Granular Banking Flows and Exchange-Rate Dynamics*

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Abstract

We identify granular financial shocks in currency markets using data on the external positions of global banks resident in world's largest cross-border banking centre, the UK. Using a new granular international banking model to guide our empirics, we show that large banks' idiosyncratic net flows into USD debt disproportionately influence exchange-rate dynamics. Empirically, we find that while the supply of US dollars from banks' counterparties is price-inelastic, UK-resident global banks' dollar demand is on-average price-elastic. Crucially, however, we document a structural shift in the compensation banks require to intermediate capital flows—from being price inelastic before the Global Financial Crisis to price elastic afterward. We empirically link this shift to a substantial increase in banks' hedging of on-balance-sheet dollar exposures through FX derivatives after the crisis. This change in intermediation behaviour may help explain the closer relationship between exchange rates and macroeconomic fundamentals in recent years.

JEL Codes: F31, F32, F41, G15, G21.

Key Words: Capital flows; Exchange rates; International banking; FX derivatives.

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1 Introduction

The disconnect between exchange rates and macro fundamentals is a long-standing puzzle in international macroeconomics (Meese and Rogoff, 1983; Obstfeld and Rogoff, 2000). Recently, a growing theoretical literature has rationalised this disconnect by incorporating financial shocks and financial frictions into open-economy macroeconomics models (Gabaix and Maggiori, 2015; Itskhoki and Mukhin, 2021a). However, open questions remain. From where do these financial (capital-flow) shocks originate? How much do exchange rates respond to these financial shocks? Which agents' financial constraints matter most for the exchange-rate response—i.e., who is the 'marginal investor' in currency markets? And what role does FX derivatives use play for this relationship?

In this paper, we investigate the granular origins and causal effects of capital-flow shocks. We do so using a unique bank-level dataset covering UK-resident global banks' external balance sheets, broken down by asset class and currency denomination. As is well known, financial assets are highly concentrated in a few large International Financial Centres (IFCs). For cross-border banking claims—which comprise over one-quarter of overall cross-border claims from 1997Q1-2023Q3—the UK represents by far the largest IFC, with cross-border assets of UK-resident global banks averaging almost twice that of their US counterparts, and peaking at around \$7.1 trillion in 2008Q1.[1] Using our dataset, we show that these financial assets are also held by a relatively small number of large financial players. Specifically, around 20% of UK-based global banks account for about 80% of banks' overall *gross and net* cross-border US dollar (USD) positions. This provides evidence of granularity in cross-border banking.

To inform our empirical analysis, and motivated by these stylised facts, we present a granular banking model of exchange-rate determination, which builds on the 'Gamma model' of Gabaix and Maggiori (2015). Unlike the canonical Gamma model, global banks' risk-bearing capacities are heterogeneous in our setting. This gives rise to variation across banks in the size of their cross-border asset positions and foreign-currency exposures, as in the data. Further, we allow banks to differ in their beliefs about the expected returns from different risky assets and liabilities. These beliefs act as bank-specific financial shocks to Uncovered Interest Parity (UIP), driven by both bank-level and aggregate factors that act as demand shifters for currency. Banks trade these assets and liabilities across borders with a set of rest-of-the-world (ROW) 'funds' that have their own financial constraints and beliefs.[2] In doing so, banks demand foreign currency while ROW funds supply it. Altogether, the resulting equilibrium expressions capture the realistic feature that idiosyncratic demand flows by large banks—due to fluctuations in

[1] See Cesa-Bianchi, Dickinson, Kosem, Lloyd, and Manuel (2021) and Beck, Lloyd, Reinhardt, and Sowerbutts (2023) for recent surveys on the UK's position as an IFC.

[2] We use the term 'fund' generically to refer to any financial player transacting debt and equity instruments cross-border with UK-resident global banks.

their beliefs—play a disproportionate role in driving exchange-rate dynamics. This provides a granular foundation for the financial shocks that resolve traditional exchange-rate puzzles.

Further, we decompose the exchange-rate response to financial shocks into the contributions of banks' demand elasticities and funds' supply elasticities for foreign currency. Importantly, the most *price-inelastic* type of intermediary prices the majority of the exchange-rate response, making them the marginal investors in currency markets. Intuitively, price-inelastic intermediaries with more limited risk-bearing capacities require larger exchange-rate movements to be willing to adjust the size of their foreign currency exposures.

Using the model as a guide, we identify granular financial shocks by constructing granular instrumental variables (GIVs) (Gabaix and Koijen, 2020) for gross and net cross-border banking flows. Intuitively, our GIVs are a time-series of exogenous capital flows into and out of USD assets by large banks, which we extract by measuring changes in large banks' positions over and above the changes common to all banks. For relevance, our instruments require a large cross-section of banks taking positions in USDs, with some banks' positions large enough that their idiosyncratic moves can influence aggregate capital flows—requirements that our dataset fulfils. For identification, the GIV framework helps to partial out (unobserved) aggregate confounders by taking the difference between the size- and equal-weighted sum of banks' cross-border flows.

Our theoretical model codifies threats to identification for the GIVs. We account for these threats in our empirical setup by controlling for a wide-array bank-level balance-sheet information (e.g., liquid-asset, deposit and capital ratios), asset return differentials (i.e., short- and long-maturity government yields) and exchange-rate expectations, as well as using, now standard, principal-component analysis to account for potentially heterogeneous exposures of banks to unobserved common shocks. This latter control is particularly important in our setting, since global financial shocks are known to play an important role in banks' cross-border portfolio decisions. Reassuringly, we find that our GIVs are uncorrelated with commonly-used proxies for the global financial cycle—unlike many instruments used in the literature. To support this further, we also carry out a detailed narrative assessment of our instrument, by accessing *Financial Times* archives, to ensure that its main drivers are plausibly exogenous events. Our analysis reveals that the lion's share of our GIVs' moves are linked with bank-specific, non-systemic shocks to large banks such as management changes, mergers or legal penalties, as well as stress-test failings and computer-system failures—as opposed to global financial events, which could introduce endogeneity into our instruments.

Armed with our granular shocks and testable predictions from theory, we turn to investigate the causal link between capital flows and exchange rates, which reveals the following results. First, by regressing exchange rate movements directly on our net (assets less liabilities) dollar-debt GIV, we estimate the causal multiplier of UK banks' net USD capital flows on the

GBP/USD exchange rate.[3] We find that a 1% increase in UK-resident banks' net dollar-debt position leads to a 0.5% appreciation of the USD against GBP on impact, within the quarter. The USD depreciates by roughly the same amount following a 1% increase in UK-resident banks' USD-debt liabilities. These effects persist too. Using a local-projections specification, we estimate that this shock results in around a 1.5% cumulative USD appreciation after 1 year, before returning to zero thereafter. When breaking down this net-flow multiplier, we find that exogenous changes in USD-denominated debt assets and deposit liabilities result in roughly equal and opposite responses in the GBP/USD exchange rate. Overall, our results indicate that, while a change in UK-resident banks' dollar-debt assets will not result in a significant exchange-rate response when offset by an equal change in dollar-deposit liabilities, mismatched changes in USD-debt positions, for example due to carry trading, will result in economically significant, and persistent, exchange-rate movements.

Second, to understand the structural underpinnings of these multipliers, we use our net dollar-debt GIV to estimate—via two-stage least squares—distinct UK-bank demand and ROW-fund supply elasticities for USDs. On the supply side, we find that the quantity of USDs supplied by banks' ROW counterparties is inelastic with respect to the GBP/USD exchange rate: *ceteris paribus*, a 1% change in the exchange rate results in a more than proportional change in the net supply of USD debt by banks' counterparties—about 0.5% according to our estimates. However, on the demand side, our point estimates suggest that the demand for USDs by UK-resident global banks is *on-average* elastic. A 1% change in the GBP/USD exchange rate results in a more than proportional change in net demand for USD debt—nearly -2%. Importantly, that the demand elasticity lies significantly above the supply elasticity implies that UK-resident global banks play a role in dampening the exchange-rate response to financial shocks compared to (the average of) other financial-market participants, such as the mutual funds studied by Camanho, Hau, and Rey (2022). A key implication of funds' inelastic dollar supply is that UK banks may face difficulties in securing dollars without incurring substantial costs through adverse FX movements.

Third, to assess the time variation in the banking system's willingness and ability to absorb capital flows, we extend our empirical setup to jointly investigate the role of banks' use of FX derivatives, their capitalisation and financial-market volatility. To measure the extent to which banks use FX derivatives to speculate versus hedge, we complement our data with quarterly information on large banks' derivatives values over the past quarter century. Specifically, we proxy banks' FX derivatives hedging activity by the covariance between the values of their on-balance-sheet and FX derivative net dollar positions. We measure bank capital by focusing on Tier-1 capital ratios, which are a function of both regulatory policy and banks' own risk-

[3]Importantly, we show that our GIVs naturally correct for valuation effects, implying that our results are not driven by mechanical changes in portfolio values due to exchange-rate movements.

management preferences. Interacting our measures of FX derivative hedging activity, bank capital and the VIX (our proxy for financial market volatility) with our net dollar-debt GIV suggests that the first and last of these factors play the most significant role in generating time variation in banks' USD-demand elasticity. The causal effect of capital flows on exchange rates is twice as large when banks' FX derivatives hedging is 1 standard deviation below and the VIX 1 standard deviation above average. Applying this, we find that the lion's share of GBP/USD FX movements reflect USD demand shifts by UK-resident banks, especially post-crisis, when banks' increased FX hedging contributed to a significantly greater elasticity of demand. These results provide novel evidence highlighting that the link between capital flows and exchange rates is highly state dependent owing to time-variation in intermediaries' risk-bearing capacity and their use of FX derivatives.

Literature Review. Our paper contributes to the substantial literature discussing the extent to which exchange rates are 'disconnected' with fundamentals (e.g., Meese and Rogoff, 1983; Fama, 1984; Obstfeld and Rogoff, 2000; Jeanne and Rose, 2002; Evans and Lyons, 2002; Koijen and Yogo, 2019a,b; Stavrakeva and Tang, 2020; Chahrour, Cormun, De Leo, Guerron-Quintana, and Valchev, 2021; Lilley, Maggiori, Neiman, and Schreger, 2022; Gourinchas, Ray, and Vayanos, 2022; Greenwood, Hanson, Stein, and Sunderam, 2023; Corsetti, Lloyd, Marin, and Ostry, 2023). Within this body of work, our paper most closely links with the growing theoretical literature that rationalises this disconnect with financial market imperfections (Itskhoki and Mukhin, 2021a,b; Fukui, Nakamura, and Steinsson, 2023; Itskhoki and Mukhin, 2024).[4] Our heterogeneous-bank theoretical framework provides the granular foundations for UIP shocks, highlighting how idiosyncratic 'belief' shocks to banks' cross-border asset demand can influence exchange-rate dynamics. Further, the narrative assessment of our instruments reveals insights about the granular origins of such shocks, highlighting how idiosyncratic bank-level changes can influence aggregate currency positions and prices. Our resulting estimates of banks' and funds' price elasticities of currency demand/supply can be used to calibrate the financial frictions that underpin state-of-the-art international macroeconomics models.

We also contribute to the growing literature that uses granular players in financial markets to estimate macro elasticities. Using their GIV methodology, Gabaix and Koijen (2022) show that US equity demand is price inelastic, which they argue rationalises the considerable volatility of equity prices. While Galaasen, Jamilov, Juelsrud, and Rey (2020) use matched firm-bank loan-level data to construct a GIV for domestic credit risk in the Norwegian banking sector, our paper is one of the first to construct a bank-level GIV for cross-border capital flows.

[4] This class of models stands in contrast to no-arbitrage ones in which the demand elasticity of exchange rates to capital flows is very large (Friedman, 1953, see). Instead, models with limits to arbitrage (e.g., Shleifer and Vishny, 1997) generate a downward-sloping demand curve for currency (e.g., Kouri, 1981; Hau and Rey, 2004, 2006; Hau, Massa, and Peress, 2010).

In related work, Camanho, Hau, and Rey (2022) build a GIV for mutual funds' international equity rebalancing flows.[5] They find that the average elasticity of the counterparties of these mutual funds, of which a subset are global banks, is about 1. In another related paper, Aldasoro, Beltrán, Grinberg, and Mancini-Griffoli (2023) use data from the BIS Locational Banking Statistics to construct GIVs for cross-border flows at the *country-level*, with a focus on transmission to emerging-market economies. Helpfully for us, they demonstrate how their country-level GIVs improve on existing (non-granular) instruments used in the literature (e.g., Blanchard, Ostry, Ghosh, and Chamon, 2016; Cesa-Bianchi, Ferrero, and Rebucci, 2018; Avdjiev, Hardy, McGuire, and von Peter, 2021). However, our instruments are constructed at the more granular bank level and so require more innocuous identification assumptions than their alternative country-level GIVs.

In concurrent work, Becker, Schmeling, and Schrimpf (2023) independently employ a GIV framework to estimate the impact of banks' cross-currency lending on exchange rates. For a range of currencies, they show that when non-US banks extend more syndicated loans in USDs relative to US banks' syndicated loans in foreign currency, the USD appreciates. Like us, they underscore the importance of intermediaries' risk-bearing capacity. In contrast, our study leverages currency mismatches between the lending and borrowing of UK-based global banks to assess the structural underpinnings of GBP/USD UIP deviations. Building on our granular international banking model, our empirical results indicate that UK-based banks' demand for USD is on-average price-elastic while their counterparties' USD supply is inelastic. Crucially, we document a substantial increase in banks' price elasticity of demand following the Global Financial Crisis, which we link to a substantial increase in banks' hedging of on-balance-sheet dollar exposures via FX derivatives. Overall, our GIVs provide robust and representative evidence that sheds new light on the causal links between capital flows and exchange rates over time.

Outline. The remainder of this paper is structured as follows. Section 2 summarises our data, and presents stylised facts. Section 3 presents our theoretical framework, the Granular Gamma model. Section 4 bridges the gap from theory to our empirical strategy, describing the construction of our novel GIVs. Section 5 presents our empirical results. Section 6 concludes.

2 Data

We first describe our dataset, and document stylised facts about aggregate and granular features of UK-resident global banks' cross-border positions.

[5] Their data captures a smaller fraction of overall cross-border flows than ours since they focus on equity flows.

2.1 UK-Resident Banks in Global Context

Our main source is a confidential quarterly panel of bank balance-sheet data constructed from regulatory filings and statistical data forms submitted to the Bank of England by domestic- and foreign-owned banks operating in the UK.[6] The panel contains detailed data on banks' cross-border claims and liabilities by asset class.[7] Most importantly for our study, these claims are reported by currency. In addition, the dataset includes information on banks' capitalisations and liquidity buffers, among other controls.

The dataset captures a substantial portion of global cross-border capital flows, reflecting the UK's position as an IFC. First, over the 1997-2023 period of our analysis, total banking claims (measured using BIS Locational Banking Statistics) comprised, on average, 26% of total cross-border claims for the same set of countries (measured using the External Wealth of Nations Dataset of Lane and Milesi-Ferretti, 2018). In turn, the claims originating from UK-based banks that are captured in our dataset represent, on average, 18% of overall cross-border banking claims over the same period. So our dataset represents around 5% of overall cross-border asset positions for the 1997Q1-2023Q3 period.

Compared to other global banking centres, UK-resident banks comprise the largest share of aggregate cross-border claims. Figure 1 shows this, plotting the time series of all banking claims originating from the UK alongside those from other source countries of cross-border bank lending. UK-resident banks' cross-border claims are significantly larger than all other countries'. On average over the period, total claims of UK-resident banks are almost twice as large as those from the US. Similar patterns are present for UK-banks' cross-border liabilities.

Cross-border banking claims originating from the UK also comprise a substantial share of the UK's overall external linkages. Claims originating from UK-based banks in our dataset represent, on average over the 1997-2023 period, 38% of the UK's total external asset position (measured with External Wealth of Nations Dataset of Lane and Milesi-Ferretti, 2018).

