expectations-based channel whereby arbitrageurs, anticipating IIs' delayed spot flows, regardless of their underlying source, execute impact trades that mimic those flows. This finding lends further support to our interpretation of the asymmetric spot exchange rate response, discussed next, as arising from the margin-call channel rather than from expectations of delayed spot flows unrelated to margin calls.

Spot Prices. Figure 4 corresponds to Figure 3 only that now responses of accumulated IIs' aggregate volume-weighted USD/ILS spot rate returns are shown. The persistent and asymmetric spot dollar buying by IIs also leads to asymmetric appreciation of the dollar: the negative shock

induces the dollar to appreciate by 0.37% on impact, or 0.43 standard deviations of IIs' spot rate return, while the positive shock depreciates the dollar by only 0.19%. The large difference between the two responses of 0.18 percentage points (or 98% response increase in relative terms) is also very significant, with a t-stat of 3.9. This significance lasts through the 4th horizon (or for three days after the shock). (The discussion on why the dollar significantly depreciates in response to the positive shock in the absence of null corresponding significant spot dollar selling is deferred to Section 6.4's discussion on IIs' forward flow behavior.)

6.2 Panel Model

Figure 5 shows panel Model (9)'s estimated impulse responses of accumulated IIs' spot flows to a two standard deviation negative and positive return shock conditional on lagged synthetic exposure being at the mean, along with the difference between these two objects (all termed with 'non-State-Dependent'); responses to a two standard deviation negative and positive return shock conditional on lagged synthetic exposure being one standard deviation above the mean, along with the difference between these two objects (all termed with 'State-Dependent'); and the difference between the state- and not-state-dependent response asymmetries. The latter *double difference* object, presented in the last sub-panel of Figure 5, is the object on interest in this section; it is given by $8\gamma_{j,int}$ and captures the additional asymmetry induced by higher synthetic exposure across IIs, thus serving as validation for the causal margin-call-channel-based interpretation of the aggregate results from the previous section. Impulse responses horizons are from impact day ($h = 0$) through 10th day after shock ($h = 10$). For completeness, we also show the linear response, which ignores the higher order coefficients both in linear and interactive form, i.e., $2 \times \beta_h, lin$.

The margin-call-channel-based interpretation from the previous section is nicely validated by Figure 5: While the positive shock fails to generate significant impact dollar selling by IIs, either conditional on lagged exposure being at the mean or one standard deviation above the mean, the negative shock induces IIs to buy 6.1 million spot dollars on impact when lagged exposure is at the mean and $16.2 million on impact when lagged exposure is one standard deviation above the mean.[16] The additional asymmetry of $9.9 million coming from greater exposure, which quantitatively indicates that response asymmetry rises by 186.6% for a one-standard-deviation increase in

[16]These responses are smaller than the aggregate ones from the previous section because the panel regressions use II-specific spot flows and thus the responses correspond to precision-weighted individual spot flows' estimated responses rather than aggregates flows' responses.

lagged IIs' synthetic exposures,[17] is also very significant, with an impact t-stat of 4.4, as summarized by the *double difference* object of interest shown in the last sub-panel. The added asymmetry remains significant through the 4th horizon, in line with the sustained significance of the exchange rate response asymmetry from Figure 4.

That the persistence of the aggregate spot flow response asymmetry in Figure 3 exceeds that of the synthetic-exposure-induced asymmetry in Figure 5 underscores the caution required when interpreting the former as arising solely from the margin-call channel. As the horizon lengthens, additional mechanisms are increasingly likely to contribute to aggregate flow dynamics. This consideration further highlights the importance of focusing on impact responses for causal identification and interpretation, a principle that guides our analysis throughout the paper.

We now formally connect the panel, micro margin call channel effect of \$9.9 million with the corresponding aggregate \$76.8 million effect.

Reconciling the Panel and Aggregate Effects. The margin call effect estimated in the panel specification can be aggregated to provide a bottom-up aggregate estimate that can be compared with the aggregate estimate obtained from the time series evidence, thereby providing an external validation of the latter's causal interpretation. Specifically, the panel regression implies that a one-standard-deviation increase in synthetic exposure raises the sign-dependent spot flow response by \$9.9 million. To aggregate this effect, we first compute each II's average synthetic exposure and retain only IIs with positive average exposure, as only these IIs contribute positively, on average, to the estimated panel margin call \$9.9 million effect. We then sum the average synthetic exposures across these institutions and multiply the resulting quantity by \$9.9 million, yielding an *aggregated* panel estimate of \$79.6 million (8×9.9).

The sum of positive average synthetic exposures equals eight standard deviations, corresponding to eight IIs with above-average synthetic exposures (with the highest and lowest average exposures equal to 1.2 and 0.002 standard deviations, respectively). Thus, the *aggregated* panel estimate can be interpreted as the spot flow response asymmetry associated with an aggregate increase in synthetic exposure of eight standard deviations across IIs with positive average synthetic exposure. Multiplying this aggregate exposure increase by the estimated \$9.9 million response as-

[17] This calculation is based (up to rounding) on the response asymmetry rising from \$5.3 million when conditioned on lagged exposure being at the mean to \$15.3 million conditioned on lagged exposure being one standard deviation higher than the mean.

sociated with a one-standard-deviation increase in exposure yields an implied aggregate effect of $79.6 million.

The resulting $79.6 million estimate is remarkably close to the $76.8 million aggregate effect obtained directly from the difference between the aggregate spot flow responses to negative and positive return shocks, with the former quantitatively accounting for effectively all of the latter effect. The close correspondence between these two independently estimated quantities provides strong support for interpreting the aggregate response asymmetry as arising from the margin call channel.

6.3 Robustness Checks

Online appendix A examines and confirms the robustness of the baseline results presented above along four dimensions. The first considers alternative lag specifications. The second removes from the estimation the 2020 period to confirm that the baseline results are robust to omission of the COVID period. The third confirms that our results are robust to controlling for BOI interventions in the dollar spot market.

The fourth and last exercise reassures that the significance and persistence of IIs' accumulated spot purchases following large negative return shocks are not coming from dollar-appreciation-induced losses on IIs' FX short positions. We accomplish this by showing that results are virtually unchanged from including II-level data on FX short positions in our panel model precisely as we include the exposure and size variables, i.e., in lagged form at the II-level, interacted with all of the regression's variables, and measured, for each day, in terms of deviations from the mean, normalized by the standard deviation. The robustness of this exercise's results make it clear that IIs with the same FX short position—and hence with the same losses on this position from dollar appreciation—still exhibit effectively the same spot flow responses from the baseline panel model, thus supporting the notion that our baseline results are driven by a margin call channel related to U.S. equity futures rather than FX short positions.[18]

[18]For all exercises, but the last, we present results for three estimations: aggregate quantity (spot flows) local projection regression, aggregate price (spot rate) local projection regression, and panel quantity (spot flows) local projection regression; for the last exercise, given its strictly granular nature, we only present the panel results.

6.4 Ruling Out Other Competing Exchange Rate Channels

A remaining concern regarding our analysis is that our results still may capture competing, non-margin-call channels that nevertheless generate similar asymmetric, sign-dependent impulse responses. Our rich array of controls, which is included in third-order polynomial form just like the central S&P 500 return variable, ensures that our results are not driven by exchange rate channels related to interest rates, risk factors, and the real economy. However, there are three important channels that can still be confounding our results' causal margin-call-channel-based interpretation.

First, the equity hedging channel can be a confounder. In particular, what we interpret as exchange rate response asymmetry coming from margin calls is potentially merely a reflection of stronger IIs' U.S. equity hedging in response to negative return shocks. I.e., IIs buy more dollar forwards following negative return shocks than sell dollar forwards following positive return shocks, thus resulting in both stronger forward dollar depreciation as well as the stronger spot dollar depreciation we observe due to the close connection between spot and forward FX markets through the covered interest parity (CIP) arbitrage condition. We now turn to discuss why we think these two channels are unlikely to confound this paper's causal interpretation.

Second, the portfolio rebalancing channel can also act as a confounder. Specifically, what we interpret as the spot flow asymmetry coming from margin calls could actually be rooted in IIs' stronger portfolio rebalancing—and thus stronger dollar buying, compensating for the decline in the dollar valued portion of their portfolio—in response to negative return shocks relative to the rebalancing from positive return shocks.

Third, the last potentially confounding channel we consider is an expectations-based channel where arbitrageurs do trades that mimic IIs' future spot and forward flows in anticipation of the resulting exchange rate pressure. This channel can be especially relevant given the persistence of IIs' flow responses.

6.4.1 Ruling Out Equity Hedging as a Confounder

We eliminate equity hedging's potentially confounding role in two stages. First, we present the sign-dependent responses of forward flows and rates, the purpose of which is set up a base for the said elimination as well as to provide an explanation for the spot dollar depreciation observed following positive return shocks. Second, using our panel model, we reinforce the aggregate

results by showing that the forward flow response does not increase with synthetic exposure, affirming the conclusion that the equity hedging channel is unrelated to the margin call channel and the spot rate asymmetry.