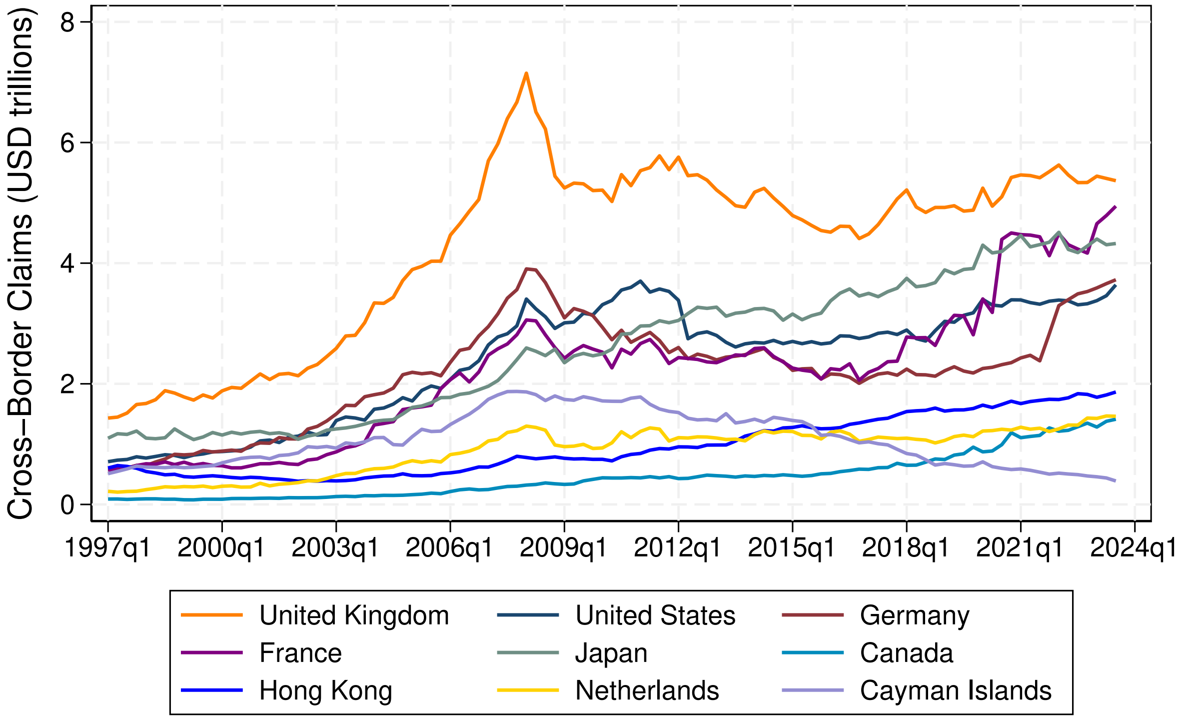
2.2 UK-Resident Banks' Cross-Border Claims

Our raw data contains information on 510 banks reporting cross-border claims in at least one quarter over the period 1997Q1-2023Q3. For our analysis, we clean our sample to focus on stable bank-currency relationships. We do so by only including banks for which we have at

[6]This dataset has been used for other purposes in a number of previous studies, including: Aiyar, Calomiris, Hooley, Korniyenko, and Wieladek (2014), Forbes, Reinhardt, and Wieladek (2017), Bussière, Hills, Lloyd, Meunier, Pedrono, Reinhardt, and Sowerbutts (2021), Andreeva, Coman, Everett, Froemel, Ho, Lloyd, Meunier, Pedrono, Reinhardt, Wong, Wong, and Żochowski (2023), Eguren-Martin, Ossandon Busch, and Reinhardt (2023), and Lloyd, Reinhardt, and Sowerbutts (2023).

[7]Within the dataset, cross-border claims and liabilities can be further disaggregated by recipient country. However, for our analysis, we aggregate up recipient-countries to consider UK-resident banks' exposures to the rest of the world as a whole, rather than specific nations.

Figure 1: Cross-Border Banking Claims by Country of Origin



Notes: Aggregate cross-border banking claims, for selected countries of origin (the major sources of cross-border banking claims), from 1997Q1 to 2023Q3. *Source*: BIS Locational Banking Statistics.

least 80 quarters of data.[8] As a consequence, we predominantly focus on the intensive margin of cross-border USD-denominated lending. The cleaned quarterly dataset includes 129 global banks, which together engage in the vast majority of cross-border bank lending from the UK.

Our key variable of interest is the quarterly change in the stock of currency-specific cross-border claims (or liabilities) between bank i and the rest of the world at time t. Here, we focus on USD-denominated claims, which comprise, on average, 47% of all claims over the sample (Figure 2a).[9] In comparison, euro-denominated claims comprise on average 36% of claims.[10]

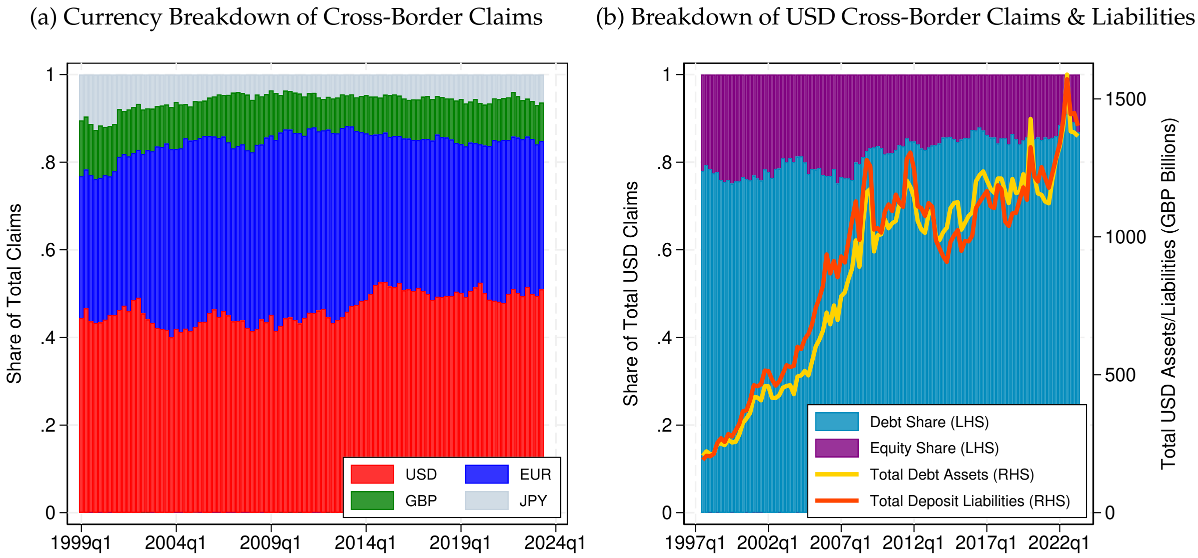
Within these USD-denominated assets, we focus on'loans and advances' (henceforth 'debt'), as opposed to equity, since fixed-income instruments map more directly to an uncovered interest parity (UIP) condition. Figure 2b decomposes total cross-border USD claims by asset type, demonstrating that debt comprises the lion's share. As of 2023Q3, the stock of USD-denominated debt was around 10-times larger than USD-denominated portfolio investments.

[8]Moreover, as with other studies that use this dataset (e.g., Bussière et al., 2021; Andreeva et al., 2023; Lloyd et al., 2023), we also winsorise our bank-level data to ensure that the quarterly growth of cross-border positions is bounded between −100% and +100%.

[9]This statistic is calculated over the period 1999Q1-2023Q3 to avoid distortions due to the creation of the euro.

[10]Euro-denominated positions do not exhibit the same level of concentration as USD positions, making them less-suitable for our subsequent analysis.

Figure 2: Decomposing UK-Based Banks' Cross-Border Claims and Liabilities



Notes: Left-hand figure decomposes UK-based banks' total external claims by currency from 1999Q1 (owing to creation of the euro) to 2023Q3. Right-hand figure decomposes total USD-denominated external claims by asset class (debt and equity) and additionally presents total USD debt assets and deposit liabilities (in GBP trillions) from 1997Q3 to 2023Q3.

The counterpart to these USD debt positions are USD-denominated deposits, liabilities from the perspective of UK banks. As the lines in Figure 2b show, UK banks' USD debt and USD deposit positions have both grown considerably over time. While these asset and liability positions have, unsurprisingly, grown in a broadly similar manner, there have been notable mismatches, with the absolute net-USD debt position averaged 71 billion GBP over our sample.[11] So, UK-resident banks often have significant net exposures to USDs on their balance sheets, which we will leverage in our theoretical framework below.[12]

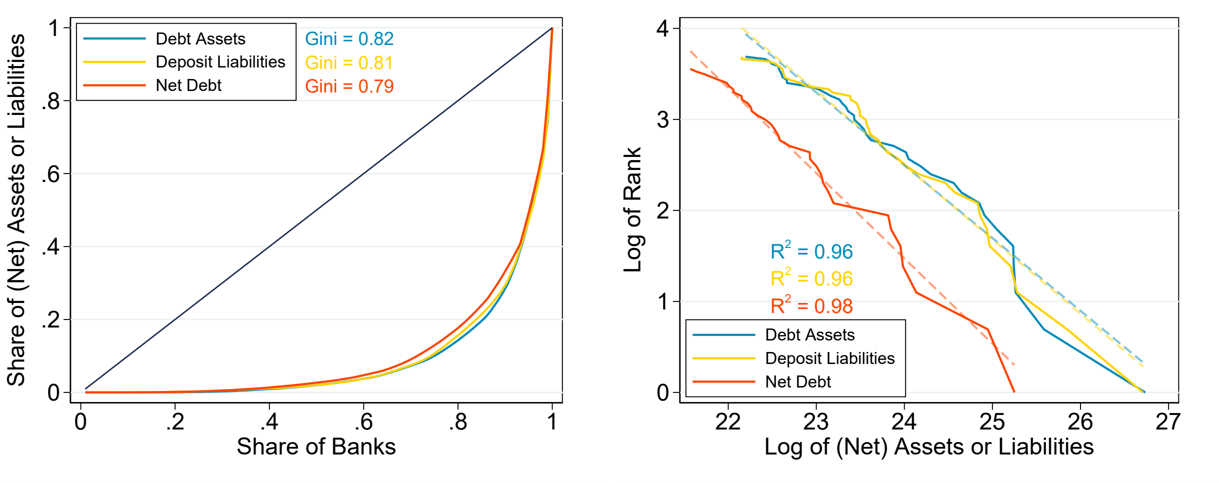
These USD exposures have also varied in sign over time. For much of the 2000s, USD deposit liabilities were larger than USD debt assets, implying that UK-resident banks were net-short the USD using fixed-income instruments. Conversely, for much of the 2010s, banks' net currency exposure for fixed-income switched, with UK-resident banks taking net-long positions in USD debt. Since US interest rates were relatively low (high) compared to the UK's for much of the 2000s (2010s), this provides suggestive evidence that UK-resident banks performed carry trades during our sample.

[11]The standard deviation of these absolute positions is 48 billion GBP. Banks' largest (smallest) net-dollar position over our sample is 210 billion GBP (0.4 billion GBP).

[12]While UK-resident banks have been subject to some Pillar 1 and 2 capital requirements on mismatched foreign-exchange positions since the mid-2010s under Prudential Regulatory Authority regulation, these do not preclude foreign-exchange mismatches on balance sheets.

Figure 3: Concentration and Granularity in Banks' Cross-Border (Net) Assets and Liabilities

(a) Size Concentration (b) Granularity



Notes: Figure 3a presents Lorenz curves and Gini coefficients respectively for global banks' average USD debt assets, deposit liabilities and absolute net-debt (debt less deposits) in 2022:Q3. Figure 3b plots log-rank vs log-size, along with linear best fit lines and the associated R^2, separately for USD debt assets, deposit liabilities and absolute net-debt in 2022:Q3. The sample in Figure 3b is restricted to the 40 largest banks for debt and deposits and 35 largest for absolute net-debt.

2.3 Granularity of UK-Resident Banks

While UK-resident banks collectively cover a sizeable portion of global cross-border claims, there is significant heterogeneity in individual banks' cross-border positions. Figure 3a displays Lorenz curves and associated Gini coefficients for UK-resident global banks' USD debt assets, deposit liabilities and absolute net debt (absolute value of debt assets less deposit liabilities) in the final period of our sample. Across these different measures of gross and net size, we see clear evidence of the Pareto principle: around 80% of total USD banking debt, deposits and net-debt exposures are held by 20% of banks.

Figure 3b also provides evidence that global banks appear to be granular (Gabaix, 2011), implying that idiosyncratic flows by large global banks can theoretically shape aggregate capital flows. Following Gabaix (2009), this figure compares the log-rank of banks' size to the log of their size—measuring size in three ways: banks' cross-border USD debt assets, deposit liabilities, and net-debt in the final period of our sample. That straight lines can fit this relationship to such a degree—the R^2 are between 0.96 and 0.98—is evidence of a power law and hence granularity in cross-border banking: the size of the n^{th} largest global bank is proportional to $1/n$. In the case of absolute net debt, the constant of proportionality is statistically indistinguishable form 1, which is consistent with Zipf's law.

In all, the size concentration—in particular in terms of *net* positions—that we document motivates our granular banking model in Section 3. It suggests that idiosyncratic flows from large banks, which we construct in Section 4, can affect aggregate quantities and prices. As shown in Section 5, consistent with this granular hypothesis, idiosyncratic capital flows from large banks (i.e., GIVs) indeed have a sizeable impact on exchange rates.

2.4 UK-Resident Banks' FX Derivatives Use

To supplement our dataset covering banks' external USD positions, we leverage unique information on the *value* of the largest UK-resident banks' FX derivatives positions over the past quarter century. FX derivatives, nearly 90% of which involve the USD in one leg of the contract (see BIS, 2025), enable banks to adjust their on-balance-sheet net-USD exposures, which we have documented in Section 2.2. Although FX-derivative *exposure* data are unavailable for UK banks over most of our sample—precluding construction of their total net exposure—the co-movement between the values of banks' on-balance-sheet and FX derivative positions provides a proxy for whether derivatives amplify or dampen exchange-rate exposure. In particular, if banks are net-long (or net-short) USD both on balance sheet and via FX derivatives, exchange-rate movements adjust their values in the same direction; if they are instead net-long in one and net short the other, valuation effects would offset each other.[13]

Figure 4a traces the value of UK-resident banks' FX derivative 'assets', defined as 'in-the-money' positions, over the past quarter century. These positions are comparable in value to banks' external USD debt assets, and reach a peak of nearly 1.5 trillion GBP by end-2022. The figure further decomposes the value of these positions into those held by the largest 5 banks (in terms of average value over the sample) and the smaller 10 banks, highlighting significant concentration in banks' derivatives use.[14]

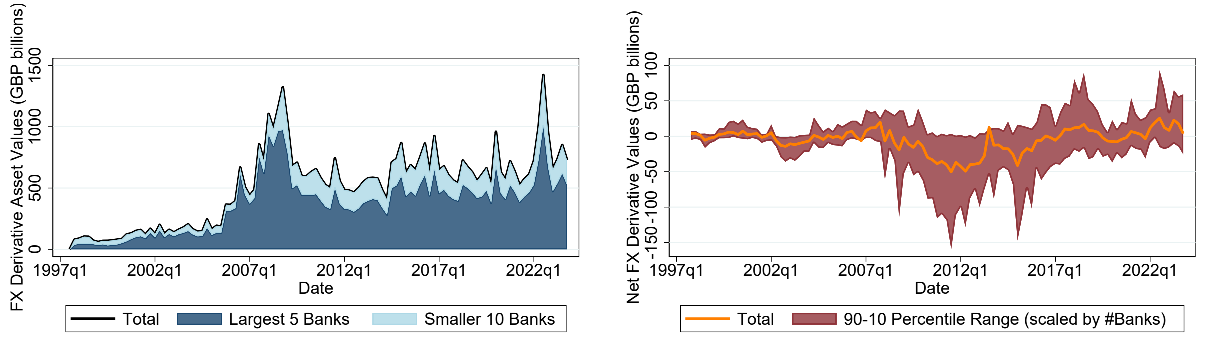
Banks' net (assets minus liabilities) FX derivative values are comparatively small, as seen in 4b, since their liability values (out-of-the-money positions) closely track their asset values. Net-FX derivative values also change sign over time. For example, aggregating over all banks, net-FX derivative valuations turn sharply negative in the 2010s, coinciding with the shift toward positive net-USD debt positions on balance sheet. This pattern is consistent with FX derivatives serving, on average, as a hedge against USD-debt exposures in the UK banking sector during this period. Importantly, however, there is substantial cross-sectional heterogeneity in the sign of net FX derivative valuations, as reflected in the shaded 10^{th}–90^{th} percentile range. We therefore focus on the co-movement between on-balance-sheet net-USD positions and net FX derivative valuations at the *bank level* in our subsequent empirical analysis.

[13] While, of course, the value of banks' debt holdings and FX derivatives positions may adjust due to changes in quantities, not just prices, there is evidence that most of the variation in investors' holdings at quarterly frequency comes from changes in price (see, e.g., Rey et al., 2024).