Role of Equity Hedging for Dollar Depreciation Following Positive Return Shocks. At the end of Section 6.1, we deferred discussion on why the dollar appreciates in response to positive return shocks, despite absence of significant spot dollar selling by IIs. The answer lies in Figures 6 and 7, which correspond to Figures 3 and 4 but instead of accumulated IIs' spot flows' and accumulated spot rate returns 'responses, they show accumulated IIs' forward flows' and accumulated forward rate returns' responses, respectively.

The positive shock now generates significant dollar *forward* selling on impact by IIs, in the amount of $48.7 million, or 0.24 standard deviations of IIs' forward flows, with this selling also generating significant dollar forward rate depreciation of 0.27%, or 0.37 standard deviations of forward rate returns. This significant dollar forward rate depreciation can explain the corresponding 0.19% spot rate depreciation, based on the CIP arbitrage condition; we confirm in online appendix B that the impact forward and spot rate response to both the positive and negative shocks are insignificantly different from one another by using the forward premium as the outcome variable in our estimation.[19]

Is Equity Hedging Asymmetric? While the dollar appreciates by more on impact following the negative shock, this asymmetric price response is not coming from an asymmetric quantity response. Specifically, IIs' impact forward buying of $51 million following the negative return shock is insignificantly larger than the corresponding forward selling of $48.5 million, with the difference between the two responses having a t-stat of only 0.17. This indicates that the asymmetric forward rate response is rooted in the asymmetric spot rate response through the CIP arbitrage

[19] We also establish in online appendix C there that our margin call channel does not entail any meaningful role for the swap market. This result is consistent with the input we received from conversations with market participants that swap dollars are not the natural funding instrument for IIs facing margin calls because swaps are equivalent to collateralized dollar loans (collateral being the ILS swapped for the dollars), thus creating additional leverage and future liquidity needs in already liquidity-stressed times.

condition.[20]

Is Asymmetric Equity Hedging Related to the Margin Call Channel? To reinforce the interpretation that spot rate asymmetry is induced by the margin call channel while forward rate asymmetry is driven by spot rate asymmetry through CIP arbitrage, we must turn to the panel model given its crucial validation role for the causal interpretation of the aggregate spot-based results. In particular, we re-estimate this model, now using accumulated forward flows at the individual II-level; these results are shown in Figure 8. This exercise provides a litmus test for the validity of the above-mentioned interpretation.

The results from Figure 8 clearly pass the said litmus test, supporting the notion that the asymmetric forward rate behavior from Figure 7 is mainly driven by the margin call channel. Specifically, there is insignificant additional impact asymmetry coming from lagged exposure being one standard deviation above the mean of only 2.2 million forward dollars, possessing a t-stat of only 0.98. I.e., IIs equity hedging behavior is independent of the level of IIs' synthetic exposure, thus establishing independence between the equity hedging channel and the margin call channel.[21]

6.4.2 Ruling Out Portfolio Rebalancing as a Confounder

A defining characteristic of this paper's results is that IIs *do not* significantly sell spot dollars on impact in response to large positive return shocks. This result contradicts the portfolio balancing channel of exchange rate determination and thus eliminates a potential confounding role for this channel in this paper results' interpretation. The reasoning for this assessment is straightforward. A necessary condition for the portfolio rebalancing channel to be meaningful in our data is

[20]The key dimension of this exercise, as well as all other exercises, is the impact response, as it provides the cleanest evidence on the margin call channel. Nevertheless, the significant asymmetry observed at the fourth through eighth horizons does not undermine the paper's margin-call-channel-based interpretation. As shown in Section 6.4.3, these delayed asymmetries do not give rise to an expectations-based channel whereby arbitrageurs undertake anticipatory FX trades in advance of the future exchange rate pressure generated by IIs' delayed flows. Accordingly, while additional mechanisms may contribute to longer-horizon flow dynamics, they do not appear to contaminate the causal interpretation of the impact response.

[21]The key dimension of this and all other exercises is the impact response, as it provides the cleanest and most credible measure of the margin-call channel. Nevertheless, it is reassuring that the absence of a relationship between forward flow response asymmetry and synthetic exposure documented in Figure 8 persists across all horizons. This finding implies that the delayed forward flow asymmetry observed from the 4th through 8th horizons in Figure 6 is unlikely to reflect margin call effects. However, both these delayed asymmetries and those present in the raw forward flow responses may, in principle, give rise to an expectations-based channel whereby arbitrageurs undertake FX trades in anticipation of future II flows and the resulting exchange rate pressure. We explicitly rule out this possibility in Section 6.4.3.

for positive return shocks to induce spot dollar selling by IIs on impact. Hence, the violation of this condition eliminates a potentially meaningful confounding role for the portfolio rebalancing channel.

However, we do observe significant *delayed* spot selling following positive shocks from the fourth horizon onward. As with the delayed spot buying following negative shocks, as well as the delayed forward flows from Figure 6, these future flows may induce anticipatory mimicking trades by arbitrageurs seeking to profit from the ensuing price pressure. It is therefore crucial to rule out such anticipatory trading in order to reinforce our margin-call-channel-based interpretation of the results. We now turn to evidence on this issue.

6.4.3 Ruling Out Expectations-Based Channel as a Confounder

We now examine the sign-dependent responses of sectoral accumulated spot and forward flows. We focus on the foreign, local banking, and local financial sectors because these sectors are the most plausible candidates to engage in the arbitrage activity underlying the expectations-based channel considered here.[22] For this channel to operate, arbitrageurs must immediately purchase (sell) spot dollars and forwards in anticipation of future purchases (sales) by IIs. By establishing positions ahead of the anticipated II FX activity, arbitrageurs can profit from the subsequent exchange rate pressure generated by those future flows.[23]

Figures 9a and 9b present the sign-dependent responses of the foreign sector's accumulated spot and forward flows, while Figures 10a–11b report the corresponding responses for the local banking and financial sectors. Across all sectors, there is no evidence of significant impact asymmetric spot or forward dollar purchases. This lack of asymmetry rules out the possibility that this paper's margin-call-channel-based interpretation is confounded by an expectations-based channel whereby market participants trade in anticipation of future II-driven exchange rate pressure. The only sector that actually significantly buys dollars of any kind on impact following the negative shock is the local financial sector, doing so in the spot market, but this buying is symmetric with

[22] For completeness, we have also examined the real sector, which is unlikely to engage in the arbitrage activity underlying the expectations-based channel considered in this section. The real sector exhibits no significant spot- or forward-dollar purchases following negative return shocks, either in absolute terms or relative to its response to positive return shocks.

[23] Examining sectoral forward-flow responses is also important because, as shown in Figure 6, IIs' forward-flow responses are persistent. To the extent that such persistence generates predictable future exchange-rate movements, it may induce anticipatory trading by arbitrageurs.

respect to the positive-shock-induced selling. Overall, the pervasive lack of impact asymmetry in dollar buying across all sectors—except IIs—reinforces our interpretation of this paper's results as arising from the margin call channel.

The figures further reveal that local banks constitute the primary *conditional* counterparty to IIs' spot transactions. Following a negative return shock, local banks cumulatively sell $80.7 million on impact, comparable to the corresponding $97.9 million spot-dollar purchase by IIs. Following a positive return shock, local banks purchase an economically and statistically insignificant $8 million, mirroring the asymmetric nature of IIs' spot-flow responses. This close conditional correspondence suggests that local banks absorb the bulk of the FX imbalance generated by IIs' margin-call-induced demand for dollars. This finding is particularly noteworthy because, unconditionally, local banks are meaningful net buyers of spot dollars over the sample period, whereas foreigners constitute the primary net sellers. The contrast highlights the importance of distinguishing between unconditional flow patterns and conditional responses to return shocks: while foreigners appear to be the dominant unconditional counterparties, local banks are the dominant counterparties to the return-shock-induced spot dollar demand generated by IIs.

7 Conclusion

This paper documents significant asymmetry in the response of IIs' dollar spot activity following large U.S. equity return shock: IIs do not sell spot dollars following a positive return shock, while buying spot dollars significantly in response to a negative return shock. The asymmetric spot flow activity takes place in tandem with a significantly stronger dollar appreciation in IIs' transactions-based spot rates following negative return shocks than the corresponding appreciation following positive return shocks. We rule out various alternative exchange rate channels to establish a causal connection between the asymmetry in spot flow response and that in the spot rate response. This set of findings, obtained from both an aggregate as well as granular econometric approach that exploits cross-sectional and time-series variation in IIs' synthetic exposures to U.S. equity, can be viewed as representing evidence in favor of a meaningful margin call channel of exchange rate determination.

We hope that this paper's findings contribute to a deeper understanding of a previously overlooked, highly non-linear exchange rate channel. In particular, our results shed light on the relationship between local IIs' positions in U.S. equity futures, their demand for spot dollars, and the

determination of exchange rates. Although our analysis is grounded in Israeli data, we believe the mechanism we identify has broader external validity for economies in which IIs maintain meaningful synthetic exposure to U.S. equities. As the role of IIs in global financial markets continues to expand, and as synthetic exposure to U.S. equities becomes increasingly attractive, this condition is likely to become more prevalent worldwide.

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Table 1: **Third-Order Polynomial Approximation of Aggregate IIs' Margin-Induced Dollar Demand.**

Object	Linear Coefficient (β)	Quadratic Coefficient (γ)	Cubic Coefficient (δ)	R^2
Mean	2.7	-17.5	2.4	95.3%
Standard Deviation	4.9	2.5	0.3	0.9%
Mean	45.5	-20.4		67.1%
Standard Deviation	8	2.8		2.3%
Mean	53.2			18.8%
Standard Deviation	9			1.8%

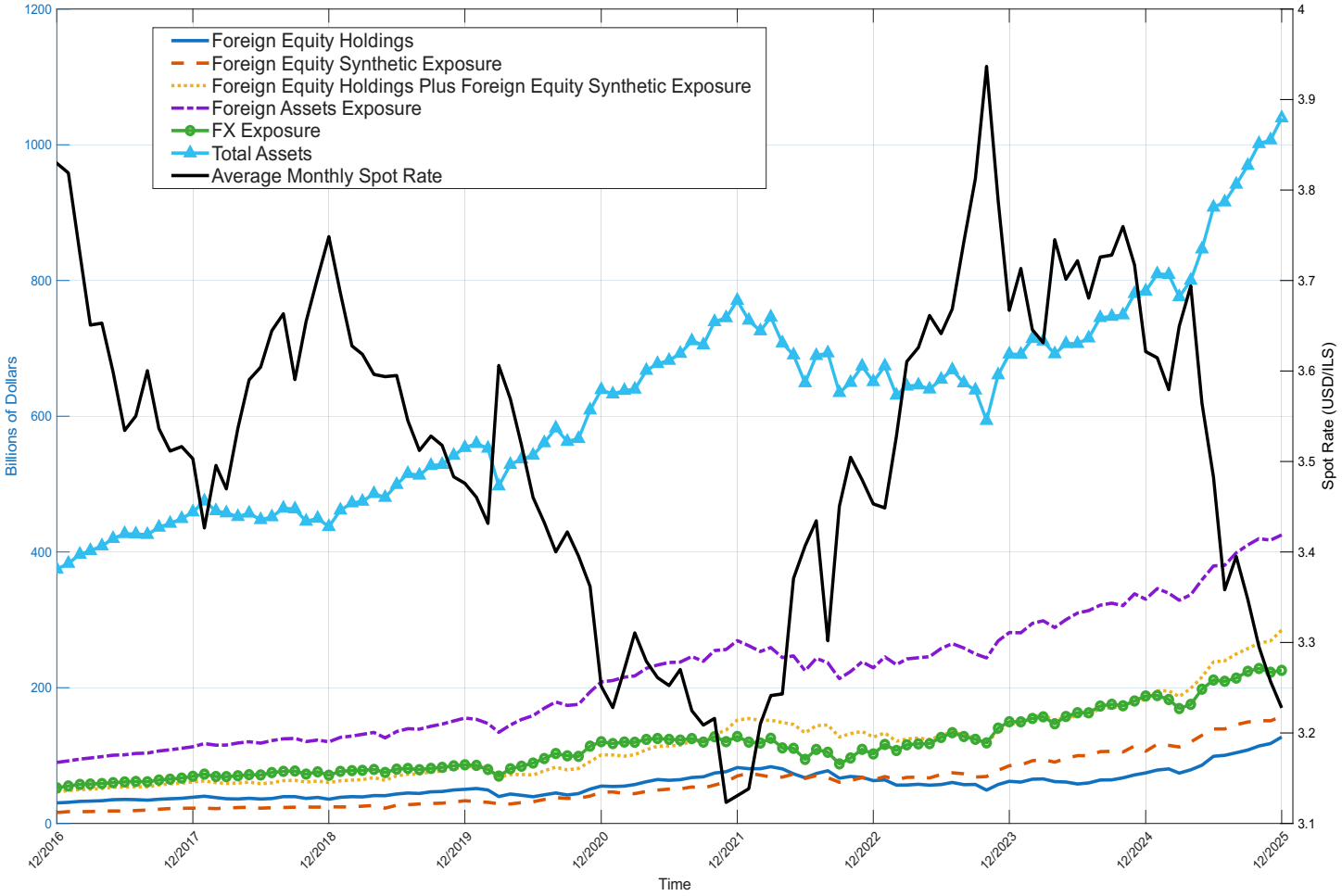
Notes: This table shows results from Section 4's Monte Carlo experiment where we fit via OLS a third-order polynomial regression in the S&P 500 return (Equation (4)) to simulated aggregate dollar demand samples obtained from Equation (2)'s true fund-level margin-induced demand functions. The coefficient values are in millions of dollars with respect to unit standard deviation return below the mean return. Mean objects are obtained from averaging estimated sample-specific objects over the 2,000 simulated samples. Standard deviation row reports the standard deviation of these sample-specific estimated objects across the 2,000 Monte Carlo objects. The first two rows report results from a third-order polynomial regression; the next two rows report results from a second-order polynomial regression; and the last two rows report results from a first-order polynomial (linear) regression.

Table 2: **Descriptive statistics for S&P 500 Return and IIs' Spot and Forward Flows and Rates.**

Response	S&P 500	Spot Flows	Spot Rate	Forward Flows	Forward Rate
Mean	0.06%	37	-0.005%	-5.2	-0.01%
Standard deviation	1.2%	152.7	0.9%	201.8	0.7%
Obs	2,251	2,251	2,251	2,251	2,251

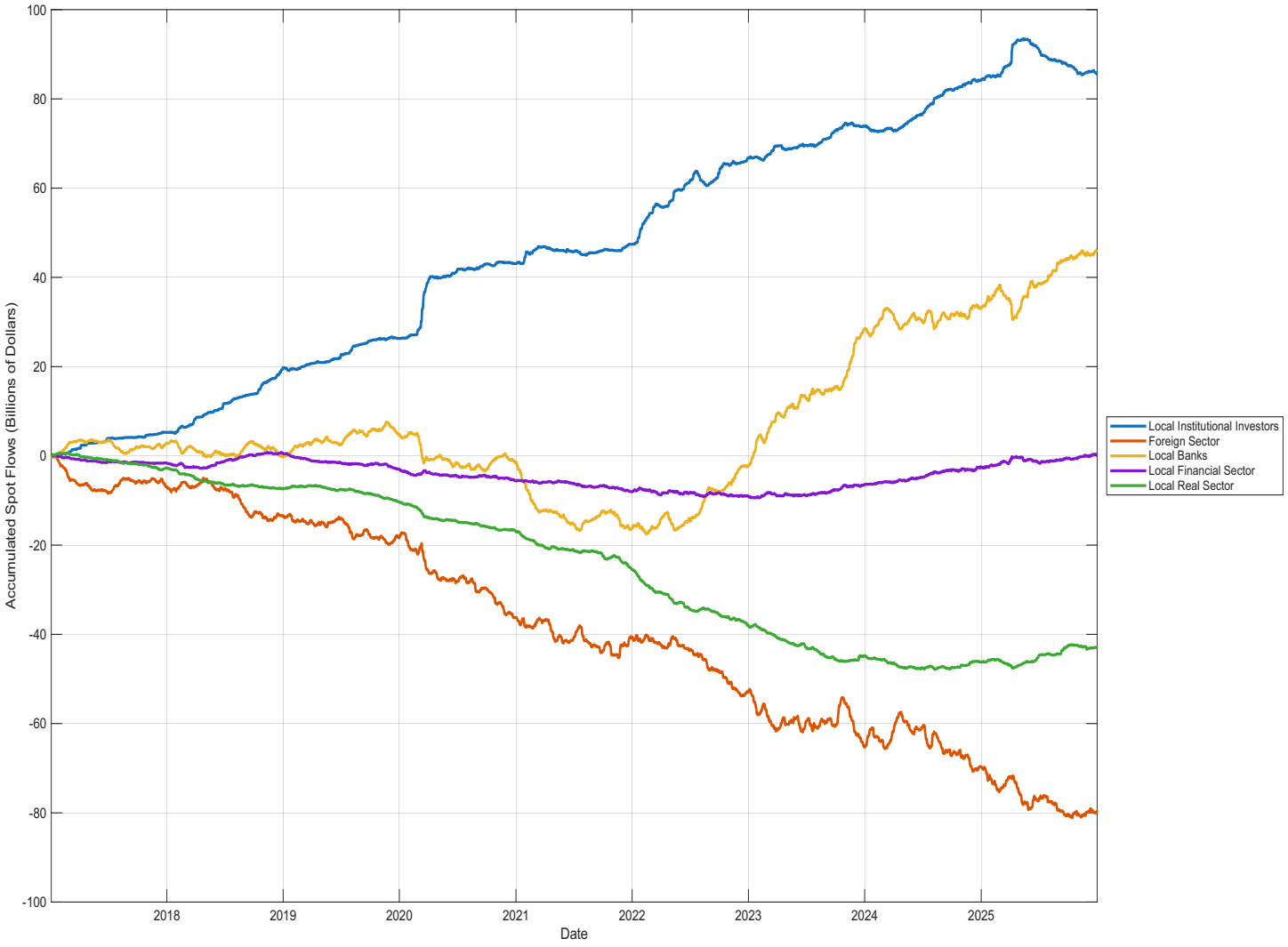
Notes: This table shows our baseline (2017-2025) daily sample period's descriptive statistics (mean and standard deviation) for S&P 500 return and IIs' spot flows and rates as well as IIs' forward flows and rates. IIs' spot and forward rates are the daily volume-weighted averages of IIs' corresponding rates from their transactions; the rates' statistics, like the S&P 500 variable, are in terms of growth rates. The flows' statistics are in millions of dollars; positive (negative) values represent buying (selling) of spot/forward dollars.