[14] Banks are only required to report derivatives values in a given quarter when these values exceed a relatively high threshold. As such, we focus on banks that report in all quarters. Since the derivatives market is highly concentrated, these 'intensive' banks capture on-average over 95% the entire sector's market value over our sample.

Figure 4: UK-Resident Banks' Total and Net FX Derivative Asset Values

(a) FX Derivative Asset Values (b) Net FX Derivative Values



Notes: Figure 4a presents the total value of all UK-resident banks' FX derivative assets (i.e., in-the-money contracts), with dark and light shadings denoting to the values held by the largest 5 banks (on average over the sample) and other 10 smaller banks, respectively. Figure 4b plots the net (assets minus liabilities) value of UK-resident banks FX derivatives holdings, with the shaded region denoting the range between 90^{th} and 10^{th} percentiles of the distribution (scaled by the number of banks). The sample is restricted to the 15 largest banks that report in each quarter of our sample, and who together hold on-average over 95% the entire sector's market value.

3 Theoretical Framework

To guide this empirical analysis and codify threats to identification, in this section, we present a granular model of FX determination, capturing capital flows in imperfect financial markets. The model builds on the 'Gamma model' (Gabaix and Maggiori, 2015), but differs in several key respects. First, since a small number of large banks account for the majority of cross-border activity, we introduce heterogeneity in risk-taking capacity across banks. Second, banks have heterogeneous and time-varying beliefs about cross-border asset returns. Together, these extensions imply that the beliefs of the largest banks exert the greatest influence on equilibrium FX dynamics. Third, banks trade financial assets with a set of 'rest-of-the-world' (ROW) funds (Camanho et al., 2022). This implies that exchange rates are determined by the supply and demand for assets by different financial agents (i.e., banks and funds). While these generalisations allow us to bridge the gap between theory and our data on bank-level cross-border claims, our framework still nests the original Gamma model.

3.1 The Granular Gamma Model

Consider a price-taking UK-resident bank i who, at time t, has access to a foreign financial asset j with a risky dollar-denominated return $R^j_{t+1} = 1 + r^j_{t+1}$ and a known domestic opportunity cost $R_t = 1 + r_t$ expressed in sterling.[15] Bank i's optimal demand $Q^j_{i,t}$ for dollar asset j at time

[15] As in Gabaix and Maggiori (2015), R_t can be equal to $1/\beta$, where $\beta \in (0, 1)$ is the household discount factor.

t maximises expected profits in sterling:[16]

$$V_{i,t}^{j}=\max_{Q_{i,t}^{j}>0}\ \mathbb{E}_t\left[\exp(b_{i,t}^{j})\cdot\left(\frac{R_{t+1}^{j}}{R_t}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}-1\right)\right]Q_{i,t}^{j},\tag{1}$$

where the exchange rate $\mathcal{E}_t$ is the price of a dollar in sterling (so an increase corresponds to a USD appreciation) and $b_{i,t}^{j}$ is bank i's subjective belief at time t about the excess cross-border return from asset j, $\frac{R_{t+1}^{j}}{R_t}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}-1$, earned at time $t+1$.[17] By including the bank-specific belief wedge $b_{i,t}^{j}$, we allow for time-varying deviations from rational expectations.[18] These time-varying beliefs can be driven by both bank-level and aggregate *demand shifters*, that act as financial shocks to UIP.[19]

Following Gabaix and Maggiori (2015), we assume banks have limited risk-bearing capacity because they can divert a fraction $\Gamma_i^{j}Q_{i,t}^{j}$ of their invested/borrowed quantity $Q_{i,t}^{j}$ for personal use. Different from earlier work, we allow Γ_i^{j} to depend on i, implying heterogeneity in risk-bearing capacity across banks. This agency problem gives rise to an incentive-compatibility constraint that ensures that banks do not divert resources in equilibrium:

$$V_{i,t}^{j}\geq\Gamma_i^{j}Q_{i,t}^{j}\cdot Q_{i,t}^{j},\tag{2}$$

which requires expected profits to weakly exceed the value of divertable resources. A higher Γ_i^{j} tightens bank i's constraint, reflecting a reduction in risk-bearing capacity.

In equilibrium, since the maximand (1) is linear in $Q_{i,t}^{j}$ and the constraint (2) is quadratic, the constraint always binds and the solution is

$$Q_{i,t}^{j}=\frac{1}{\Gamma_i^{j}}\cdot\mathbb{E}_t\left[\exp(b_{i,t}^{j})\cdot\left(\frac{R_{t+1}^{j}}{R_t}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}-1\right)\right],\tag{3}$$

which states that the optimal size of bank i's position in dollar asset j is proportional to bank i's beliefs and the expected excess return on j, modulated by their risk-bearing capacity. Equation (3) highlights that differences in risk bearing capacity Γ_i^{j} and/or beliefs $b_{i,t}^{j}$ across banks can

[16] Both foreign- and UK-owned banks residing in the UK are required to report profits in sterling for regulatory reasons.

[17] Our dataset includes separate records for assets and liabilities, so we can investigate each individually. We present in equation (1) the asset case where $\mathbb{E}_t(\exp(b_{i,t}^{j})\cdot(\frac{R_{t+1}^{j}}{R_t}\frac{\mathcal{E}_{t+1}}{\mathcal{E}_t}-1))>0$ so bank i optimally chooses a long position in asset j, $Q_{i,t}^{j}>0$, financed by shorting the domestic safe asset. The liability case ($Q_{i,t}^{j}<0$) where bank i invests in the domestic safe asset and shorts asset j is analogous because the problem is symmetric about a zero-excess return.

[18] Similar 'belief' shocks have been used in a large literature studying incomplete information, irrational expectations and heterogeneous beliefs in international macroeconomics (e.g., Evans and Lyons, 2002; Bacchetta and Van Wincoop, 2006; Burnside, Eichenbaum, Kleshchelski, and Rebelo, 2011).

[19] In our empirical analysis, in Section 4, we explain further how $b_{i,t}^{j}$ can be defined more broadly as a demand shifter. A large literature focuses on such UIP shocks (e.g., Kouri, 1976; Kollmann, 2005; Fahri and Werning, 2014).

generate differences in the size of banks' equilibrium cross-border positions $Q^j_{i,t}$. If $b^j_{i,t} = 0$ and $\Gamma^j_i = \Gamma^j$, equation (3) collapses to the optimality condition in the baseline Gamma model in Gabaix and Maggiori (2015) with homogeneous banks and rational expectations, but where the return to j is risky.

Approximation. To bridge the gap between theory and data, we approximate equation (3) using a first-order Taylor expansion around the model's steady state and difference the approximate expression over time, to yield:

$$\Delta q^j_{i,t} \approx \left(\frac{1+\overline{Q}^j_i\Gamma^j_i}{\overline{Q}^j_i\Gamma^j_i}\right)\cdot\Big(\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t\Big) + \Delta b^j_{i,t}, \tag{4}$$

where lower-case letters refer to the natural logarithm of variables $e_t := \ln(\mathcal{E}_t)$ and $q^j_{i,t} := \ln(Q^j_{i,t})$, bars refer to variables in steady state $\overline{Q}^j_i$ and Δ refers to the difference between t and $t-1$ (with $\Delta\mathbb{E}_t[x_{t+1}] := \mathbb{E}_t[x_{t+1}] - \mathbb{E}_{t-1}[x_t]$). Appendix A.1 provides details of this derivation.

Equation (4) relates the percentage change in bank i's demand $\Delta q^j_{i,t}$ for USD-asset j to the percentage change in the asset's expected excess (carry-trade) return $\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t$ and the percentage change in bank i's beliefs $\Delta b^j_{i,t}$. The price elasticity of demand $\phi^j_i := \frac{1+\overline{Q}^j_i\Gamma^j_i}{\overline{Q}^j_i\Gamma^j_i}$, which is increasing in bank i's risk-bearing capacity and decreasing in their steady-state amount intermediated, is always greater than 0. Thus, UK bank i's demand curve for USD-asset j is downward sloping in the relative price of dollars e_t. Changes in bank i's beliefs serve to shift their demand for asset j and, consequently, for USD.

We consider a symmetric steady state in which beliefs are the same for all banks: $\overline{b}^j_i = \overline{b}^j\ \forall i$. Banks therefore agree on the expected return to asset j in steady state $\exp(\overline{b}^j)(\frac{\overline{R}^j}{\overline{R}} - 1)$ and so take steady-state cross-border positions $\overline{Q}^j_i$ that are inversely proportional to their risk-bearing capacities Γ^j_i.[20] As a result, price elasticities of demand are the same for all banks around the steady state $\phi^j_i := \phi^j_B\ \forall i$:

$$\Delta q^j_{i,t} \approx \phi^j_B\cdot\Big(\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t\Big) + \Delta b^j_{i,t}. \tag{5}$$

This arises because, although banks with greater risk-bearing capacities (lower Γ^j_i) tend to have more elastic demand (higher ϕ^j_i), they also take commensurately larger steady-state cross-border positions (higher $\overline{Q}^j_i$), which decreases their demand elasticity until ϕ^j_i is constant across banks. Appendix A.1 shows that banks' demand elasticity ϕ^j_B can depend on the *average* risk-bearing capacity across all banks (Γ^j) as well as the *total* amount intermediated in steady state by the banking sector ($\overline{Q}^j$), such that $\phi^j_B := \frac{1+\overline{Q}^j\Gamma^j}{\overline{Q}^j\Gamma^j}$.

[20]That is, in steady state, equation (3) is $\overline{Q}^j_i = \frac{1}{\Gamma^j_i}\left[\exp(\overline{b}^j)\cdot\left(\frac{\overline{R}^j}{\overline{R}} - 1\right)\right]$ such that $\overline{Q}^j_i\Gamma^j_i$ is independent of i.

Importantly, while we have thus far remained agnostic as to the distribution of Γ_i^j, note that under a symmetric steady state with $\bar{b}_i^j = \bar{b}^j \ \forall i$, the distribution across i of $1/\Gamma_i^j$ maps directly to the distribution of $\overline{Q}_i^j$ (see equation (3) in steady state). Therefore, if $1/\Gamma_i^j$ follows a Pareto distribution across banks, then the steady-state bank-size distribution $\overline{Q}_i^j$ does as well. This enables us to consider the implications of granularity in bank size, as observed in the data.

3.2 Global Financial Market Equilibrium

To derive equilibrium conditions for dollar asset j, we solve for the aggregate demand of UK-resident banks for j and specify the behaviour of banks' rest-of-the-world (ROW) counterparties with respect to j.

We begin by taking the size-weighted average of equation (5), which gives the dynamics of UK-based banks' aggregate demand for cross-border asset j:

$$\Delta q_{S,t}^j = \phi_B^j \left(\Delta \mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta \mathbb{E}_t[e_{t+1}] - \Delta e_t \right) + \Delta b_{S,t}^j, \tag{6}$$

where the size-weighted averages (aggregates) are defined as $\Delta q_{S,t}^j := \sum_{i=1}^n S_{i,t-1} \Delta q_{i,t}^j$ and $\Delta b_{S,t}^j := \sum_{i=1}^n S_{i,t-1} \Delta b_{i,t}^j$, using weights $S_{i,t-1}^j := \frac{Q_{i,t-1}^j}{\sum_{i=1}^n Q_{i,t-1}^j}$. Thus, percentage changes in the aggregate demand by UK-resident banks for dollar asset j evolve in proportion to expected excess returns and percentage changes in the size-weighted average of their individual beliefs $\Delta b_{S,t}^j$. Again, since the price elasticity ϕ_B^j is greater than 0, the aggregate demand curve is downward sloping in exchange rates, with aggregate beliefs $\Delta b_{S,t}^j$ serving as a demand shifter for asset j and USD. Importantly, the beliefs of granular banks matter disproportionately for aggregate beliefs due to size weighting, and hence matter most for banks' aggregate demand.

To derive dynamics for the rest of the world's aggregate supply of dollar asset j, we assume there exist a set of ROW 'funds'—any financial agent trading cross-border with UK-resident global banks—whose cross-border positions are analogously linked to their subjective beliefs, denoted by $b_{F,t}^j$, and expected excess returns:[21]

$$\Delta q_{F,t}^j = -\phi_F^j \left(\Delta \mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta \mathbb{E}_t[e_{t+1}] - \Delta e_t \right) + \Delta b_{F,t}^j. \tag{7}$$

The price elasticity of supply ϕ_F^j, being analogously tied to ROW funds' financial constraints and positions, is always positive. Therefore, funds' aggregate supply curve of US dollar asset j is upward sloping in the relative price of USD Δe_t, with changes in funds' beliefs acting as a supply shifter for asset j and USD.

Combining these equations with global market clearing $\Delta q_{S,t}^j = \Delta q_{F,t}^j$—i.e., equating UK-

[21] Concretely, ROW funds supply the foreign dollar asset j to UK banks, invest cross border in the sterling domestic safe asset and evaluate profits in USD.

resident banks' demand for asset j with ROW funds' supply of it—we derive expressions for equilibrium exchange-rate dynamics and the dynamics of domestic-resident banks' aggregate holdings of asset j, as outlined in the following proposition.

Proposition 1 (Equilibrium in Asset Market j**)** *In the Granular Gamma model, the equilibrium US dollar appreciation and the percentage change in UK-banks' cross-border holdings of dollar-denominated asset j can be approximated by*

$$\Delta e_t = \frac{1}{\phi_B^j + \phi_F^j}\Delta b_{S,t}^j - \frac{1}{\phi_B^j + \phi_F^j}\Delta b_{F,t}^j + \left(\Delta \mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta \mathbb{E}_t[e_{t+1}]\right), \tag{8}$$

$$\Delta q_{S,t}^j = \frac{\phi_F^j}{\phi_B^j + \phi_F^j}\Delta b_{S,t}^j + \frac{\phi_B^j}{\phi_B^j + \phi_F^j}\Delta b_{F,t}^j. \tag{9}$$

Proof: Combine global market clearing $\Delta q_{S,t}^j = \Delta q_{F,t}^j$ with asset demand, equation (6), and supply, equation (7). See Appendix A.2 for more details. □

Equation (8) highlights that the equilibrium relationships between exchange-rate dynamics and changes in beliefs are governed by the multiplier $M^j := \frac{1}{\phi_B^j + \phi_F^j}$, which captures equilibrium feedback effects between prices and quantities. When UK banks become more optimistic about the return to investing in USD-asset j, $\Delta b_{S,t}^j \uparrow$, the USD appreciates against sterling. When ROW funds become more optimistic about the return to selling USD-asset j, $\Delta b_{F,t}^j \uparrow$, the USD depreciates against sterling. This is because changes in beliefs increase the quantity of asset j demanded and supplied by banks and funds, respectively (see equation (9)).

The exchange-rate response to changes in beliefs is larger when banks' and funds' price elasticities are lower: $M^j \uparrow$ if ϕ_B^j, $\phi_F^j \downarrow$. Thus, the set of intermediaries—banks or funds—with more inelastic demand/supply exert greater influence over equilibrium exchange-rate dynamics. Intuitively, this is because more inelastic intermediaries require greater compensation via larger exchange-rate movements to be willing to adjust the size of their balance sheets, i.e., their foreign currency exposures.[22] Which types of intermediary is more price-elastic is an empirical question, which we address in Section 5.

Equilibrium exchange-rate dynamics in equation (8) also depend on expected exchange rate movements and cross-border asset return differentials. We will control for these in our empirical analysis.

[22]Although ϕ_B^j and ϕ_F^j depend on both the intermediaries' risk-bearing capacity and the steady-state amount intermediated (see equation (4)), only the former can affect the relative value of ϕ_B^j and ϕ_F^j since the two types of financiers must intermediate equal and opposite amounts in equilibrium.

3.3 Empirical Considerations

Before turning to our empirical strategy, we briefly outline two considerations for extending our baseline Granular Gamma model when confronted with our data.

Inelastic Intermediaries. As in the Gamma model of Gabaix and Maggiori (2015), the functional form of the incentive-compatibility constraint (2) in our Granular Gamma model does not allow for inelastic currency demand—i.e., ϕ_B^j cannot be less than 1. However, estimating equation (5) empirically can in principal deliver any value for the price elasticity ϕ_B^j. This suggests scope to adapt the Gamma model setup to allow for inelastic demand.