Figure 1: **Time Series of IIs' Foreign Equity Holdings, Foreign Equity Synthetic Exposure, Foreign Asset Exposure, FX Exposure, Total Assets, and Spot Rate.**



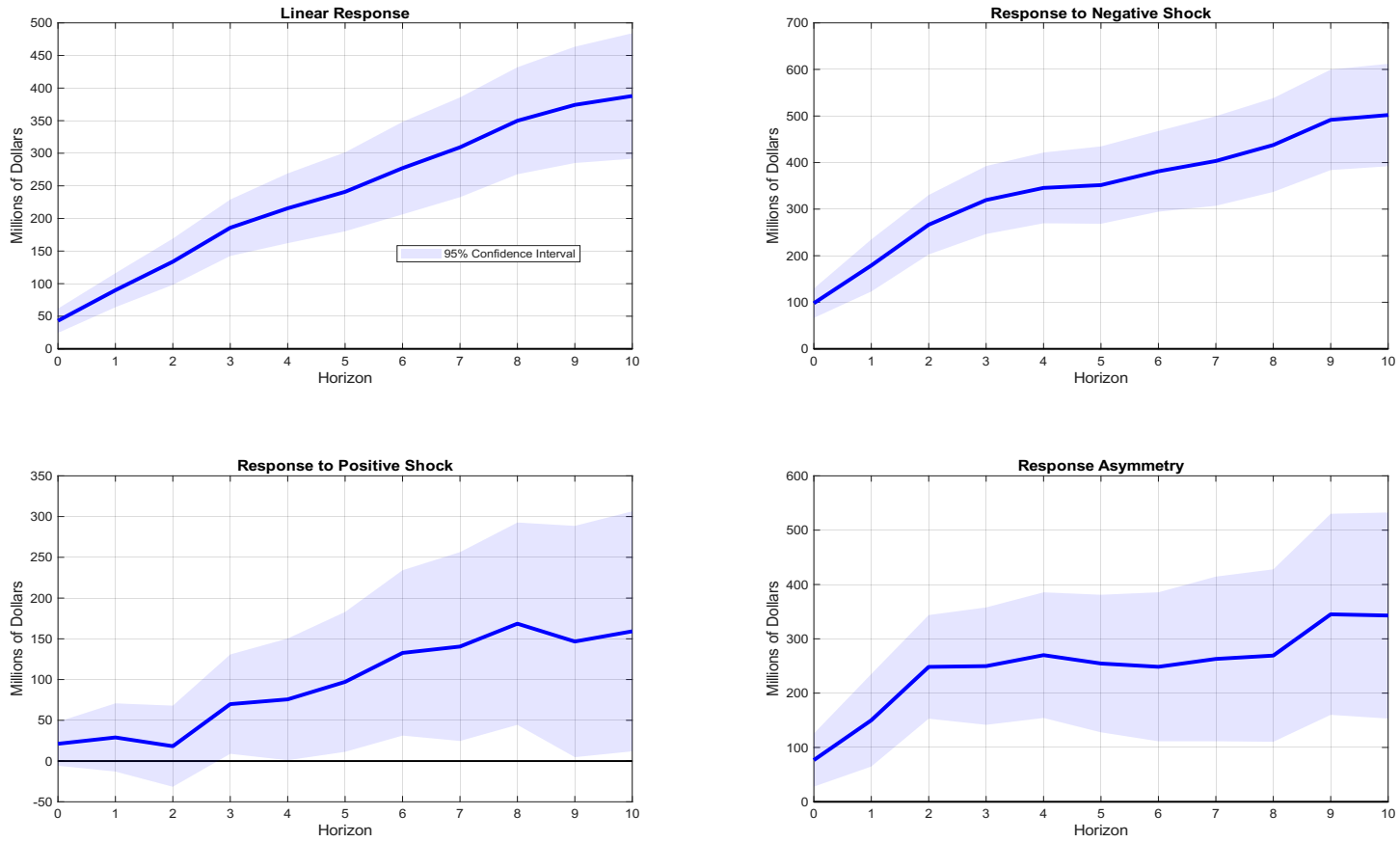
Notes: This figure presents the time series of the monthly billion dollar values of IIs' foreign equity holdings (solid blue line), foreign equity synthetic exposure (dashed red line), the sum of the latter two variables—i.e., total foreign equity exposure (dotted yellow line), foreign asset exposure (dash-dotted purple line), FX exposure (circled green line), and total assets (triangular cyan line), along with IIs' aggregate (transactions-based, volume-weighted average) spot rate (solid black line). Data are from the BOI and cover 12/2016–12/2025. Time (monthly dates) is on the x-axis. Left y-axis units are in billions of dollars, corresponding to all variables except for the spot rate, which corresponds to the right y-axis and is in USD/ILS units.

Figure 2: **Time Series of Accumulated Spot Flows by Sector.**



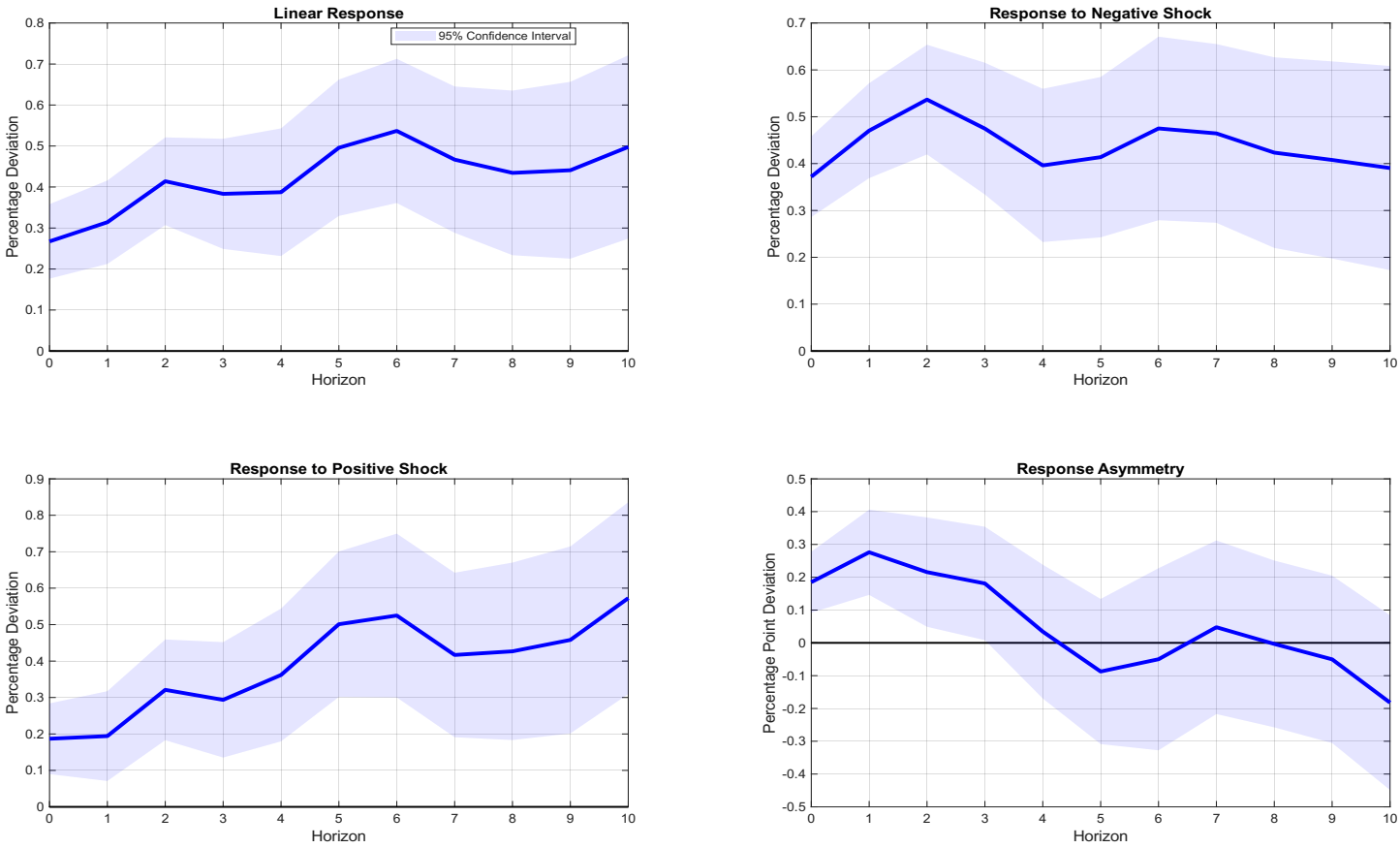
Notes: This figure presents the time series of accumulated daily dollar spot flows by sector. On top of the II sector (which, for completeness, is also included in the figure and is represented by the solid blue line), this figure includes four additional sectors: foreign sector (solid orange line), which includes all types of foreign financial entities; local banking sector (solid yellow line), which includes the Israeli commercial banks; local financial sector (solid purple line), which includes Israeli mutual funds, exchange traded funds, hedge funds, and proprietary trading firms; and local real sector (solid green line), which represents the net spot flows from transactions involving Israeli exporters and importers;. Negative accumulated flows' values represent the accumulated selling of spot dollars; positive values represent the accumulated buying of spot dollars. Data are from the BOI and cover 1/3/2017–12/31/2025. Time is on the x-axis. Values are in billions of dollars.

Figure 3: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: Accumulated IIs' Aggregate Spot Flows.**



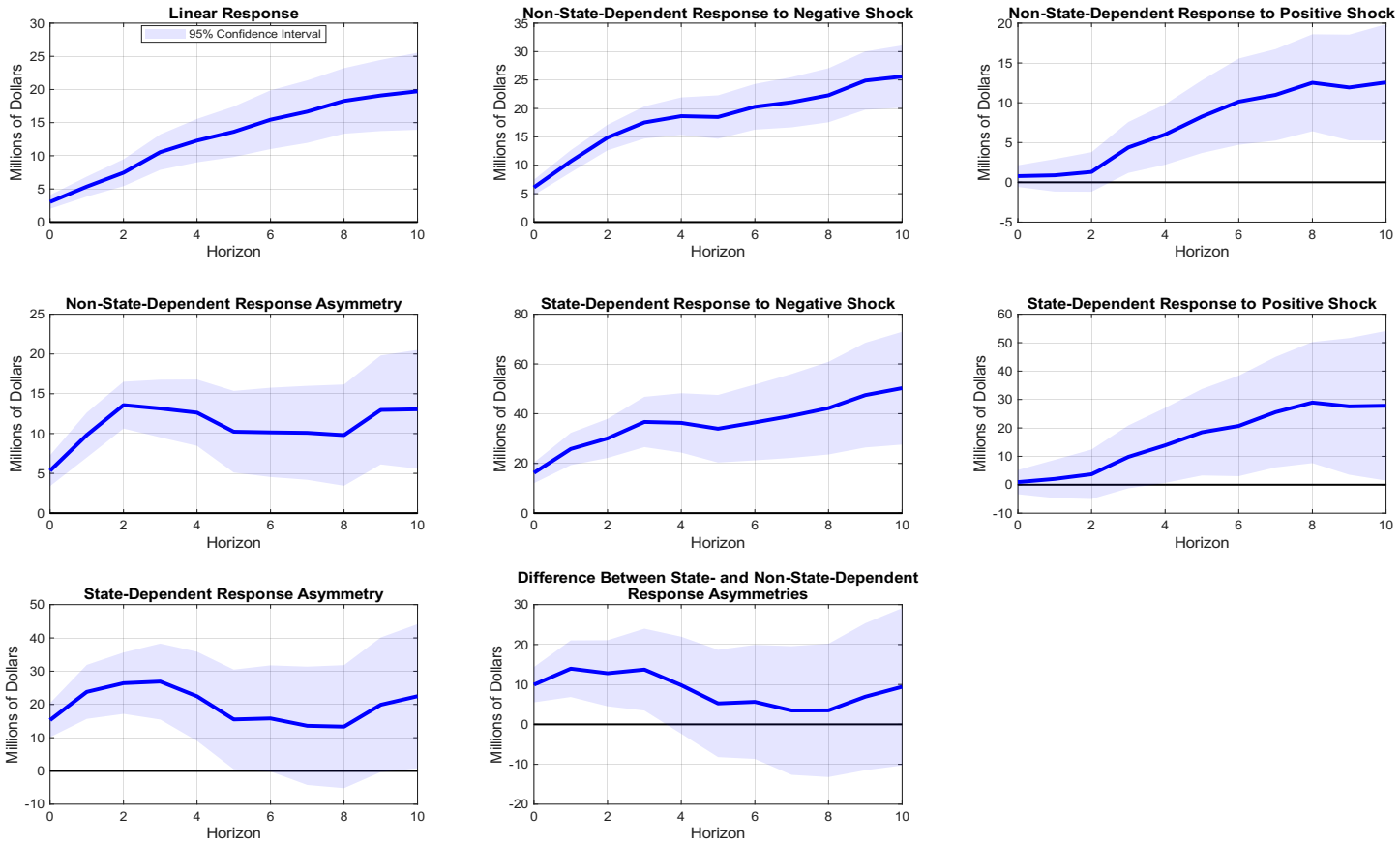
Notes: This figure presents the aggregate model's impulse responses (solid lines) of accumulated IIs' aggregate spot flows to a two standard deviation negative and positive U.S. equity return shock, obtained from using cumulative differences in accumulated IIs' aggregate spot flows as the outcome variable in the aggregate model. For comparison purposes, the response to the positive shock is multiplied by -1. The figure also presents the difference between the response to the negative shock and the positive shock ('Response Asymmetry') and the linear effect of the shock ('Linear Response'—obtained from taking only the linear component of the response to the negative shock). 95% confidence bands (shaded areas) are based on standard errors computed from the heteroskedasticity- and autocorrelation-consistent procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated spot flows are in million of dollars changes relative to the pre-shock value of the accumulated spot flow variable.

Figure 4: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: IIs' Aggregate Spot Rate.**



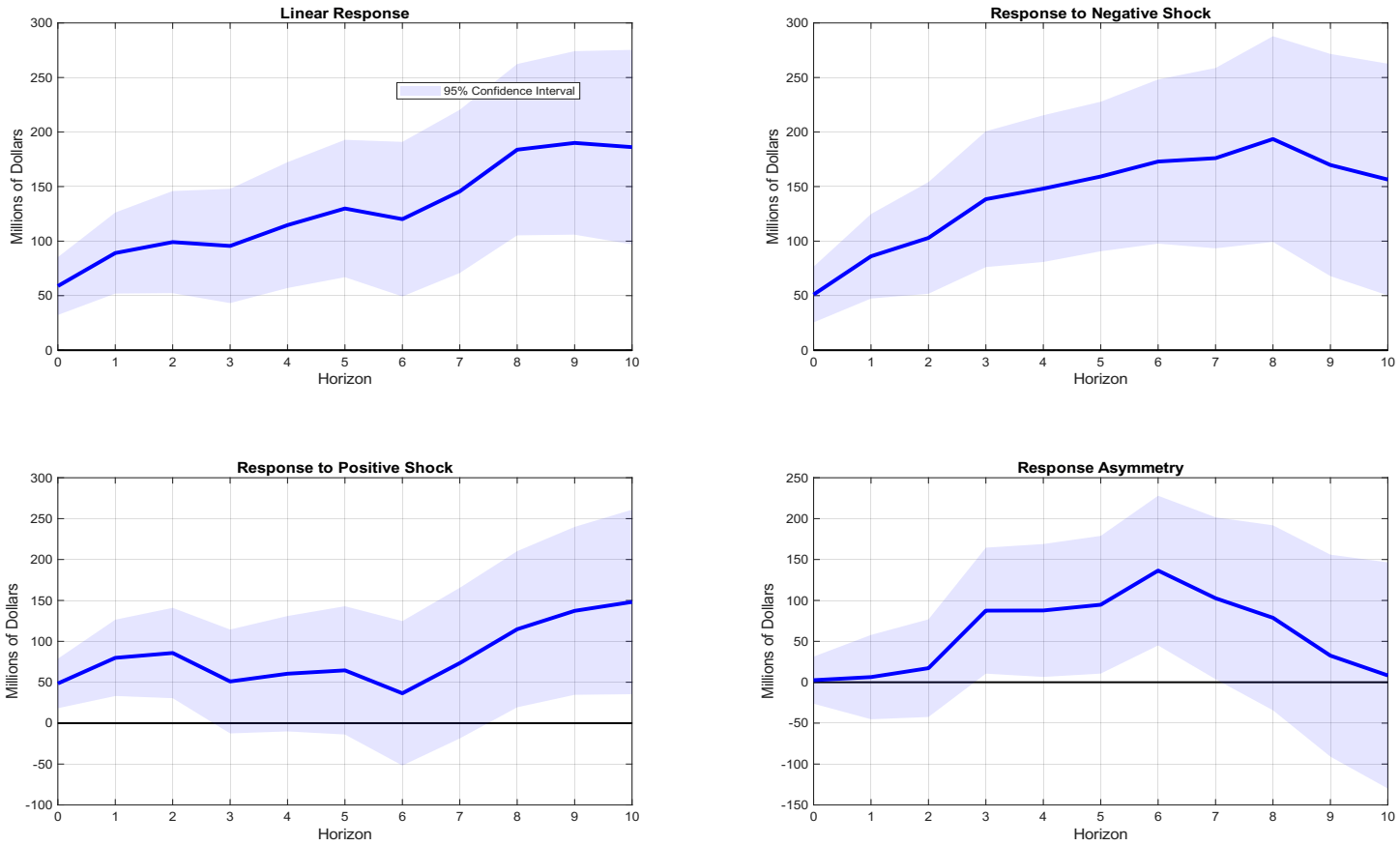
Notes: This figure presents the aggregate model's impulse responses (solid lines) of IIs' aggregate (transactions-based, volume-weighted average) spot rate to a two standard deviation negative and positive U.S. equity return shock, obtained from using cumulative IIs' aggregate spot rate returns as the outcome variable in the aggregate model. For comparison purposes, the response to the positive shock is multiplied by -1. The figure also presents the difference between the response to the negative shock and the positive shock ('Response Asymmetry') and the linear effect of the shock ('Linear Response'—obtained from taking only the linear component of the response to the negative shock). 95% confidence bands (shaded areas) are based on standard errors computed from the heteroskedasticity- and autocorrelation-consistent procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for spot rate are in percentage change units relative to the pre-shock value of spot rate.