One extension could be to alter the divertable fraction to $(\Gamma_i^j Q_{i,t}^j)^{\gamma_i^j}$, with parameter γ_i^j, such that the incentive-compatibility constraint becomes:

$$V_{i,t}^j \geq (\Gamma_i^j Q_{i,t}^j)^{\gamma_i^j} \cdot Q_{i,t}^j.$$

With this exponential friction, the first-order condition of the bank becomes:

$$Q_{i,t}^j = \frac{1}{\Gamma_i^j} \cdot \mathbb{E}_t \left[\exp(b_{i,t}^j) \cdot \left(\frac{R_{t+1}^j}{R_t} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} - 1 \right) \right]^{\frac{1}{\gamma_i^j}},$$

which we can approximate as:

$$\Delta q_{i,t}^j \approx \frac{1}{\gamma_i^j} \frac{1 + (\Gamma_i^j \overline{Q}_i^j)^{\gamma_i^j}}{(\Gamma_i^j \overline{Q}_i^j)^{\gamma_i^j}} \cdot \Big(\Delta \mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta \mathbb{E}_t[e_{t+1}] - \Delta e_t \Big) + \Delta b_{i,t}^j. \tag{10}$$

By redefining $\phi_i^j := \frac{1}{\gamma_i^j} \frac{1+(\Gamma_i^j \overline{Q}_i^j)^{\gamma_i^j}}{(\Gamma_i^j \overline{Q}_i^j)^{\gamma_i^j}}$, the demand curve in (10) can be seen to be analogous to that in (4). Crucially, however, the parameter governing the severity of the agency friction γ_i^j gives rise to a demand curve for cross-border positions that can have a price elasticity ϕ_i^j below unity. Our empirical results in Section 5.2 will allow us to discern between specific micro-foundations for the Granular Gamma model.

FX Derivatives. Like the Gamma model, our Granular Gamma model assumes that bank i's position in USD-asset j translates exactly into USD exposure. In practice, however, banks can adjust their USD exposures via FX derivatives (see, e.g., Hacioglu-Hoke et al., 2026; Dao et al., 2025). For example, bank i can overlay a USD FX derivative (e.g., swap or forward) exposure, denoted $D_{i,t}$, such that their total net-USD exposure from holding USD-asset j is given by:

$$X_{i,t}^j := Q_{i,t}^j + D_{i,t}^j.$$

If bank i is constrained by their USD *exposure* $X^j_{i,t}$, rather than their holdings $Q^j_{i,t}$, then their USD demand curve, equation (5), becomes:

$$\Delta x^j_{i,t} \approx \phi^{j,X}_B \left(\Delta \mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta E_t[e_{t+1}] - \Delta e_t \right) + \Delta b^j_{i,t}, \tag{11}$$

where $x^j_{i,t} := \ln(X^j_{i,t})$ and $\phi^{j,X}_B := \left(\frac{1+\overline{X}^j_i \Gamma^j_i}{\overline{X}^j_i \Gamma^j_i} \right)$ denotes the price elasticity of demand of USD exposure with respect to exchange rates. See Appendix A.3 for further details.

The relationship between the elasticities of banks' USD flows to exchange rates ϕ^j_B and of USD exposures to exchange rates $\phi^{j,X}_B$ depends on how changes in banks' dollar derivatives exposures $\Delta d^j_{i,t} := \Delta \ln(D^j_{i,t})$ co-move with changes in on-balance-sheet dollar positions $\Delta q^j_{i,t}$. In particular, if $\text{Cov}(\Delta q^j_{i,t}, \Delta d^j_{i,t}) > 0$, such that bank i uses FX derivatives to amplify USD exposure (i.e., to speculate), then $\phi^{j,X}_B > \phi^j_B$ since, in this case, on-balance-sheet dollar flows reflect only part of bank i's total adjustment in net dollar exposure to changes in exchange rates (expected returns). Conversely, if $\text{Cov}(\Delta q^j_{i,t}, \Delta d^j_{i,t}) < 0$, such that bank i uses FX derivatives to dampen currency exposure (i.e., to hedge), then $\phi^{j,X}_B < \phi^j_B$ since, in this case, on-balance-sheet dollar flows overstate the change in bank i's net dollar exposure to changes in exchange rates.

A key implication is that movements in ϕ^j_B over time may not only reflect changes in risk-bearing capacity Γ^j_i, but also changes in the extent to which banks use FX derivatives to hedge or speculate. In particular, greater FX hedging via derivatives would increase ϕ^j_B and therefore decrease the multiplier M^j from flows to exchange rates. We will investigate this in Section 5.3 using a proxy for $\text{Cov}(\Delta q^j_{i,t}, \Delta d^j_{i,t})$ based on the value of banks' FX derivatives positions.

4 Empirical Strategy

Guided by our theoretical framework, we exploit the significant heterogeneity and concentration in banks' cross-border USD positions to construct granular financial (capital-flow) shocks using the GIV approach of Gabaix and Koijen (2020). As we have illustrated in Section 2, some banks are large enough to impact aggregate quantities and their idiosyncratic behaviour survives aggregation. Through the lens of the model described in Section 3, idiosyncratic moves by banks can arise due to changes in beliefs. GIVs then extract the idiosyncratic moves by large, granular banks by comparing their behaviour (via size-weighted aggregation) with the behaviour of average banks (via equal-weighted aggregation). Since these banks are granular, the GIVs are relevant for aggregate capital flows and hence exchange rates.

We proceed by describing our GIV construction and outlining our estimation procedure. Then, we discuss potential threats to identification and how we mitigate those concerns.

4.1 Granular Instrumental Variables

To estimate the elasticities ϕ_B^j and ϕ_F^j, we construct GIVs that capture exogenous idiosyncratic beliefs by granular banks. Using the subscript ξ to denote the difference between the size- and equal-weighted average of any variable $X_{i,t}^j$ such that $X_{\xi,t}^j := X_{S,t}^j - X_{E,t}^j$, with $X_{S,t}^j := \sum_{i=1}^n S_{i,t-1}^j X_{i,t}^j$ and $X_{E,t}^j := \frac{1}{n}\sum_{i=1}^n X_{i,t}^j$, we specify the following form for changes in bank-specific beliefs

$$\Delta b_{i,t}^j = u_{i,t}^j + \lambda_i^j \eta_t^j + \theta^j C_{i,t-1}^j, \quad \text{with} \quad \mathbb{E}[u_{i,t}^j(\eta_t^j, \Delta b_{F,t}^j)] = 0, \tag{12}$$

for all t, where $u_{i,t}^j$ are exogenous unobserved i.i.d. shocks, η_t^j are vectors of unobserved common factors with unobserved bank-specific loadings λ_i^j, and $C_{i,t-1}^j$ are observed controls with unknown coefficients θ^j.[23] Since bank-specific belief shocks $u_{i,t}^j$ are i.i.d., they are uncorrelated with aggregate bank factors (η_t^j) and ROW-fund beliefs ($\Delta b_{F,t}^j$): $\mathbb{E}[u_{i,t}^j(\eta_t^j, \Delta b_{F,t}^j)] = 0$.

We construct our GIV for asset j, z_t^j, from observables, by taking the difference between the size- and equal-weighted change in cross-border holdings $z_t^j := \Delta q_{\xi,t}^j$. Using equation (5), we see that these GIVs admit a structural interpretation through the lens of the Granular Gamma model, being comprised of the size-minus-equal weighted combination of changes in bank-level beliefs $z_t^j = \Delta b_{\xi,t}^j$:

$$z_t^j = u_{\xi,t}^j + \lambda_\xi^j \eta_t^j + \theta^j C_{\xi,t-1}^j. \tag{13}$$

To guard against the possibility that banks' loadings on unobserved common factors are correlated with size ($\lambda_\xi^j \neq 0$), we construct estimates for the common factors η_t^j from principal components of bank-level flows to use as controls.[24] We describe this procedure in detail in Section 4.4. Given that we control for relevant observables $C_{i,t-1}^j$ as well, our GIVs reflect the size-minus-equal weighted combination of i.i.d. bank-level belief *shocks*:

$$z_t^j = u_{\xi,t}^j. \tag{14}$$

Consistent with the GIV procedure removing common shocks, we show in Appendix D that our GIVs, unlike many other instruments in the literature, are unrelated to common proxies of the global financial cycle (see Section 4.4 for further details).

In the subsequent sections, we discuss how these GIVs can be used to estimate the multipliers and elasticities present in the Granular Gamma model. Intuitively, since the GIVs place

[23] The unobserved common factors are assumed to take the parametric form: $\lambda_i^j \eta_t^j = \sum_{k=1}^K \lambda_{i,k}^j \eta_{k,t}^j$, where the first factor is a time fixed effect.

[24] Specifically, we residualise $\Delta q_{i,t}^j$ with respect to our estimates of the common factors η_t^j (alongside $C_{i,t-1}^j$) prior to constructing $z_t^j := \Delta q_{\xi,t}^j$. We also control for η_t^j (and $C_{i,t-1}^j$) in our regression specifications for inference.

a greater weight on the beliefs of large banks, idiosyncratic belief shocks to such large banks affect the banking-sectors' aggregate beliefs and are thus *relevant* for exchange rates. Further, when our GIVs reflect the size-minus-equal weighted combination of i.i.d. bank-level belief shocks $z_t^j = u_{\xi,t}^j$, they are *exogenous* as well. We discuss the steps we take to tighten our identification, including a narrative strategy to verify the exogeneity of our GIVs, in Section 4.4.

Since we have data on banks' debt assets (A) and deposit liabilities (L), we can also construct GIVs for banks' *net* debt positions. In particular, we define bank i's net USD-denominated debt flow as $\Delta q_{i,t}^{net} := \frac{1}{2}\left(\Delta q_{i,t}^A - \Delta q_{i,t}^L\right)$ since $\overline{Q}^A \approx \overline{Q}^L$. Using equation (5), the bank-level net flow reflects

$$\Delta q_{i,t}^{net} = \phi_B^{net}\left(\frac{1}{2}\mathbb{E}_t[r_{t+1}^A - r_{t+1}^L] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t\right) + \frac{1}{2}\left(\Delta b_{i,t}^A - \Delta b_{i,t}^L\right), \tag{15}$$

where, since $\overline{Q}^A \approx \overline{Q}^L$, we treat $\phi_B^A \approx \phi_B^L$, which we label as ϕ_B^{net}. This equation illustrates that we can treat $j = net$ analogously to both $j = \{A, L\}$ with $\Delta b_{i,t}^{net} := \frac{1}{2}\left(\Delta b_{i,t}^A - \Delta b_{i,t}^L\right)$ and $\mathbb{E}_t[r_{t+1}^{net}] := \frac{1}{2}\mathbb{E}_t\left[r_{i,t+1}^A - r_{i,t+1}^L\right]$. We can then construct the net-debt GIV as

$$\Delta z_t^{net} := \frac{1}{2}\left(z_t^{A^D} - z_t^{L^D}\right). \tag{16}$$

Since it is net flows that matter for FX dynamics, we are particularly interested in the effects of our net-debt GIV.

4.2 Multiplier Estimation

We first estimate the causal effect of changes in banks' cross-border USD asset and liability positions on exchange rates, as outlined in Proposition 2. To derive an estimable expression for this 'multiplier' M^j, we use equations (12) and (13) to rewrite the equilibrium condition (8) in terms of observables and an error term:

$$\Delta e_t = M^j z_t^j + \left(\Delta\mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}]\right) + \epsilon_t^j, \tag{17}$$

where $\epsilon_t^j := M^j\left(u_{E,t}^j + \lambda_E^j \eta_t^j + \theta^j C_{Ej,t-1} + \Delta\mathbb{E}_t[b_{F,t+1}^j]\right)$ and $M^j := \frac{1}{\phi_B^j + \phi_F^j}$.

To identify the multiplier M^j with OLS estimation of equation (17), two conditions are required. First, the change in expected excess returns to asset j should be included. Second, the GIV z_t^j must be uncorrelated with the unobserved error term ϵ_t^j, that is, uncorrelated with η_t^j and $C_{Ej,t-1}$ since $u_{\xi,t}^j$ is uncorrelated with the other terms by construction.

To satisfy the first requirement, we estimate the regression implied by equation (17) while including realised changes in short- and long-maturity government bond-yield differentials as control variables, alongside survey data capturing changes in expected exchange rates from *Consensus Economics* (as in Stavrakeva and Tang (2020)) and lags of realized exchange-rate movements. To satisfy the second requirement, the exogeneity of the GIV, we take a number of steps to tighten our identification, which we explain in Section 4.4. These include controlling for weighted bank-level controls (Section 4.4.2), accounting for unobserved common shocks η_t^j using principal-components analysis (Section 4.4.3) as well as a narrative check of the GIVs themselves (Section 4.4.4).

4.3 Elasticity Estimation with Two-Stage Least Squares

We then turn to estimate the two price elasticities ϕ_B^j and ϕ_F^j that compose the multiplier, which are defined in equations (6) and (7), respectively, using our GIVs. As we detail below, the same GIV 'bank demand shock' can be used to identify both banks' demand elasticity and funds' supply elasticity with respect to exchange rates.

To estimate ROW funds' aggregate supply elasticity ϕ_F^j, we use z_t^j as an instrument for the exchange rate Δe_t in regressions for the *size-weighted* change in banks' cross-border positions $\Delta q_{S,t}^j$, as implied by combining equations (7) and market clearing:

$$\Delta q_{S,t}^j = \phi_F^j \Delta e_t - \phi_F^j \left(\Delta \mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta \mathbb{E}_t[e_{t+1}] \right) + \Delta b_{F,t}^j. \tag{18}$$

The instrument's relevance follows from equation (8), which defines the relationship between size-weighted changes in beliefs and FX dynamics, since belief shocks by large banks survive aggregation. For exogeneity, we need the instrument to be uncorrelated with the error terms in both the first-stage (17) and second-stage (18) regressions: $\mathbb{E}[z_t^j(\epsilon_t^j, \Delta b_{F,t}^j)] = 0$. This corresponds to the classic case of using a demand shock to estimate the supply elasticity.

To estimate UK-resident banks' aggregate demand elasticity ϕ_B^j, we use z_t^j as an instrument for the exchange rate Δe_t in regressions for the *equal-weighted* change in banks' cross-border positions $\Delta q_{E,t}^j$, as implied by taking an equal-weighted average of equation (5):

$$\Delta q_{E,t}^j = -\phi_B^j \Delta e_t + \phi_B^j \left(\Delta \mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta \mathbb{E}_t[e_{t+1}] \right) + \underbrace{u_{E,t}^j + \lambda_E^j \eta_t^j + \theta^j C_{E,t-1}^j}_{:=\nu_t^j}. \tag{19}$$

In this case, the instrument's relevance again follows from equation (8). Similarly, exogeneity requires: $\mathbb{E}[z_t^j(\epsilon_t^j, \nu_t^j)] = 0$. Intuitively, equation (19) builds on the fact that individual banks' currency demands also react to the FX movements induced by granular banks' demand shocks. As a result, we can identify banks' demand elasticity by regressing any weighted sum of banks' idiosyncratic demand flows on our instrumented exchange rate changes, provided these weights are uncorrelated with banks' size (else we recover the supply elasticity).[25]

4.4 Threats to Identification

Here, we describe the additional steps we take to strengthen our identification, prior to estimating the regressions implied by equations (17), (18) and (19). The first of these, the potential presence of FX valuation effects, are accounted for by the GIV methodology. The next two of these, accounting for bank-level and unobserved common factors, are reflected in our specification of bank-level beliefs in equation (12). The final steps, using narrative techniques to investigate the sources of large movements in our GIV and showing that our GIV is uncorrelated with the global financial cycle, are complementary.

4.4.1 Exchange-Rate Valuation Effects

A general concern when assessing the relationship between FX changes on quantities of cross-border assets and liabilities is the presence of exchange-rate valuation effects. In principle, these can create a mechanical link between FX changes and quantities that influence any assessment of causal linkages. However, since FX valuation effects are common across banks, they are accounted for in the construction of our instruments.

To see this, we decompose the change in a bank i's asset-j position, $Q^j_{i,t} - Q^j_{i,t-1}$ into a valuation-effect and capital-flow component according to

$$Q^j_{i,t} - Q^j_{i,t-1} := \underbrace{\left(\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} R^j_t - 1\right)}_{\text{Valuation Effect}} Q^j_{i,t-1} + \underbrace{F^j_{i,t}}_{\text{Capital Flow}} Q^j_{i,t-1}. \tag{20}$$

With this, the following corollary clarifies how the GIV approach controls for FX valuation effects.