Figure 5: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Panel Model: Accumulated IIs' Spot Flows.**



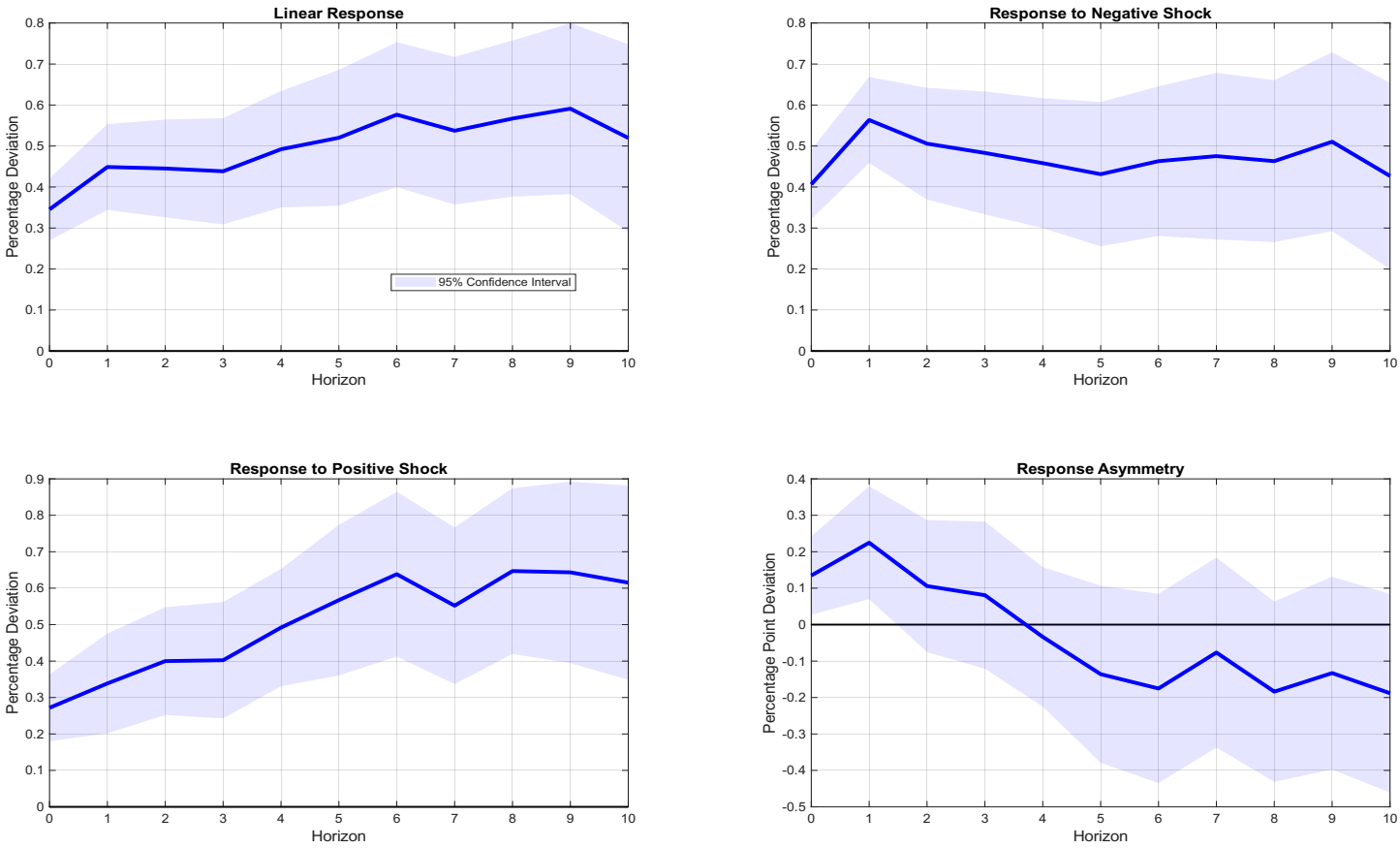
Notes: This figure presents the panel model's impulse responses (solid lines) of accumulated IIs' spot flows to a two standard deviation negative and positive U.S. equity return shock when lagged synthetic exposure is at the mean, along with the difference between the two responses (all termed with 'Non-State-Dependent'); and the corresponding responses and their difference when lagged synthetic exposure is one standard deviation above the mean (all termed with 'State-Dependent'), along with the difference between the state- and non-state-dependent response differences. For comparison purposes, responses to the positive shock are multiplied by -1. For completeness, we also show the linear response, which ignores the higher order coefficients both in linear and interactive form. 95% confidence bands (shaded areas) are based on standard errors computed from the spatially-, heteroskedasticity-, and autocorrelation-consistent procedure of Driscoll and Kraay (1998), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated spot flows are in million of dollars changes relative to the pre-shock value of the accumulated spot flow variable.

Figure 6: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: Accumulated IIs' Aggregate Forward Flows.**



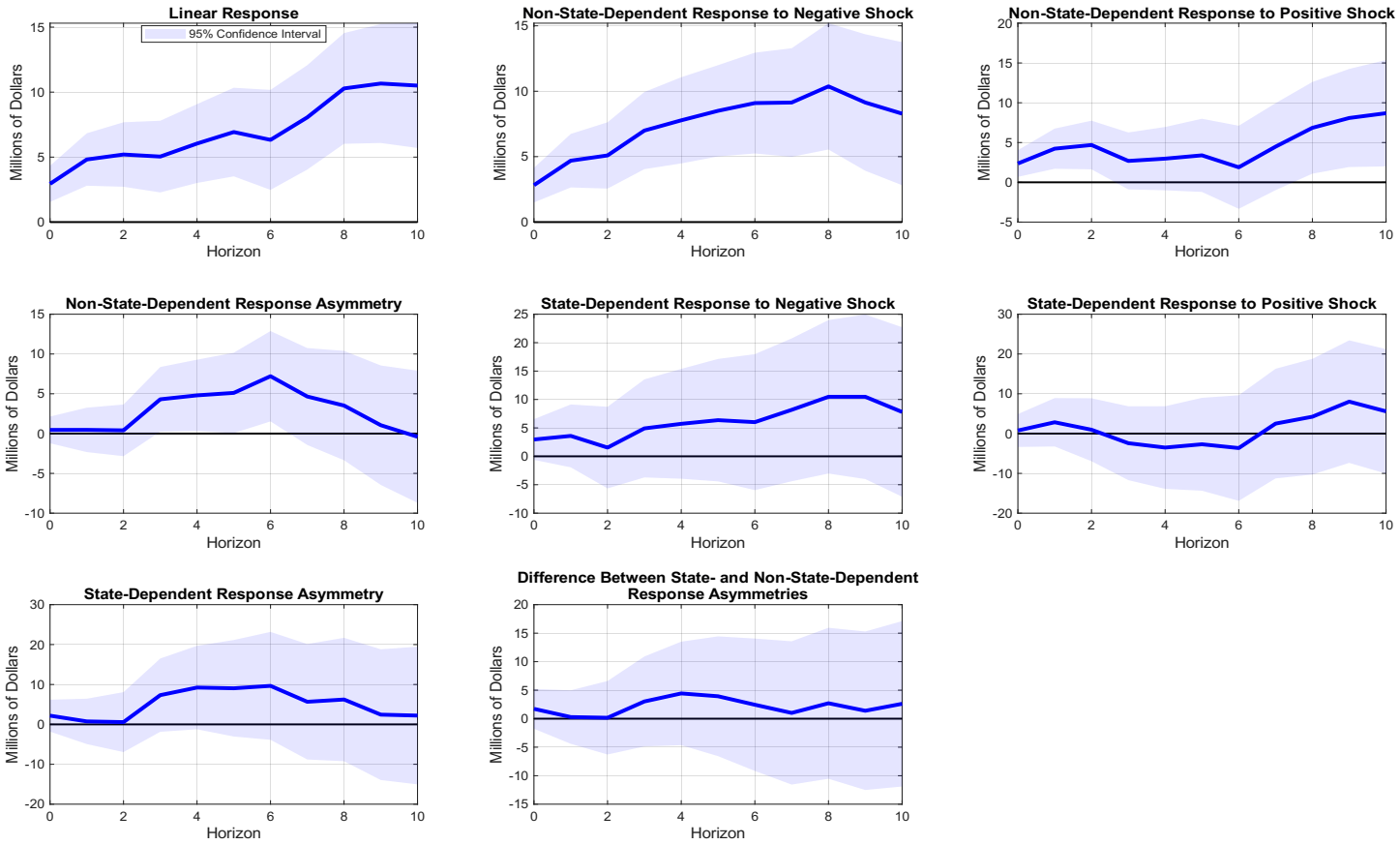
Notes: This figure presents the aggregate model's impulse responses (solid lines) of accumulated IIs' aggregate forward flows to a two standard deviation negative and positive U.S. equity return shock, obtained from using cumulative differences in accumulated IIs' aggregate forward flows as the outcome variable in the aggregate model. For comparison purposes, the response to the positive shock is multiplied by -1. The figure also presents the difference between the response to the negative shock and the positive shock ('Response Asymmetry') and the linear effect of the shock ('Linear Response'—obtained from taking only the linear component of the response to the negative shock). 95% confidence bands (shaded areas) are based on standard errors computed from the heteroskedasticity- and autocorrelation-consistent procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated forward flows are in million of dollars changes relative to the pre-shock value of the accumulated forward flow variable.

Figure 7: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: IIs' Aggregate Forward Rate.**



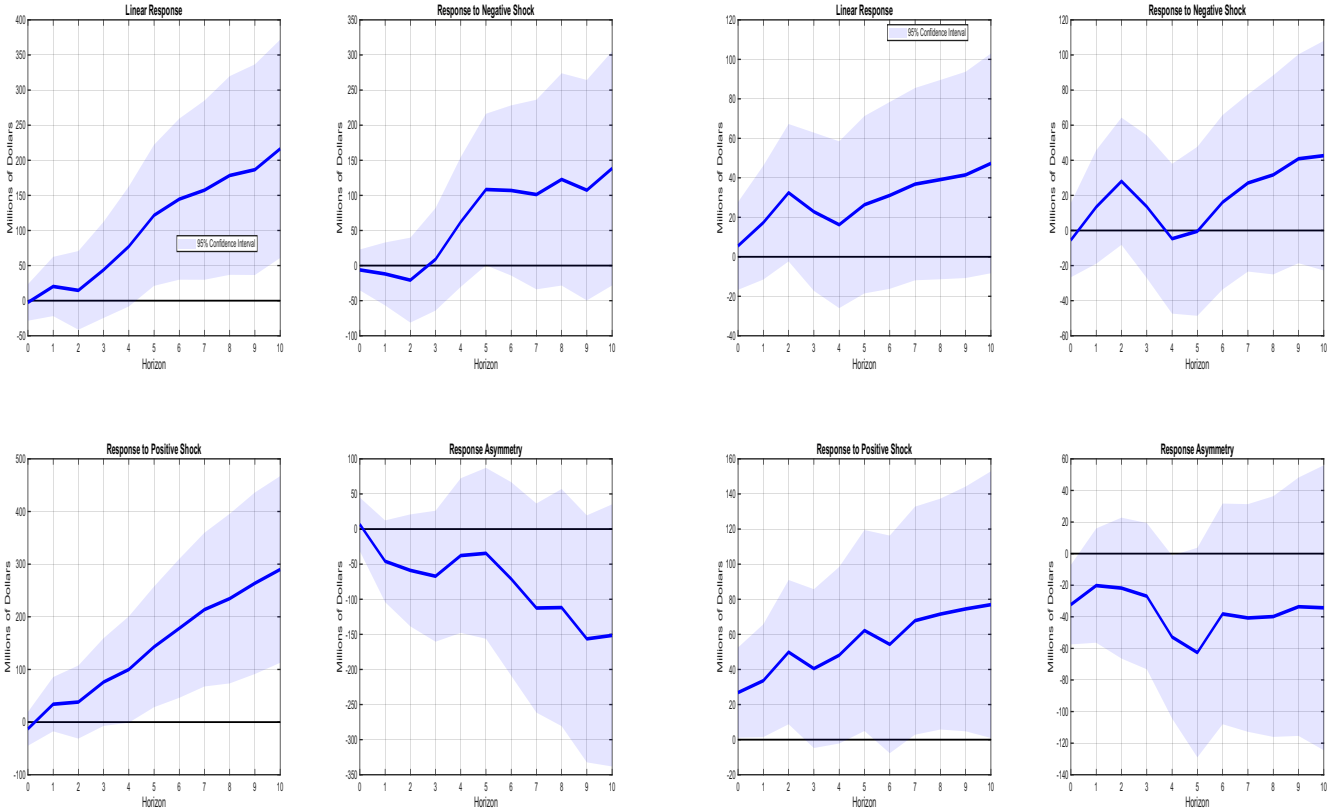
Notes: This figure presents the aggregate model's impulse responses (solid lines) of IIs' aggregate (transactions-based, volume-weighted average) forward rate to a two standard deviation negative and positive U.S. equity return shock, obtained from using cumulative IIs' aggregate forward rate returns as the outcome variable in the aggregate model. For comparison purposes, the response to the positive shock is multiplied by -1. The figure also presents the difference between the response to the negative shock and the positive shock ('Response Asymmetry') and the linear effect of the shock ('Linear Response'—obtained from taking only the linear component of the response to the negative shock). 95% confidence bands (shaded areas) are based on standard errors computed from the heteroskedasticity- and autocorrelation-consistent procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for forward rate are in percentage change units relative to the pre-shock value of forward rate.

Figure 8: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Panel Model: Accumulated IIs' Forward Flows.**



Notes: This figure presents the panel model's impulse responses (solid lines) of accumulated IIs' forward flows to a two standard deviation negative and positive U.S. equity return shock when lagged synthetic exposure is at the mean, along with the difference between the two responses (all termed with 'Non-State-Dependent'); and the corresponding responses and their difference when lagged synthetic exposure is one standard deviation above the mean (all termed with 'State-Dependent'), along with the difference between the state- and non-state-dependent response differences. For comparison purposes, responses to the positive shock are multiplied by -1. For completeness, we also show the linear response, which ignores the higher order coefficients both in linear and interactive form. 95% confidence bands (shaded areas) are based on standard errors computed from the spatially-, heteroskedasticity-, and autocorrelation-consistent procedure of Driscoll and Kraay (1998), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated forward flows are in million of dollars changes relative to the pre-shock value of the accumulated forward flow variable.