Corollary 1 (Exchange-Rate Valuation Effects) *In the Granular Gamma model, granular instrumental variables are unaffected by exchange-rate valuation effects:*

$$z^j_t = F^j_{S,t} - F^j_{E,t} \tag{21}$$

Proof: Since $\frac{\mathcal{E}_t}{\mathcal{E}_{t-1}} R^j_t \approx 1$, we can approximate (20) as $F^j_{i,t} = \Delta q^j_{i,t} - \Delta e_t - r^j_t$. This gives the size-weighted capital flow $F^j_{S,t} = \Delta q^j_{S,t} - \Delta e_t - r^j_t$ and the equal-weighted capital flow $F^j_{E,t} = \Delta q^j_{E,t} - \Delta e_t - r^j_t$. Combining these averages with the definition of our instruments

[25] On the other hand, since funds' supply is only affected by granular demand shocks via market clearing, we use banks' size-weighted flows in regression (18) to estimate the supply elasticity.

$z_t^j := \Delta q_{\xi,t}^j$, we arrive at $z_t^j = F_{S,t}^j - F_{E,t}^j$. □

This corollary implies that our estimates of the exchange-rate multiplier codified in equation (17) will not be affected by valuation effects. Since these correspond also to the multipliers in our first-stage regressions, the same is true of our estimated supply and demand elasticities in equations (18) and (19): they capture the responsiveness of cross-border positions to changes in the exchange rate, excluding valuation effects.

4.4.2 Bank Controls

A second concern, formalised by equation (12), is how we account for time-varying bank-specific factors $C_{i,t}^j$. Our confidential bank-level data set provides a range of control variables (listed in Appendix B.1) that can account for variation in different banks' cross-border portfolios across time that might not be plausibly exogenous. We use controls for both the asset and liabilities-side of UK-based banks' balance sheets and, using the quarterly bank-level information at our disposal, we construct size- and equal-weighted aggregates of each.

On the asset-side of the balance sheet, we control for the overall size of each bank using a measure of their (log) total assets, deflated by the GDP deflator. In addition, we control for their liquid-asset ratio, to account for potential differences across banks depending on their buffers of liquid assets,[26] as well as the share of banks' foreign assets over total assets to account for *ex ante* differences in the degree of internationalisation across banks.

On the liability-side, we construct controls for banks' core-deposits ratio, to capture the extent to which banks have access to alternative funding sources in the face of shocks, and the commitment share (defined as the percentage of unused commitments over assets). We also control for banks' capital ratio. Our measure is defined as the percentage of a banking organisation's regulatory Tier 1 risk-based capital-to-asset ratio.

4.4.3 Unobserved Common Factors

Additionally, equation (12) highlights a potential role for common shocks to bank-level beliefs η_t^j that have heterogeneous effects across banks λ_i^j. To control for unobserved common shocks η_t^j, we use principal component analysis to obtain estimates of common factors $\hat{\eta}_t^j$. Following Gabaix and Koijen (2020), to do this, we start by rewriting equation (5) using the definition (12) to get:

$$\Delta q_{i,t}^j = \theta_t^j + \theta^j C_{i,t-1}^j + \zeta_{i,t}^j \tag{22}$$

[26] Kashyap and Stein (2000) show that monetary policy can have a greater impact on banks with lower liquid-asset buffers.

where θ_t^j denotes a time fixed effect for asset j that absorbs the expected returns in $\Delta\mathbb{E}_t[r_{t+1}^j] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t$, as well as any other time-varying object that is the same for all banks i, and the error term is $\zeta_{i,t}^j := u_{i,t}^j + \lambda_i^j \eta_t^j$. We denote the residual from a panel regression of $\Delta q_{i,t}^j$ on our bank-level controls $C_{i,t-1}^j$ and a time fixed-effect θ_i^j as $\hat{\zeta}_{i,t}^j$. For each period, we then obtain estimates of the unobserved common factors at time t, $\hat{\eta}_{k,t}^j$ for $k = 1, ..., K$, by performing principle-component analysis on the residuals $\hat{\zeta}_{i,t}^j$ across banks.[27] Intuitively, our estimates $\hat{\eta}_{k,t}^j$ capture factors that explain common movements across banks' capital flows, but which banks load on heterogeneously since we include time fixed effects.

We then construct our GIVs $z_t^j := \Delta q_{\xi,t}^j$ using $\Delta q_{i,t}^j$s that have been residualised with respect to our estimates of the common factors $\hat{\eta}_{k,t}^j$ and bank controls $C_{i,t-1}^j$.[28] If our estimates $\hat{\eta}_{k,t}^j$ span the set of unobserved common factors for which banks' loadings correlate with size, then the GIV procedure will recover the exogenous granular belief shocks: $z_t^j = u_{\xi,t}^j$.

4.4.4 Narrative Checks

Finally, we carry out a narrative inspection of our GIVs to assess the extent to which they are driven by plausibly exogenous events. Unfortunately, a complete discussion of this exercise is limited, owing to confidentiality restrictions on our data. However, in this sub-section we summarise the headline findings from our narrative checks.

To support this, Figure 9 plots a decomposition of the quarterly GIV for USD-denominated net-debt positions (16), which are normalised to reflect standard-deviation changes relative to the mean. The Figure isolates 'Large Banks' who, in a given period, each individually contribute to at least 10% of the GIV in that period. In each period, the contribution of these 'Large Banks' is summed to deliver the blue bar. In practice, while the exact composition of these 'Large Banks' changes each period, they draw from a small set of institutions in our dataset (< 10). So the plot reveals the granular composition of our GIVs for net USD debt.

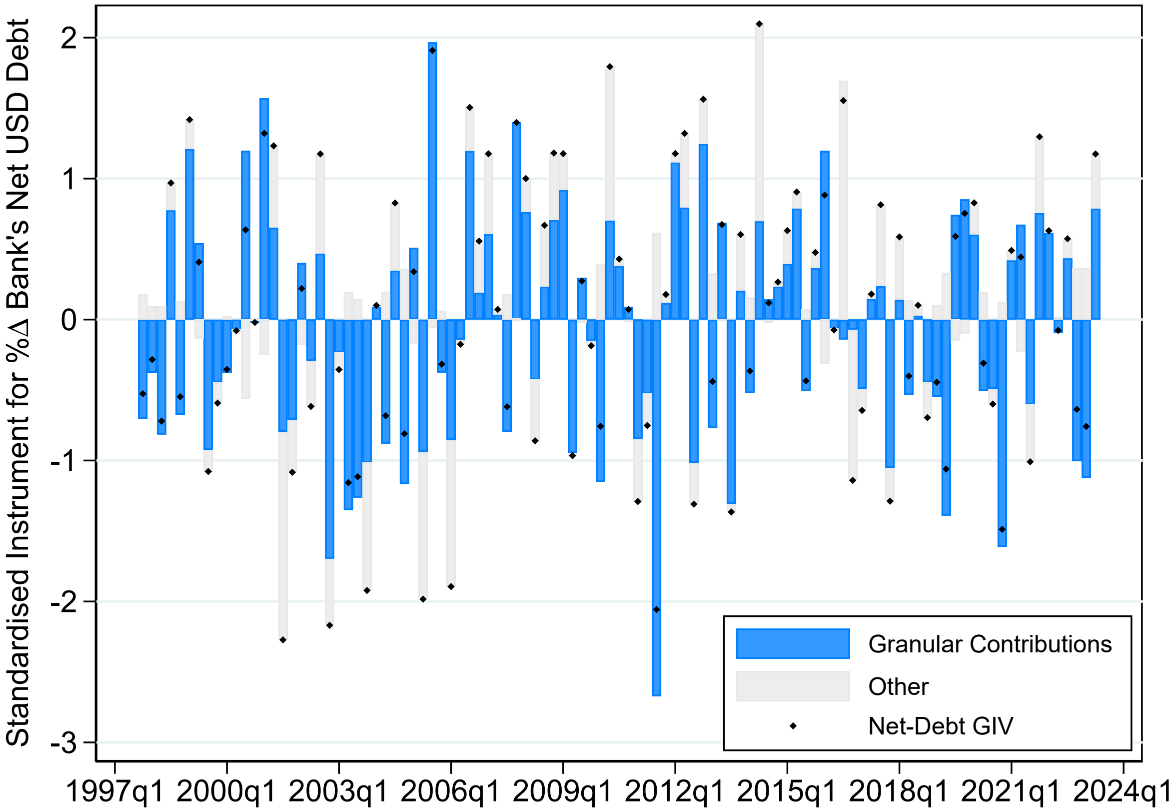
Using information available to us about the identity of these large banks, we then carry out a narrative assessment of key events that occur in periods when a given bank contributes to a substantial portion of the GIV for USD-denominated net-debt positions. To do this, we manually search and analyse the *Financial Times* archives to identify the key pieces of news pertaining to specific large banks in the quarters in which they move the GIV. Further details of these narrative checks, including sources, are listed in Appendix C.

While this exercise is unlikely to ever fully confirm the exogeneity of the instrument, these checks do reassuringly reveal that most of the key drivers of moves in the GIV are associated with idiosyncratic events, which are unlikely to be systematically related to the macroeconomic

[27] In practice, we keep the first 20 principle components.

[28] We also control for $\hat{\eta}_{k,t}^j$ and $C_{i,t-1}^j$ in our regression specifications for inference.

Figure 5: Granular Bank Contributions to GIV for Net USD Cross-Border Debt Claims



Notes: Decomposition of standardised quarterly granular instrument for net USD-denominated cross-border debt claims over the period 1997Q3-2023Q3. 'Granular Contributions' bar contains total contribution of all banks that explain over 10% of the GIV in a given period. Over the whole sample, this contains a small number of banks (< 10), although a more granular decomposition is not possible owing to confidentiality restrictions on the data.

outlook or possible confounders (e.g., global risk sentiment). Amongst the news headlines pertaining to large banks in periods in which they explain a large portion of our GIV are: being involved in a merger or acquisition; facing a change in leadership; receiving a legal fine; failing a stress test; or, in one instance, facing a computer failure that limited its ability to process cross-border payments.

4.4.5 GIV and the Global Financial Cycle

In addition, as further evidence that our GIVs are composed of idiosyncratic, non-systemic shocks to large banks, we show in Table D.1 in Appendix D that the net-debt GIV plotted in Figure 9 is not correlated with proxies for the global financial cycle—the VIX index and the global common risky-asset price factor of Miranda-Agrippino and Rey (2020)—nor by the stance of US monetary policy, which has been shown to orchestrate capital flows around the world.

5 Evidence on Exchange Rates and Banking Flows

We now apply our theoretically-founded empirical framework and present our empirical results for the relationship between cross-border banking flows and exchange rates.

5.1 The Granular Origins of Exchange-Rate Fluctuations

To measure the causal multiplier for UK-resident banks' flows into USD assets on the GBP/USD exchange rate, as captured in Proposition 2, we build on equation (17) and estimate the following relationship by OLS:

$$\Delta e_t = \sum_{j=1}^{m} M^j z_t^j + \beta_M' C_t + u_t, \tag{23}$$
$$\text{where} \quad C_t = \left[(\Delta r_{t+1} - \Delta r_{t+1}^*), \Delta\mathbb{E}_t[e_{t+1}], \Delta e_{t-1}, \Delta e_{t-2}, C_{S,t-1}, \hat{\eta}_t^j\right],$$

where we are primarily interested in estimates for the multipliers M^j for $j = \{A, L\}$ and $j = \{net\}$, C_t is a vector of controls with a corresponding vector of coefficients β_M, asterisks (*) denote UK returns, and u_t is a disturbance. Our first set of controls are changes in US-minus-UK local currency return differentials $\Delta r_{t+1}^j - \Delta r_{t+1}^{j,*}$, which we proxy with relative short- (6 month) and long- (10 year) maturity government bond yields.[29] We additionally use *Consensus Economics* forecasts of exchange rates to control for changes in exchange-rate expectations $\mathbb{E}_t[\Delta e_{t+1}]$, as well as two lags of the dependent variable ($\{\Delta e_{t-1}, \Delta e_{t-2}\}$). Next, we include size-weighted, by banks' net debt position, averages of lagged bank-level controls $C_{S,t-1}$, namely banks' total assets, international-asset shares, liquid-asset ratios, core-deposit ratios, commitment shares, and capital ratios. Finally, we include the first twenty principal components extracted from changes in banks' net debt flows $\hat{\eta}_t$ as proxies for unobserved common factors.

Table 1 presents our first set of results. The coefficients on z_t^j represent the causal effect of a 1% increase in UK-resident banks' aggregate holdings of USD instruments on the nominal price of dollar in pounds expressed in percent. In Panel A, we report multipliers for USD debt assets and deposit liabilities, estimated jointly. Quantitatively, a 1% flow into USD debt by UK banks appreciates the dollar by nearly 0.5% on impact against sterling, within the quarter, while a 1% increase in dollar-denominated deposits depreciates the dollar by a similar amount. The magnitudes of the estimated multipliers for debt assets and deposit liabilities are remark-

[29] We assume that these debt instruments are held to maturity, and so use changes in yields from time $t-1$ to t as our measure of changes in returns.

Table 1: Multiplier Estimates for External Asset, Liability and Net Flows on Exchange Rates

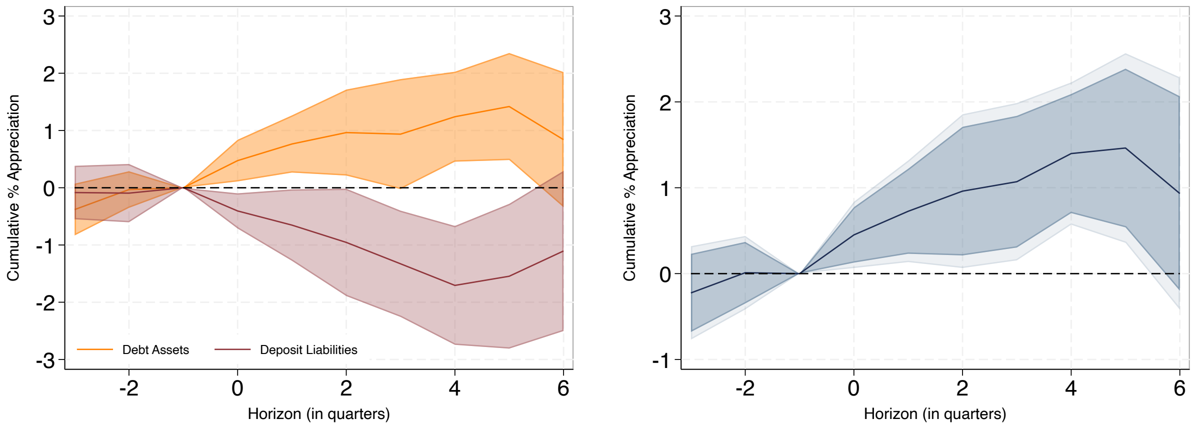
	(1)	(2)
	DEP. VAR.: % change nominal GBP/USD (Δe_t)	
PANEL A: Multipliers for USD Debt-Asset and Deposit-Liability Flows		
z_t^A (Debt Assets)	0.42*	0.47**
	(0.21)	(0.22)
z_t^L (Deposits Liabilities)	-0.47*	-0.40**
	(0.26)	(0.19)
$\Delta\mathbb{E}_t[e_{t+1}]$		0.77***
		(0.12)
Δe_{t-1}		-0.29***
		(0.07)
Δe_{t-2}		-0.08*
		(0.04)
$\Delta(r^{us}_{6M,t} - r^{uk}_{6M,t})$		0.02***
		(0.01)
$\Delta(r^{us}_{10Y,t} - r^{uk}_{10Y,t})$		-0.01
		(0.02)
Observations	101	101
Macro Controls	No	Yes
Bank Controls	No	Yes
Components	No	20
R^2	0.04	0.70
PANEL B: Multipliers for Net USD-Debt Flows		
z_t^{net} (Net Debt)	0.44**	0.45**
	(0.22)	(0.20)
Observations	101	101
Macro Controls	No	Yes
Bank Controls	No	Yes
Components	No	20
R^2	0.04	0.69

Notes: Coefficient estimates from equation (23) using data for 1997Q1-2023Q3. Panel A presents multiplier estimates for USD debt assets and deposit liabilities (estimated jointly). Panel B presents estimates for net positions, with coefficients on control variables suppressed for presentational purposes. Macro controls: changes in expectations for the GBP/USD exchange rate $\mathbb{E}_t[e_{t+1}]$; two lags of realized GBP/USD exchange-rate movements Δe_{t-1} and Δe_{t-2}, 6-month government bond yields $(r^{us}_{6M} - r^{uk}_{6M})$, 10-year government bond yields $(r^{us}_{10Y} - r^{uk}_{10Y})$. Bank controls are (net) size-weighted: total assets, international-asset shares, liquid-asset ratios, core-deposit ratios, commitment shares, capital ratios. Principal components are extracted from changes in net assets. Newey and West (1987) standard errors with 12 lags are in parentheses. Significance at 10%, 5% and 1% denoted by $*$, $**$, and $***$, respectively.