Figure 9: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: Accumulated Foreigners' Aggregate Spot and Forward Flows.**

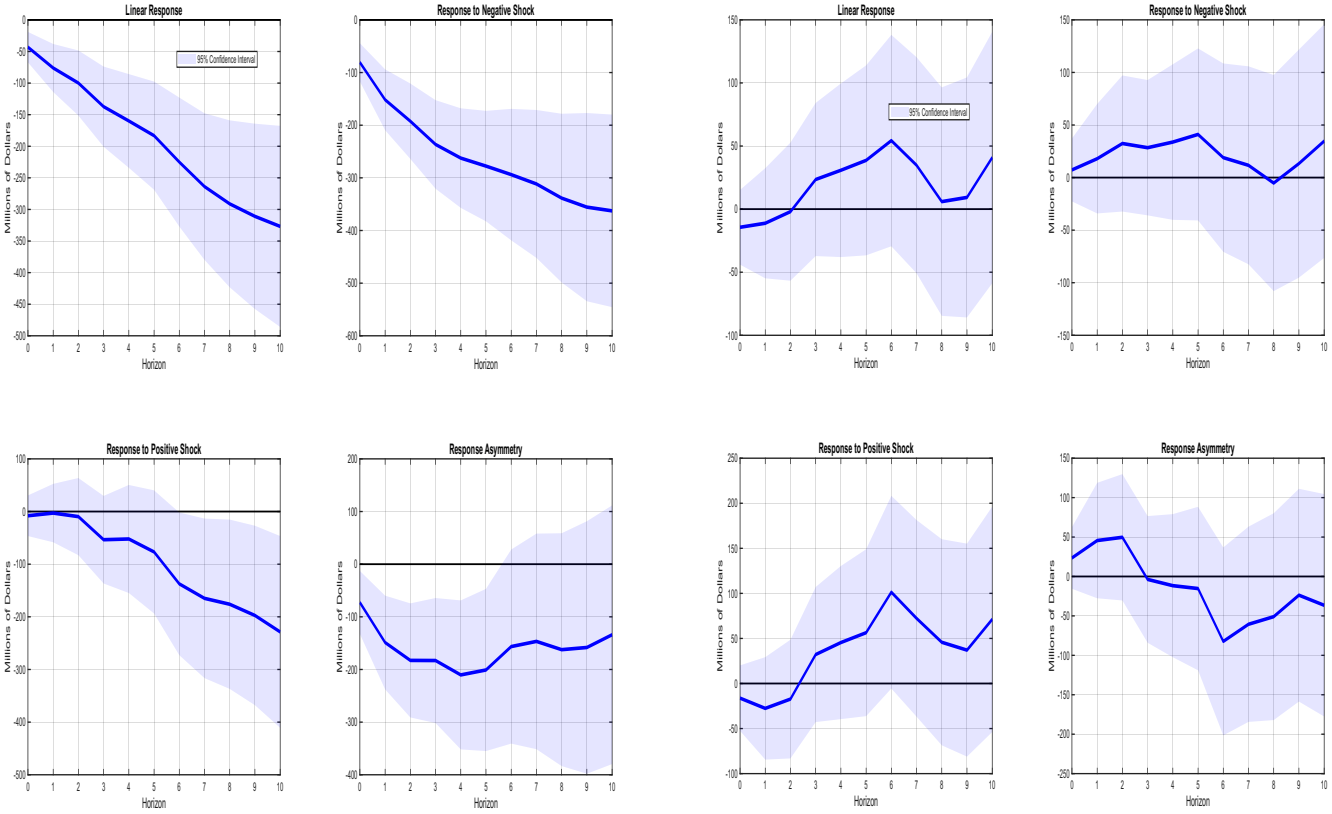


(a) Accumulated Foreigners' Aggregate Spot Flows.

(b) Accumulated Foreigners' Aggregate Forward Flows.

Notes: Panel A presents the aggregate model's impulse responses (solid lines) of accumulated foreigners' aggregate spot flows to two-standard-deviation negative and positive U.S. equity return shocks. Panel B presents the corresponding responses for accumulated aggregate forward flows. For comparison purposes, the response to the positive shock is multiplied by -1. Both panels also display the difference between the responses to the negative and positive shocks ('Response Asymmetry') and the linear component of the response to the negative shock ('Linear Response'). The shaded areas denote 95% confidence bands based on heteroskedasticity- and autocorrelation-consistent standard errors computed using the procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated spot and forward flows are in million of dollars changes relative to the pre-shock value of the accumulated forward flow variable.

Figure 10: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: Accumulated Local Banks' Aggregate Spot and Forward Flows.**

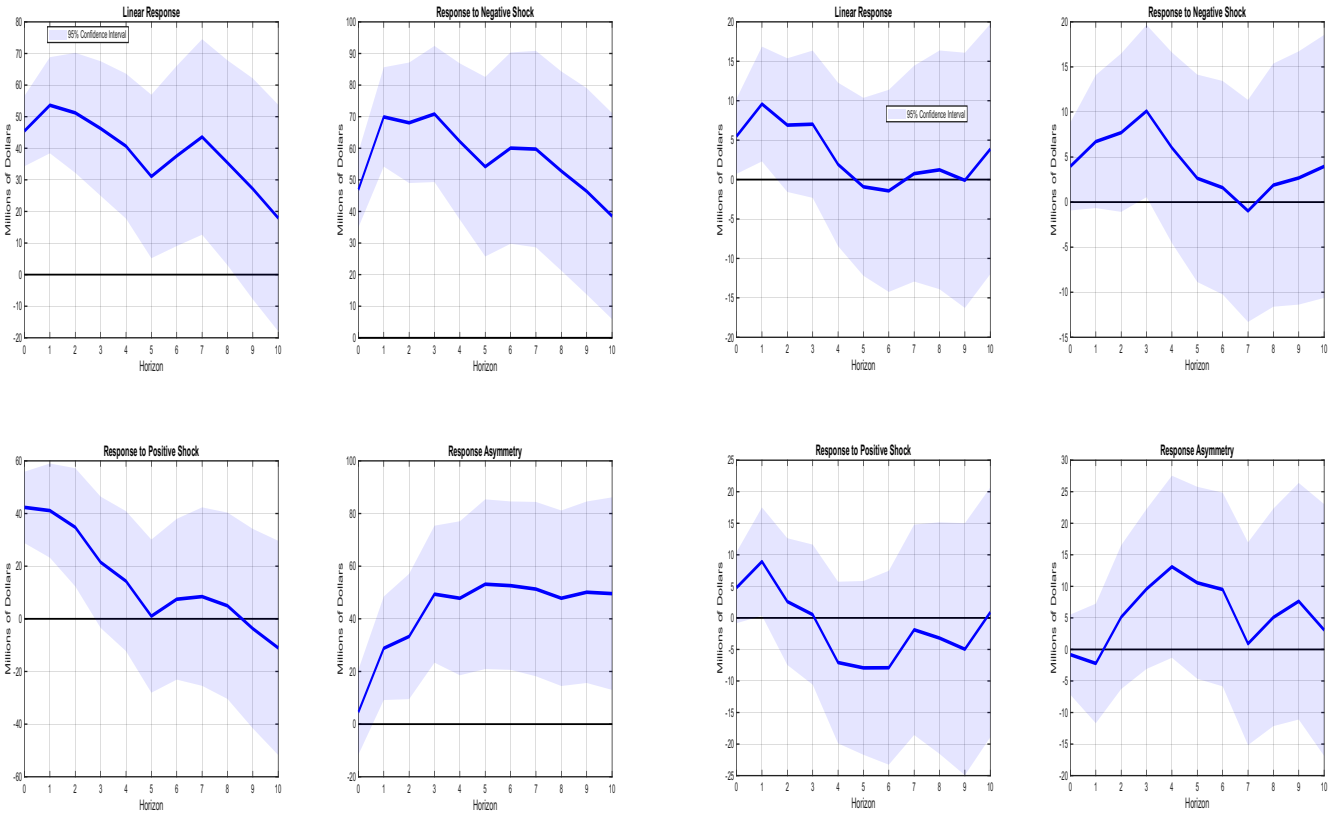


(a) Accumulated Local Banks' Aggregate Spot Flows.

(b) Accumulated Local Banks' Aggregate Forward Flows.

Notes: Panel A presents the aggregate model's impulse responses (solid lines) of accumulated local banks' aggregate spot flows to two-standard-deviation negative and positive U.S. equity return shocks. Panel B presents the corresponding responses for accumulated aggregate forward flows. For comparison purposes, the response to the positive shock is multiplied by -1. Both panels also display the difference between the responses to the negative and positive shocks ('Response Asymmetry') and the linear component of the response to the negative shock ('Linear Response'). The shaded areas denote 95% confidence bands based on heteroskedasticity- and autocorrelation-consistent standard errors computed using the procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated spot and forward flows are in million of dollars changes relative to the pre-shock value of the accumulated forward flow variable.

Figure 11: **Sign-Dependent Impulse Responses to U.S. Equity Return Shock: Aggregate Model: Accumulated Financial Sector's Aggregate Spot and Forward Flows.**



(a) Accumulated Financial Sector's Aggregate Spot Flows.

(b) Accumulated Financial Sector's Aggregate Forward Flows.

Notes: Panel A presents the aggregate model's impulse responses (solid lines) of accumulated local financial sector's aggregate spot flows to two-standard-deviation negative and positive U.S. equity return shocks. Panel B presents the corresponding responses for accumulated aggregate forward flows. For comparison purposes, the response to the positive shock is multiplied by -1. Both panels also display the difference between the responses to the negative and positive shocks ('Response Asymmetry') and the linear component of the response to the negative shock ('Linear Response'). The shaded areas denote 95% confidence bands based on heteroskedasticity- and autocorrelation-consistent standard errors computed using the procedure of Newey and West (1987), with truncation lag equal to $h+1$ (where $h = 0, 1, ..., 10$ is the local projection horizon). Horizons (trading days) are on the x-axis (impact horizon (0) to 10th horizon). Values for accumulated spot and forward flows are in million of dollars changes relative to the pre-shock value of the accumulated forward flow variable.