Figure 6: Dynamic Multipliers for Assets, Liabilities and Net Flows on Exchange Rates

(a) Dollar Debt Assets and Deposit Liabilities

(b) Net Dollar-Debt Positions (Debt − Deposits)



Notes: Multiplier estimates from local-projection estimation of equation (23) using data for 1997Q1-2023Q3. Figure 6a presents multiplier estimates for specific assets and liabilities (estimated jointly). Figure 6b presents multiplier estimates for net-debt positions. Shaded areas denote 90% (Panels a and b) and 95% (Panel b) confidence intervals from Newey and West (1987) standard errors with 12 lags. All local projections include the same control variables used in column (4) of Table 1.

ably similar to one another—consistent with theory—and are little changed when including controls, although confidence bounds are tightened.[30]

In Panel B, we focus in on the multiplier for the net dollar debt position—i.e., USD debt assets minus deposit liabilities. Our point estimates imply that a 1% increase in UK banks' net dollar-debt position leads to a 0.45% appreciation of the dollar vis-à-vis sterling on impact. Of note, the R^2 in column (1) coming from the regression that includes only the net-dollar debt GIV is 4%, which showcases the relevance of our granular financial shock for exchange-rate dynamics, as compared to, e.g., the explanatory power of monetary policy shocks. Since the multipliers are given by $M^j = \frac{1}{\phi_B^j + \phi_F^j}$, our estimates already hint at a fairly inelastic market. This is noteworthy because no-arbitrage theory would predict elasticities to be significantly higher and multipliers to be close to zero.

Next, we extend regression (23) to estimate the dynamic effects of cross-border USD banking flows on the GBP/USD exchange rate. To do this, we estimate the regression as a local projection (Jordà, 2005), directly projecting the h-period-ahead exchange-rate change, $\Delta^h e_{t+h} := e_{t+h} - e_{t-1}$, on the same variables included in the on-impact results in Table 1.

Figure 6a reveals that the causal effects of UK banking flows into USD debt assets and deposit liabilities are persistent. Subsequent to the on-impact multiplier of around 0.45 from column (2) of Table 1, a 1% increase debt-asset flows is associated with a cumulative USD appreciation of around 1.5% one year after the shock. Estimates for the other side of the carry

[30]Coefficients on many of the additional controls are significant, and come with the expected sign.

trade, banks' deposit liabilities, reveal a roughly equal and opposite story. Consistent with our model where a persistent increase in demand generates a persistent shift in the level of the exchange rate, these multipliers take 6 quarters to revert back to zero after the initial shock, which may reflect the maturity of the modal debt asset being purchased. Overall, these estimates suggest that equal-and-opposite changes in UK-resident banks' USD debt-asset and liability positions are associated with near-zero overall effects on the exchange rate.

Figure 6b, however, shows how mismatches in banks' USD debt-asset vs. USD deposit liability positions can have substantial exchange rate effects. Plotting the impulse response of the GBP/USD exchange rate to exogenous changes in banks' net dollar-debt position (i.e., debt-assets minus deposit-liabilities) reveals that a 1% change in banks' net carry-trade position in USD is associated with around a 2% appreciation of the dollar *vis-à-vis* sterling one year after the shock. And, once again, this effect is persistent.

Finally, to put our multiplier estimates for nominal exchange rates into perspective, we translate them into different units to demonstrate how exogenous cross-border banking flows per unit of UK GDP influence the nominal GBP/USD exchange rate one-year ahead. Our results imply that a net flow into dollar-denominated debt by UK banks equivalent to 1% of UK GDP appreciates the dollar by about 2.5% one year after the shock.

Robustness. In Appendix D, we show that the results from this section are robust to (i) excluding the global financial crisis; (ii) splitting the sample around the global financial crisis; and (iii) using changes in UIP deviations rather than exchange-rate movements as the dependent variable.

5.2 Elastic Banks and Inelastic Funds

Motivated by these causal effects, we next estimate the supply and demand elasticities for net USD-debt using a two-stage least squares estimation procedure. These structural elasticities underpin the equilibrium FX dynamics from Section 5.1.

To estimate the supply elasticity for net dollar-debt from ROW 'funds' ϕ_F^{net}, we use the following regression building on equation (18):

$$\Delta q_{S,t}^{net} = \phi_F^{net} \Delta e_t + \beta_{\phi_F}^{net} C_t + u_t, \tag{24}$$

where we use z_t^{net} as an instrument for Δe_t, along with the same macroeconomic and size-weighted bank controls C_t from regression (23) which have coefficients denoted by $\beta_{\phi_F}^{net}$.

Panel A of Table 2 presents estimates of the supply elasticity from our second-stage regression. The first-stage F-statistic is significantly above 10, supporting the relevance of our

Table 2: Supply and Demand Elasticity Estimates for Net Flows *vis-à-vis* Exchange Rates

PANEL A: 2nd Stage for Supply Elasticity (ϕ_F^{net}) DEP. VAR.: $\Delta q_{S,t}^{net}$	
Δe_t	0.518**
	(0.221)
Observations	101
1st-Stage F-stat.	34.62
Macro Controls	Yes
Bank Controls	Yes
Components	20
PANEL B: 2nd Stage for Demand Elasticity ($-\phi_B^{net}$) DEP. VAR.: $\Delta q_{E,t}^{net}$	
Δe_t	-1.856***
	(0.706)
Observations	101
1st-Stage F-stat.	46.75
Macro Controls	Yes
Bank Controls	Yes
Components	20

Notes: PANEL A: Coefficient estimates from regression (24). PANEL B: Coefficient estimates from regression (25). All regressions estimated with data for 1997Q1-2023Q3. Corresponding first-stage regression coefficients reported in Appendix D. Coefficients on macro and bank controls suppressed for presentational purposes. Bank controls are size-weighted (PANEL A) and equal-weighted (PANEL B). The remaining notes from Table 1 concerning the macro controls, bank controls and principle components apply. Newey and West (1987) standard errors with 12 lags are in parentheses. Significance at 10%, 5% and 1% denoted by $*$, $**$, and $***$, respectively.

GIV.[31] The coefficient estimates robustly reveal a significant positive supply relationship between exchange rate dynamics and cross-border net USD-debt flows, with point estimates for the price elasticity of USD supply from ROW financial players ϕ_F^{net} sitting at about 0.5. These elastic estimates imply that, on average over our sample, ROW funds' flows respond less than proportionately to exchange-rate movements—by about a factor of half.

To estimate the corresponding demand elasticity for net dollar-debt by UK-resident banks ϕ_B^{net}, we build on equation (19) using z_t^{net} as an instrument for Δe_t in the following regression:

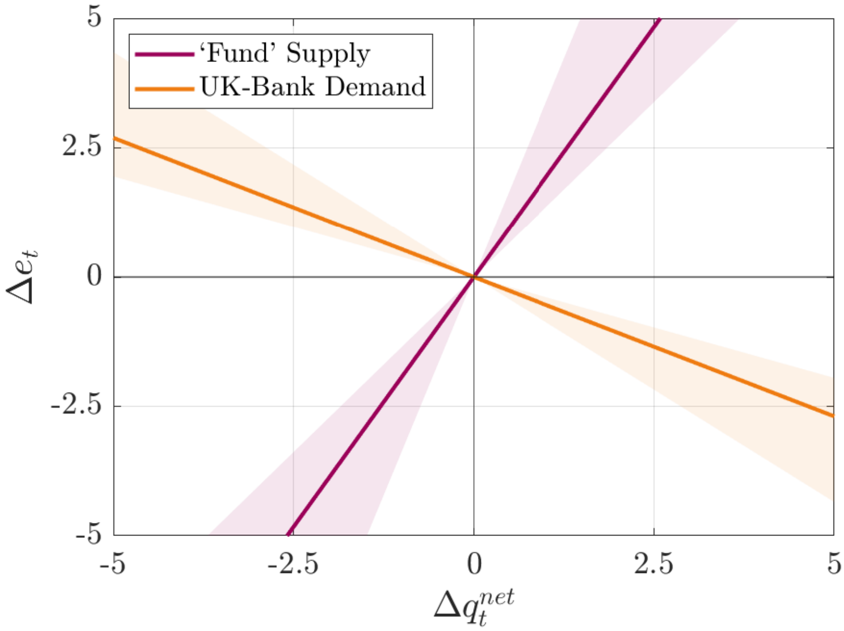
$$\Delta q_{E,t}^{net} = -\phi_B^{net} \Delta e_t + \beta_{\phi_B}^{net} C_t + u_t, \tag{25}$$

where we now use equal-weighted averages as bank-level controls in C_t, which have coefficients $\beta_{\phi_B}^{net}$.

Panel B of Table 2 presents estimates of the demand elasticity from the second stage regression (25). Once again, the first-stage F statistics show that our GIV is relevant. In this case,

[31]The first-stage results are provided in Appendix D.

Figure 7: Elastic UK-Bank Demand and Inelastic 'Fund' Supply of USDs



Notes: Supply and demand relationship between the change in the GBP/USD exchange rate Δe_t and changes in net dollar debt (debt − deposit) quantities Δq_t^{net} implied by elasticity estimates in Table 2. Shaded areas denote 1 standard-deviation error bands implied by the Newey and West (1987) standard errors, with 12 lags.

point estimates imply that (the negative of) UK-resident banks' price elasticity of demand for USD debt $-\phi_B^{net}$ is about -1.9. Reassuringly, combining these estimated demand and supply elasticities according to $M^{net} = \frac{1}{\phi_B^{net}+\phi_F^{net}}$ produces multiplier values very similar to those reported in Panel B of Table 1. Interestingly, these estimates indicate that, while the elasticity of dollar supply from ROW funds is inelastic with respect to exchange rates, the elasticity of demand by UK-resident banks is elastic on average over our sample—with point estimates lying above unity. That is, our estimates imply that a 1% appreciation of the USD is associated with a more than proportional increase in demand for USDs by UK-resident banks—by nearly double.

Figure 7 plots the relationship between 'fund' supply and bank demand for dollars implied by the coefficient estimates in Table 2. It highlights graphically that UK banks' demand curve (in yellow) is, on average, significantly flatter than their foreign counterparties' supply curve (in red). In decomposing the multiplier $M^{net} = \frac{1}{\phi_B^{net}+\phi_F^{net}}$, the fact that the demand elasticity ϕ_B^{net} lies significantly above the supply elasticity ϕ_F^{net} implies that UK-resident banks help dampen the FX response to financial shocks compared to the average of other market participants, such as various types of non-bank financial institutions. A key implication of funds' inelastic dollar supply is that UK banks may face difficulties in securing dollars, incurring substantial costs through adverse FX movements.

5.3 Time-Varying Multipliers and Elasticities

In this section, we extend our empirical framework to test for time variation in the banking systems' willingness and ability to absorb capital flows. In particular, we jointly investigate three potential drivers of time-variation in the multiplier from banking flows to exchange rates: (1) bank hedging via FX derivatives; (2) bank capital; and (3) financial market volatility. Changes in both bank capital and financial market volatility may directly influence the agency friction at the heart of the Granular Gamma model and hence their price elasticity. FX hedging using derivatives, on the other hand, dampens the extent to which net-USD debt flows translate into dollar exposures, and so decreases the compensation banks demand for a given agency friction.

Our metric for UK-resident banks' FX hedging via derivatives $Hedge$, informed by our analysis in Section 3.3, is constructed as:

$$Hedge_t := \frac{-1}{N}\sum_{i=1}^{N}\rho_{i,t}^{(12)}[\Delta q_i^{net}, \Delta d_i^{net}], \tag{26}$$

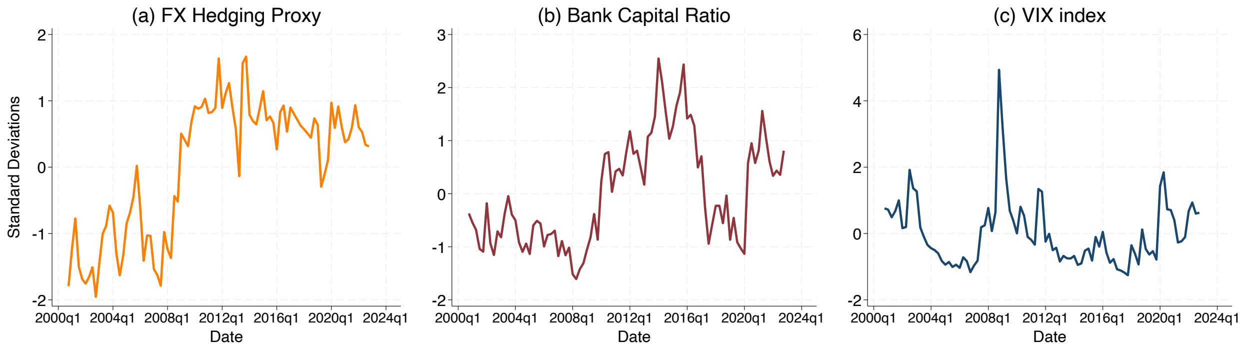
where $\rho_{i,t}^{(12)}[\Delta q_i^{net}, \Delta d_i^{net}]$ refers to the correlation between changes in the value of bank i's on-balance-sheet net-USD debt position and off-balance-sheet FX derivatives position over the preceding 12 quarters. Intuitively, $Hedge_t$ captures the notion that if the value of banks' FX derivative holdings fall when their net-USD debt position improves, then FX derivatives are mechanically serving as a hedge ($Hedge_t > 0$). If instead they co-move positively ($Hedge_t < 0$), FX derivatives mechanically act as a speculative instrument.

We measure the UK banking system's capitalisation using a size-weighted average of their Tier-1 capital ratios Cap_S, which are a function of both regulatory policy and banks' internal risk-management preferences. We proxy financial market volatility using the VIX index.

Figure 8 plots our time-series measures of bank FX hedging, bank capital and financial market volatility as standardised variables—i.e., as deviations from mean in units of standard deviations. A key observation is our proxy for banks' hedging via FX derivatives sharply increased at the onset of the global financial crisis and remained elevated thereafter (Panel a). This sharp increase reflects a jump in correlation from about -10%—suggesting FX derivatives, on-average, served as a speculative tool in the pre-crisis period—to +20%—suggesting they acted more as hedge during and post crisis. By comparison, banks' capital ratios (Panel b) increased later, in the lead-up to the Basel II reforms, fell sharply at the onset of the Fed tightening cycle in 2016, before rebounding when the Fed returned to the ZLB during the Covid-19 pandemic. The VIX index in Panel c displays notable spikes during the dot-com crash, the global financial crisis, the euro-area sovereign debt crisis, and the pandemic.

To test for non-linearities linked to FX derivatives use, bank capital and financial market

Figure 8: Interactions



Notes: Time series of FX hedging proxy $Hedge_t$ (Panel a) constructed according to equation (26), size-weighted bank Tier-1 capital ratio $Caps_{S,t}$ (Panel b), and the VIX_t index (Panel c). Variables are z-scored to have zero mean and unit variance. These variables are used as state variables in regression (27) to test for non-linearities in the multiplier from banking flows to exchange rates.

volatility jointly, we extend regression (23) by interacting our net dollar-debt GIV z_t^{net} with each of these standardized state variables $State_t^s = \{VIX_t, Caps_{S,t}, Hedge_t\}$, lagged one period:

$$\Delta e_t = M z_t^{net} + \sum_s \delta^s \left(z_t^{net} \times State_{t-1}^s \right) + \sum_s \vartheta^s State_{t-1}^s + \beta_M^j C_t^j + u_t \tag{27}$$

where M represents the multiplier when financial volatility, banks' capital ratios and banks' FX hedging are at their long-run average and δ^s represents how this multiplier changes when a state variable s increases by 1 standard deviation.

Table 3 presents our results. In each column, the multiplier M for net-USD debt when the state variables are at their historical averages is about 0.43 and significant, in line with the results from Section 5.1. More importantly, we see that greater bank FX derivative hedging, a lower VIX index and greater bank capital ratios are associated with a lower multiplier from banking flows to exchange rates, although only the former two are significant when all three are included in our preferred regression together, in column (4). Quantitatively, the multiplier can be about fully offset when banks' FX derivative hedging use is 1 standard deviation above average or the VIX index is 1 standard deviation below, and roughly doubled when these metrics are, respectively, 1 standard deviation below and above average.

These findings highlight that FX derivatives use and financial volatility carry important implications for the relationship between cross-border banking flows and foreign-exchange markets. In particular, they suggest that increased FX hedging via derivatives, especially in times of low volatility, by flattening banks' demand curves for USDs, significantly dampens the relationship between capital flows and exchange rates. This may help explain the stronger relationship between exchange rates and fundamentals post crisis (see, e.g., Bussiere et al.,

Table 3: Time-Varying Multiplier of Net Flows on Exchange Rates

	(1)	(2)	(3)	(4)
	Dep. Var.: % change nominal GBP/USD (Δe_t)			
z_t^{net}	0.418*	0.432*	0.429**	0.442**
	(0.248)	(0.232)	(0.189)	(0.196)
$z_t^{net} \times Hedge_{t-1}$	-0.527***			-0.402**
	(0.175)			(0.182)
$z_t^{net} \times Caps_{S,t-1}$		-0.425**		0.067
		(0.180)		(0.246)
$z_t^{net} \times VIX_{t-1}$			0.541***	0.446***
			(0.162)	(0.150)
Observations	89	89	89	89
Macro Controls	Yes	Yes	Yes	Yes
Bank Controls	Yes	Yes	Yes	Yes
Components	20	20	20	20
R^2	0.742	0.734	0.753	0.772

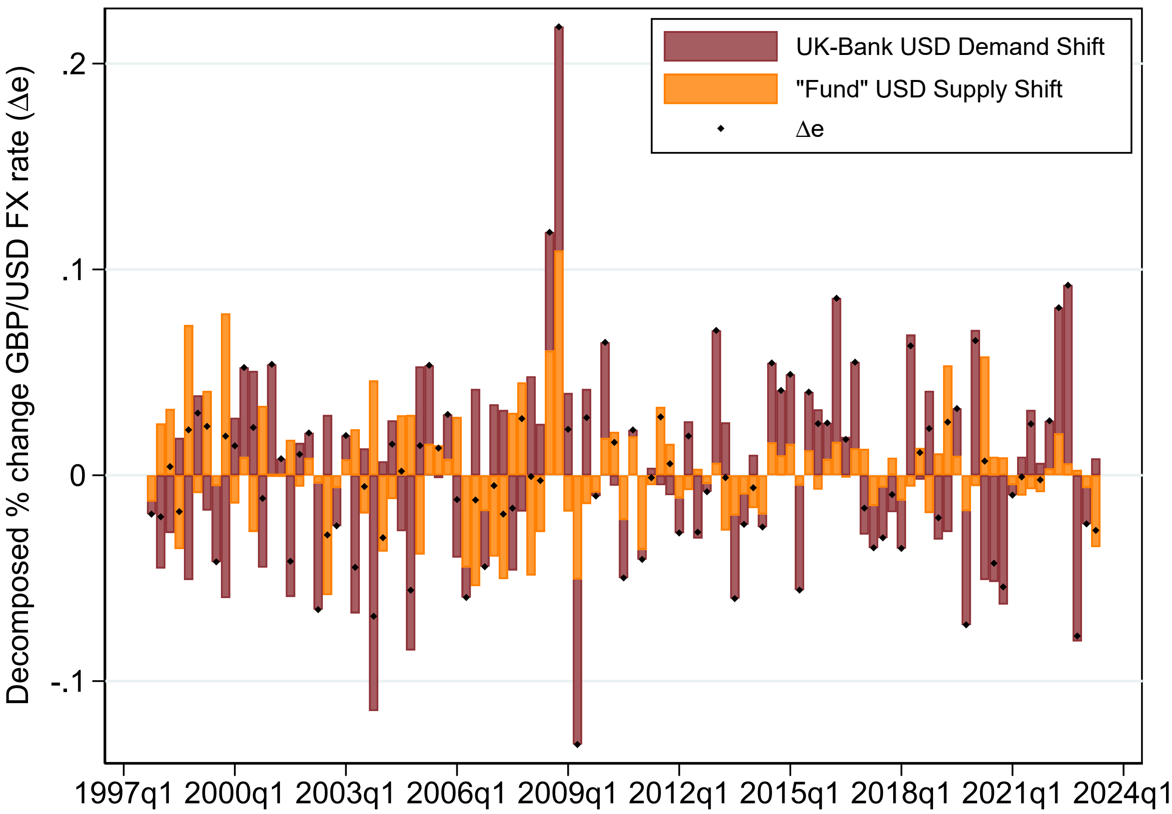
Notes: Coefficient estimates from equation (27) using data from 2000Q1-2023Q3. Coefficients on macro and size-weighted bank controls suppressed for presentational purposes. The remaining notes from Table 1 concerning the macro controls, bank controls and principle components apply. Newey and West (1987) standard errors with 12 lags are in parentheses. Significance at 10%, 5% and 1% denoted by $*$, $**$, and $***$, respectively.

2018; Engel et al., 2022; Engel and Wu, 2024). We test this explicitly by separately estimating demand elasticities in 2 distinct states: (1) when banks' hedging via FX derivatives is above average and financial volatility is not spiking, defined as the VIX is below 1.5 standard deviations above its historical average; and (2) when banks' hedging is below average and/or the VIX is spiking. The results are presented in Table D.3 and highlight, indeed, that banks are significantly more elastic in state (1) than state (2).[32]

Finally, armed with our time-varying bank demand, as well as fund supply, elasticities, we decompose realized GBP/USD exchange rate movements into shifts in bank demand and fund supply elasticities for dollars. Figure 9 presents the results. This decomposition highlights that most exchange-rate movements reflect dollar demand shifts by UK-resident banks, especially post crisis when banks' increased FX hedging leads them to become more elastic. Important episodes of heightened market volatility, such as the significant dollar appreciation during the global financial crisis, reflect increases in dollar demand by both UK banks and 'funds'.

[32]While in principle time-variation in the multiplier could be due to time-variation in funds' dollar supply elasticity, this is not borne out in the data.

Figure 9: Exchange Rate Decomposition into UK-Bank Demand and Fund Supply Shifts



Notes: Decomposed GBP/USD exchange-rate movements into shifts in UK-bank dollar demand (in maroon) and 'fund' dollar supply (in yellow) based on estimated time-varying bank elasticities in Table D.3 and the constant fund supply elasticity in Table 2. Black diamonds refer to realized exchange rate change.

6 Conclusion

In this paper, we have used data on the external assets and liabilities of banks based in the world's largest IFC, the UK, to investigate the granular origins and causal effects of capital flow shocks. These banking positions, which comprise around one-fifth of cross-border banking flows and 38% of the UK's total external position, revealed important granularity across banks in relation to their foreign-exchange positions. A small number of large banks account for a large fraction of UK-based banks' USD positions over time.

Motivated by this granularity, we developed a new granular model of exchange-rate determination. To test the model's predictions, we idenfitied granular financial shocks by constructing GIVs, which reflect exogenous cross-border banking flows in and out of USD assets by large banks. Using these GIVs, we have shown that cross-border banking flows have a significant causal impact on exchange rates. A 1% increase in UK-resident banks' net dollar-debt positions leads to a persistent dollar appreciation that peaks at around 1.5% against sterling. We have also shown that these effects are highly state dependent, with effects nearly twice as large when banks' FX derivatives hedging activity decrease by one standard deviation below average. This highlights the importance of banks' time-varying risk-bearing capacity for exchange-rate dynamics.

Moreover, we have used our granular financial shocks to estimate distinct bank demand and 'fund' supply elasticities in the foreign-exchange market. Interestingly, our estimates reveal that demand for USDs by UK-resident banks is price elastic on-average with respect to exogenous changes in the exchange rate, whereas the supply of USDs by rest-of-the-world financial players is price inelastic.

Our finding of elastic dollar demand by UK-based banks suggests that the effect of global financial shocks on currency may be dampened by banks' currency demand. In turn, policies that impact banks' risk-bearing capacity, through FX derivatives markets especially, may further help to mitigate vulnerabilities by flattening demand curves for currency further. We defer a deeper investigation of the macroeconomic consequences and policy considerations of our findings to future work.

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Appendix

A Model Appendix

A.1 Details on Approximation

We approximate the model using a first-order Taylor expansion of the bank's optimality condition

$$Q^j_{i,t} = \frac{1}{\Gamma^j_i} \cdot \mathbb{E}_t \left[B^j_{i,t} \left(\frac{R^j_{t+1}}{R_t} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} - 1 \right) \right], \tag{A.1}$$

around the steady state $\overline{Q}^j_i = \frac{1}{\Gamma^j_i} \left(\overline{B}^j_i \left(\frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} - 1 \right) \right)$ where we used $B^j_{i,t} := \exp(b^j_{i,t})$. We derive the approximation in the following steps:

$$\begin{aligned}
\overline{Q}^j_i + (Q^j_{i,t} - \overline{Q}^j_i) \approx & \frac{1}{\Gamma^j_i} \cdot \mathbb{E}_t \Bigg[\overline{B}^j_i \left(\frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} - 1 \right) + \left(\frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} - 1 \right) (B^j_{i,t} - \overline{B}^j_i) + \overline{B}^j_i \frac{1}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} (R^j_{t+1} - \overline{R}^j) \\
& - \overline{B}^j_i \frac{\overline{R}^j}{\overline{R}^2} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} (R_t - \overline{R}) + \overline{B}^j_i \frac{\overline{R}^j}{\overline{R}} \frac{1}{\overline{\mathcal{E}}} (\mathcal{E}_{t+1} - \overline{\mathcal{E}}) - \overline{B}^j_i \frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}^2} (\mathcal{E}_t - \overline{\mathcal{E}}) \Bigg] \\
(Q^j_{i,t} - \overline{Q}^j_i) \approx & \frac{1}{\Gamma^j_i} \cdot \Bigg\{ \left(\overline{B}^j_i \frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} \right) \cdot \mathbb{E}_t \left[\frac{(R^j_{t+1} - \overline{R}^j)}{\overline{R}^j} - \frac{(R_t - \overline{R})}{\overline{R}} + \frac{(\mathcal{E}_{t+1} - \overline{\mathcal{E}})}{\overline{\mathcal{E}}} - \frac{(\mathcal{E}_t - \overline{\mathcal{E}})}{\overline{\mathcal{E}}} \right] \\
& + \left[\overline{B}^j_i \left(\frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} - 1 \right) \right] \cdot \frac{(B^j_{i,t} - \overline{B}^j_i)}{\overline{B}^j_i} \Bigg\} \\
(Q^j_{i,t} - \overline{Q}^j_i) \approx & \frac{1}{\Gamma^j_i} \cdot \left\{ \left(\overline{B}^j_i \frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} \right) \cdot \mathbb{E}_t \left[\tilde{r}^j_{t+1} - \tilde{r}_t + \tilde{e}_{t+1} - \tilde{e}_t \right] + \left[\overline{B}^j_i \left(\frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} - 1 \right) \right] \cdot \tilde{b}^j_{i,t} \right\} \\
(Q^j_{i,t} - \overline{Q}^j_i) \approx & \frac{1}{\Gamma^j_i} \cdot \left\{ \left(\overline{Q}^j_i \Gamma^j_i + 1 \right) \cdot \mathbb{E}_t \left[\tilde{r}^j_{t+1} - \tilde{r}_t + \tilde{e}_{t+1} - \tilde{e}_t \right] + \left(\overline{Q}^j_i \Gamma^j_i \right) \cdot \tilde{b}^j_{i,t} \right\} \\
(Q^j_{i,t} - \overline{Q}^j_i) \approx & \left(\frac{1 + \overline{Q}^j_i \Gamma^j_i}{\Gamma^j_i} \right) \cdot \mathbb{E}_t \left[\tilde{r}^j_{t+1} - \tilde{r}_t + \tilde{e}_{t+1} - \tilde{e}_t \right] + \overline{Q}^j_i \cdot \tilde{b}^j_{i,t} \\
\frac{(Q^j_{i,t} - \overline{Q}^j_i)}{\overline{Q}^j_i} \approx & \left(\frac{1 + \overline{Q}^j_i \Gamma^j_i}{\overline{Q}^j_i \Gamma^j_i} \right) \cdot \mathbb{E}_t \left[\tilde{r}^j_{t+1} - \tilde{r}_t + \tilde{e}_{t+1} - \tilde{e}_t \right] + \tilde{b}^j_{i,t} \\
\tilde{q}^j_{i,t} \approx & \left(\frac{1 + \overline{Q}^j_i \Gamma^j_i}{\overline{Q}^j_i \Gamma^j_i} \right) \cdot \left(\mathbb{E}_t[\tilde{r}^j_{t+1}] - \tilde{r}_t + \mathbb{E}_t[\tilde{e}_{t+1}] - \tilde{e}_t \right) + \tilde{b}^j_{i,t},
\end{aligned}$$

where line 1 writes out the full first-order Taylor expansion of equation (A.1), line 2 cancels terms, line 3 uses lower-case tildes to denote percent deviations from steady state, line 4 uses the steady-state identity $\overline{Q}^j_i = \frac{1}{\Gamma^j_i} \left(\overline{B}^j_i \left(\frac{\overline{R}^j}{\overline{R}} \frac{\overline{\mathcal{E}}}{\overline{\mathcal{E}}} - 1 \right) \right)$, line 5 simplifies, line 6 divides both sides by $\overline{Q}^j_i$ and line 7 expresses the left-hand side in terms of percent deviations from steady state.

To derive equation (4), take the difference of this expression between time $t-1$ and t, using the law of iterated expectations to ensure that expectations are taken conditional on time t

$$\Delta\tilde{q}^j_{i,t} \approx \left(\frac{1+\overline{Q}^j_i\Gamma^j_i}{\overline{Q}^j_i\Gamma^j_i}\right)\cdot\Big(\Delta\mathbb{E}_t[\tilde{r}^j_{t+1}] - \Delta\tilde{r}_t + \Delta\mathbb{E}_t[\tilde{e}_{t+1}] - \Delta\tilde{e}_t\Big) + \Delta\tilde{b}^j_{i,t}$$

Since lower-case tildes denote percent deviation from steady state and are approximately equal to log deviations from steady state (i.e., $\tilde{x}_t = \frac{X_t-\overline{X}}{\overline{X}} \approx x_t - \overline{x}$, where $x \equiv \log(X)$), then steady-states cancel out in first difference, so we arrive at equation (4)

$$\Delta q^j_{i,t} \approx \left(\frac{1+\overline{Q}^j_i\Gamma^j_i}{\overline{Q}^j_i\Gamma^j_i}\right)\cdot\Big(\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t\Big) + \Delta b^j_{i,t},$$

where we denote price elasticity of demand as $\phi^j_i = \left(\frac{1+\overline{Q}^j_i\Gamma^j_i}{\overline{Q}^j_i\Gamma^j_i}\right)$.

Of note, in a symmetric steady state in which all banks have the same beliefs $\overline{B}^j_i = \overline{B}^j$, we have that $\overline{Q}^j_i\Gamma^j_i = \left(\overline{B}^j\left(\frac{\overline{R}^j}{\overline{R}} - 1\right)\right)$ so that $\phi^j_{Bi} = \phi^j_B\ \forall i$, specifically, $\phi^j_B = \frac{1+\left(\overline{B}^j\left(\frac{\overline{R}^j}{\overline{R}}-1\right)\right)}{\left(\overline{B}^j\left(\frac{\overline{R}^j}{\overline{R}}-1\right)\right)}$. Thus, the price elasticity of demand is a function of the steady state (subjective) cross-border excess return or UIP deviation.

We can add more structure to this steady state to gain intuition for the determinants of this steady state UIP deviation. For example, consider the case where $\overline{B}^j = 1$ for simplicity and $\Gamma^j_i = \overline{S}^{-1}_{ij}\Gamma^j$, with $\overline{S}_{ij} := \frac{\overline{Q}^j_i}{\sum_{i=1}^n \overline{Q}^j_i}$ and n is the number of banks, such that banks' risk-bearing capacities are inversely proportional to their relative steady-state size. In this case, $\left(\overline{B}^j\left(\frac{\overline{R}^j}{\overline{R}} - 1\right)\right) = \overline{Q}^j\Gamma^j$, where $\overline{Q}^j = \sum_{i=1}^n \overline{Q}^j_i$. Thus, $\phi^j_B = \left(\frac{1+\overline{Q}^j\Gamma^j}{\overline{Q}^j\Gamma^j}\right)$, i.e., banks' price elasticity of demand is a function of the average risk-bearing capacity of the banking sector as a whole and the total amount intermediated by the banking sector in steady state.

A.2 Proof of Proposition 1

To find the equilibrium, we use equations (6) and (7) together with $\Delta q^j_{S,t} = \Delta q^j_{F,t}$. This gives

$$\begin{aligned}\phi^j_B\Big(\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t\Big) + \Delta b^j_{S,t} = \\ -\phi^j_F\Big(\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t\Big) + \Delta b^j_{F,t},\end{aligned} \tag{A.2}$$

which simplifies to

$$\Delta e_t = \frac{1}{\phi^j_B+\phi^j_F}\Delta b^j_{S,t} - \frac{1}{\phi^j_B+\phi^j_F}\Delta b^j_{F,t} + \Big(\Delta\mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta\mathbb{E}_t[e_{t+1}]\Big). \tag{A.3}$$

To find the equilibrium change in quantities, we plug this expression back into equation (6) and obtain

$$\Delta q^j_{S,t} = \frac{\phi^j_F}{\phi^j_B + \phi^j_F} \Delta b^j_{S,t} + \frac{\phi^j_B}{\phi^j_B + \phi^j_F} \Delta b^j_{F,t}. \tag{A.4}$$

A.3 FX Derivatives Extension

Assume that a price-taking UK-resident bank i takes an uncovered position $X^j_{i,t}$ in dollar-denominated asset j with return R^j_{t+1} as well as an FX covered position $D^j_{i,t}$ in the same asset, where $X^j_{i,t} = Q^j_{i,t} + D^j_{i,t}$, by borrowing a domestic opportunity cost R_t in sterling. Further, assume that the return R^j_{t+1} is known and safe and that covered interest parity approximately holds. Then, bank i's optimal demand for dollar exposure $X^j_{i,t}$ from asset j is given by:

$$V^j_{i,t} = \max_{X^j_{i,t}>0} \ \mathbb{E}_t \left[\exp(b^j_{i,t}) \cdot \left(\frac{R^j_{t+1}}{R_t} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} - 1 \right) \right] X^j_{i,t} - \mathbb{E}_t \left[\exp(b^j_{i,t}) \cdot \underbrace{\left(\frac{R^j_{t+1}}{R_t} \frac{\mathcal{F}_t}{\mathcal{E}_t} - 1 \right)}_{=0 \text{ under CIP}} \right] D^j_{i,t},$$

$$V^j_{i,t} = \max_{X^j_{i,t}>0} \ \mathbb{E}_t \left[\exp(b^j_{i,t}) \cdot \left(\frac{R^j_{t+1}}{R_t} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} - 1 \right) \right] X^j_{i,t}. \tag{A.5}$$

Further, assume that banks' face a constraint on the size of their FX exposures only of the form:

$$V^j_{i,t} \geq \Gamma^j_i X^j_{i,t} \cdot X^j_{i,t}. \tag{A.6}$$

Then, banks' optimal USD exposure using asset j has the form:

$$X^j_{i,t} = \frac{1}{\Gamma^j_i} \cdot \mathbb{E}_t \left[\exp(b^j_{i,t}) \cdot \left(\frac{R^j_{t+1}}{R_t} \frac{\mathcal{E}_{t+1}}{\mathcal{E}_t} - 1 \right) \right]. \tag{A.7}$$

Following the same steps outlined in Appendix A.1 gives equation (11) from the main text:

$$\Delta x^j_{i,t} \approx \phi^{j,X}_B \left(\Delta \mathbb{E}_t[r^j_{t+1}] - \Delta r_t + \Delta E_t[e_{t+1}] - \Delta e_t \right) + \Delta b^j_{i,t}. \tag{A.8}$$

B Data Appendix

B.1 Bank-Level Controls

Within our regressions we use size- and/or equal-weighted bank-level controls from our bank-level dataset. These bank-level controls include:

- log(Real Total Assets), deflated by GDP deflator.
- Capital Ratio, defined as each banking organisation's regulatory Tier-1 risk-based capital-to-asset ratio, in percent.
- Liquid-Asset Ratio, defined as the ratio of the banking organisation's liquid assets to total assets, in percent.
- Core Deposits Ratio, defined the ratio of the banking organisation's core deposits to total assets, in percent.
- Commitment share, defined as the ratio of unused commitments to total assets, in percent.
- International share, defined as the ratio of bank's foreign assets to total assets, in percent.

B.2 Macro Controls

Our macro controls include:

- VIX index from *CBOE*.
- 6-month and 10-year government bond yields, in the US and UK, from Gürkaynak et al. (2007) and the Bank of England, respectively.
- Mean survey forecasts for 3-month-ahead GBP/USD exchange rate from *Consensus Economics*.

C Narrative Checks of Granular Instrument

As discussed in Section 4.4.4, we carry out a narrative inspection of our granular instrument series to assess the extent to which the main changes in our GIVs are driven by plausibly exogenous events. In this Appendix, we describe our approach to the narrative checks, including documenting the sources we use to carry out the checks and presenting high-level conclusions from the analysis. Unfortunately, a complete discussion of our findings is precluded by confidentiality restrictions on our data.

To conduct the narrative inspection, we first decompose our granular instrument by bank. An aggregated example of this decomposition is presented in Figure 9. However, within our dataset, we are able to further decompose 'Large Banks', which reflects banks explaining at least one-fifth of a full-sample standard deviation of our GIV, into individual banks (the specific composition of which is confidential). As a consequence, we can see period-by-period which entities accounted for the most substantial moves in the size-minus-equal-weighted instrument.

Having observed which banks explain these large moves in each period, we then conduct a narrative search by manually accessing the Financial Times (FT) archives. We access the FT Historical Archives for the period 1997 to 2016 through the Bank of England Information Centre access to Gale Source.[33] For the 2017-2019 period, we use the FT search function.

For each quarter, we search for news articles pertaining to the specific bank(s) that explain a significant portion of the variation within the period. We use search terms that capture the banks' names, and allow variants thereof. We limit the date-range of each search to the first and last days of each quarter. Having accessed the search results, we then manually read through all relevant articles (excluding advertisements for each bank), and assess whether it is of relevance to the banks' international operations. Since these articles reveal the name of the bank, we cannot share the links.

Nevertheless, to summarise the results of the narrative checks, we manually classify the events that we find into different key terms. These terms are presented visually in a word cloud in Figure C.1. In the cloud, the relative size of the terms denotes the relative frequency with which the terms arise from our narrative checks. Reassuringly, many of key terms pertain to bank-specific features, which are unlikely to be tightly linked to systemic factors, such as the financial cycle. Common terms include those relating to mergers, management changes and fines for the different institutions. In addition, stress-test results and computer failures also show up.

[33] See https://www.gale.com/intl/c/financial-times-historical-archive.

Figure C.1: Key Terms from Narrative Checks of Large-Bank Moves in Granular Instruments

Notes: Key terms from manual narrative checks of granular instruments. Terms come from searching historical Financial Times archives for news stories pertaining to specific banks that drive our granular instrument in each period. Relative size of terms denotes the relative frequency of the key terms in our narrative-check results.

D Additional Empirical Results

Table D.1 presents coefficient estimates from a regression of our net-debt GIV Δz_t^{net} on the VIX index, the global financial cycle factor of Miranda-Agrippino and Rey (2020), and the 6-month US zero-coupon bond rate in levels in Panel A and in changes (log-changes for the VIX) in Panel B. In both cases, we see that these proxies for the global financial cycle enter statistically insigificantly and have no explanatory power (see the adjusted R^2) for our GIV. This stands in contrast to other prominent instruments for capital flows used previously in the literature, as discussed in Aldasoro et al. (2023).

Table D.1: GIV for Net-Debt Flows Not Related to Global Financial Cycle

PANEL A DEP. VAR.: Δz_t^{net}	(1)	(2)	(3)
vix_t	.0001		
	(.0002)		
GFC_t		-.0000	
		(.0000)	
$r^{us}_{6M,t}$			-.0002
			(.0006)
Observations	101	101	101
R^2	0.00	0.00	0.00
PANEL B DEP. VAR.: Δz_t^{net}	**(1)**	**(2)**	**(3)**
Δvix_t	.0003		
	(.0003)		
ΔGFC_t		-.0001	
		(.0001)	
$\Delta r^{us}_{6M,t}$			.0036
			(.0040)
Observations	101	101	101
R^2	0.01	0.02	0.01

Notes: Coefficient estimates from a regression of our net-debt GIV Δz_t^{net} on the VIX index, the global financial cycle factor of Miranda-Agrippino and Rey (2020), and the 6-month US zero-coupon rate in levels (Panel A) and in changes (Panel B), with the VIX index in log-changes. Newey and West (1987) standard errors with 12 lags are in parentheses. Significance at 10%, 5% and 1% denoted by $*$, $**$, and $***$, respectively.

Table D.2 presents the first stage regression results used to compute our estimates for the demand and supply elasticities displayed in Table 2.

Table D.2: 1st Stage Regressions of Exchange Rates on GIV for Net-Flows

PANEL A: 1st Stage for Supply Elasticity (ϕ_R^{net}) DEP. VAR.: Δe_t	
z_t^{net}	0.450**
	(0.197)
Observations	101
1st-Stage F-stat.	34.62
Macro Controls	Yes
Bank Controls	Yes
Components	20
PANEL B: 1st Stage for Demand Elasticity ($-\phi^{net}$) DEP. VAR.: Δe_t	
z_t^{net}	0.416**
	(0.193)
Observations	101
1st-Stage F-stat.	46.75
Macro Controls	Yes
Bank Controls	Yes
Components	20

Notes: PANEL A: Coefficient estimates from 1st stage regression (24). PANEL B: Coefficient estimates from 1st stage regression (25). All regressions estimated with data for 1997Q1-2023Q3. Coefficients on macro and bank controls suppressed for presentational purposes. Bank controls are size-weighted (PANEL A) and equal-weighted (PANEL B). The remaining notes from Table 1 concerning the macro controls, bank controls and principle components apply. Newey and West (1987) standard errors with 12 lags are in parentheses. Significance at 10%, 5% and 1% denoted by $*$, $**$, and $***$, respectively.

Table D.3: UK-Bank Demand Elasticities by Bank Hedging and VIX States

2nd Stage for Demand Elasticity ($-\phi^{net}$) DEP. VAR.: $\Delta q_{E,t}^{net}$	High Bank Hedging and Low VIX	Low Bank Hedging and/or High VIX
Δe_t	-2.38*	-0.52***
	(1.45)	(0.11)
Observations	51	39
1st-Stage F-stat.	7.65	17.90
Macro Controls	No	No
Bank Controls	No	No
Components	20	20

Notes:

Table D.4: UIP

	(1)	(2)
DEP. VAR.: % change UIP ($\Delta\mathbb{E}_t[e_{t+1}] - \Delta e_t + \Delta r_t^{US} - \Delta r_t^{UK}$)		
z_t^{net}	-0.369*	-0.399*
	(0.201)	(0.229)
$z_t^{net} \times Hedge_{S,t-1}$		0.392*
		(0.182)
$z_t^{net} \times Cap_{S,t-1}$		0.009
		(0.212)
$z_t^{net} \times VIX_{t-1}$		-0.429***
		(0.159)
Observations	101	89
Macro Controls	Yes	Yes
Bank Controls	Yes	Yes
Components	20	20
R^2	0.458	0.590

Notes:

Table D.5: UIP2

PANEL A: 2nd Stage for Supply Elasticity (ϕ_R^{net}) DEP. VAR.: $\Delta q_{S,t}^{net}$	
ΔUIP_t	-0.691**
	(0.328)
Observations	101
1st-Stage F-stat.	46.12
Macro Controls	Yes
Bank Controls	Yes
Components	20
PANEL B: 2nd Stage for Demand Elasticity ($-\phi^{net}$) DEP. VAR.: $\Delta q_{E,t}^{net}$	
ΔUIP_t	2.136**
	(0.998)
Observations	101
1st-Stage F-stat.	39.69
Macro Controls	Yes
Bank Controls	Yes
Components	20

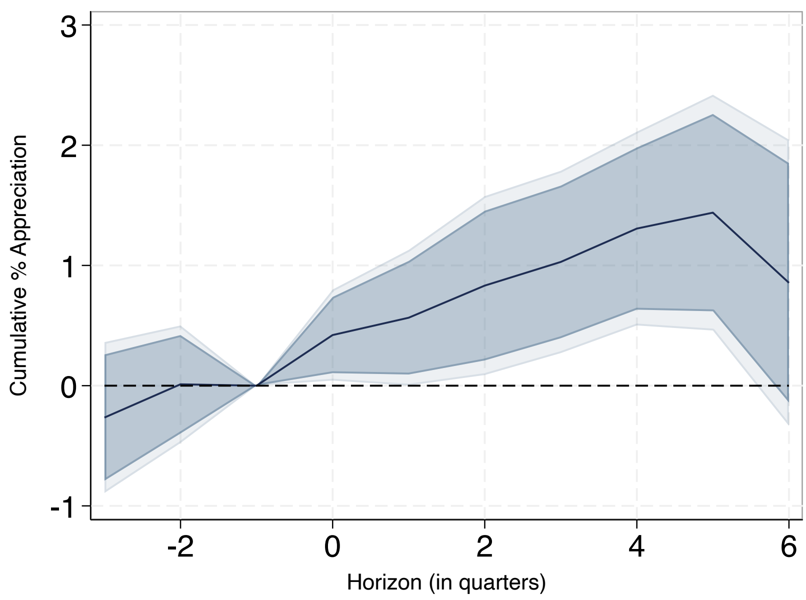
Notes:

Table D.6: Ex-GFC

	(1)	(2)
DEP. VAR.: % change nominal GBP/USD exchange rate (Δe_t)		
z_t^{net}	0.421**	0.412**
	(0.193)	(0.204)
$z_t^{net} \times Hedge_{S,t-1}$		-0.351**
		(0.165)
$z_t^{net} \times Cap_{S,t-1}$		0.080
		(0.200)
$z_t^{net} \times VIX_{t-1}$		0.442***
		(0.154)
Observations	97	85
Macro Controls	Yes	Yes
Bank Controls	Yes	Yes
Components	20	20
R^2	0.617	0.708

Notes:

Figure D.1: Ex-GFC Dynamic



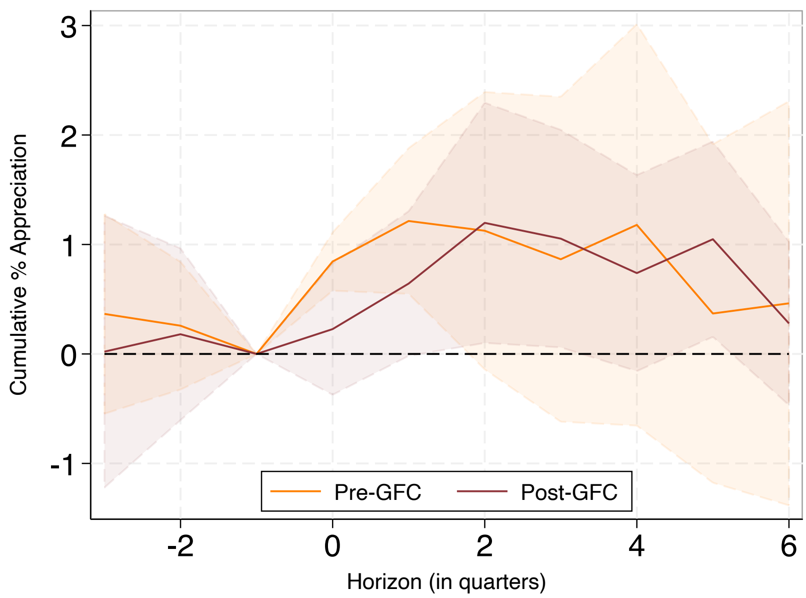
Notes:

Table D.7: Ex-GFC2

PANEL A: 2nd Stage for Supply Elasticity (ϕ_R^{net})	
DEP. VAR.: $\Delta q_{S,t}^{net}$	
Δe_t	0.511**
	(0.255)
Observations	101
1st-Stage F-stat.	44.37
Macro Controls	Yes
Bank Controls	Yes
Components	20
PANEL B: 2nd Stage for Demand Elasticity ($-\phi^{net}$)	
DEP. VAR.: $\Delta q_{E,t}^{net}$	
Δe_t	-1.841***
	(0.687)
Observations	101
1st-Stage F-stat.	44.37
Macro Controls	Yes
Bank Controls	Yes
Components	20

Notes:

Figure D.2: Pre- Post-GFC Dynamic



Notes: