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Global Portfolio Rebalancing and Exchange Rates

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We examine international equity allocations at the fund level and show how excess foreign returns influence portfolio rebalancing, capital flows, and currencies. Our equilibrium model of incomplete foreign exchange (FX) risk trading where exchange rate risk partially segments international equity markets is consistent with the observed dynamics of equity returns, exchange rates, and fund-level capital flows. We document that rebalancing is more intense under higher FX volatility and find heterogeneous rebalancing behavior across different fund characteristics. A granular instrumental variable approach identifies a positive currency supply elasticity. (*JEL* G11, G15, G23)

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Understanding the links between exchange rates and capital flows is a long-standing issue in international economics. This issue is becoming more pressing as gross capital flows have dwarfed trade flows and gross stocks of

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cross-border assets and liabilities have increased dramatically from around 60% of world gross domestic product (GDP) in the mid-1990s to approximately 200% in 2015 (Lane and Milesi-Ferretti 2007).[1] Capital gains and losses on those assets have significant effects on the dynamics of countries' external asset positions. The macroeconomic literature finds that valuation effects induced by asset price changes have become quantitatively large relative to the traditional determinants of the current account.[2] Valuation effects influence the portfolio allocation decisions of investors and may trigger capital flows.[3] Most transactions on the foreign exchange market involve trading of assets rather than goods. Yet, there is surprisingly little systematic documentation about the interaction between exchange rates and trade in assets at the microeconomic level. How do international investors adjust their risk exposure in response to the fluctuations in realized returns they experience on their positions? Do they rebalance their portfolios toward their desired weights, or do they increase their exposure to appreciating assets? What are the consequences of those portfolio decisions for capital flows and exchange rate dynamics?

This paper analyzes time-series variation in international asset allocations of a large cross-section of institutional investors. A distinctive feature of our approach is its microeconomic focus: while international capital flows and returns are two key variables in international macroeconomics, a purely aggregate analysis is plagued by issues of endogeneity, heterogeneity, and statistical power. For example, asset returns may be reasonably exogenous to an individual fund and its allocation decisions, but this is not true at the aggregate level, where capital flows are likely to influence asset and exchange rate returns. Fund heterogeneity can obscure the aggregate dynamics, but can also generate testable predictions on rebalancing behavior at the micro level. We exploit this heterogeneity by constructing a granular instrumental variable following Gabaix and Koijen (2020), and we use idiosyncratic large funds shocks to identify the elasticity of supply of foreign exchange (FX), a key parameter in our model.

To better frame our analysis, we start with a two-country equilibrium model of optimal dynamic portfolio rebalancing and an endogenous exchange rate. There are very few microfounded macroeconomic models of exchange rate

[1] They peaked at slightly more than 200% in 2007, at the eve of the financial crisis. We use the Coordinated Portfolio Investment Survey (CPIS) dataset to estimate the portfolio component of the same statistics: it increased from 43% of world GDP in 2001 to more than 76% in 2015.

[2] For data on the increase of gross assets and liabilities and valuation effects, see Lane and Milesi-Ferretti (2007), Tille (2008), Gourinchas and Rey (2007), and Fratzscher, Juvenal, and Sarno (2010). For a special focus on exchange rate valuations and currency composition of external assets, see Lane and Shambaugh (2010), Della Corte, Sarno, and Sestieri (2012), Benetrix, Lane, and Shambaugh (2015), and Maggiori, Neiman, and Schreger (2020).

[3] Portes and Rey (2005) provide an early study of the geography of capital flows. Lilley et al. (2020) highlight a strong correlation between portfolio flows and exchange rates for the financial crisis period. Stavrakeva and Tang (2018) show how flight to safety and dollar appreciation are intimately linked during the Great Recession.

determination based on capital flows and imperfect financial integration. One prominent exception is Gabaix and Maggiori (2015), who find that exchange rate changes follow from financial flows induced by trade in the segmented goods market and limits to intertemporal FX arbitrage. In their model, the exchange rate is determined by speculators who are the only agents who can hold both countries' debt. Our model builds on that of Hau and Rey (2006), which does not model the goods market, but focuses instead on international trade in assets and its interactions with the foreign exchange market.[4] In this respect, we follow the spirit of portfolio balance models in international finance pioneered by Kouri (1976), Kouri (1983), and Kouri et al. (1978), who model the joint behavior of asset prices (bonds and equity) and of the exchange rate.[5] Our model allows for a joint determination of optimal equity portfolios of domestic and foreign investors and of the exchange rate. This is a crucial difference with Gabaix and Maggiori (2015), who find that demand for foreign exchange is driven solely by goods trade, as their model does not feature endogenous asset trade nor optimal portfolio choice.[6]

Our model has two representative investors (home and foreign) with two distinct stock markets and a local riskless bond in fully price-elastic supply. Differential returns and endogenous exchange rate risk across the two stock markets motivate the rebalancing behavior of the international investors in both countries and simultaneously drive the exchange rate and asset price dynamics in an incomplete market setting. Taking the short term rates as given, we solve jointly for equity prices and the exchange rate using optimal equity demands, two market-clearing conditions for the equity markets, and a market-clearing condition for the exchange rate market, in which net currency demand meets the supply of risk averse foreign exchange arbitrageurs. Our approach is closely related to the recent paper of Koijen and Yogo (2020), who use optimal demand for countries' equity and bonds as well as market-clearing equations for short-term bonds, long-term bonds, and equities to determine asset prices and the exchange rate. They assume that the short-term rate is pinned down by monetary

[4] See Stavrakeva and Tang (2020) for a general equilibrium model taking into account the institutional details of the foreign exchange markets and allowing for deviations from rational expectations using survey data.

[5] See also Branson and Henderson (1985) and Blanchard, Giavazzi, and Sá (2005). These early portfolio balance models are rich in insights, but they lack microfoundations. Empirical testing of the portfolio balance approach, relying on aggregate data, proved difficult (see Frankel (1982a); Frankel (1982b); Rogoff (1984)). Driskill and McCafferty (1980), using a portfolio balance model with sticky prices, distinguish between the effects of real and monetary shocks on exchange rate volatility.

[6] For linearized microfounded dynamic stochastic general equilibrium models of the open economy with optimal portfolio choice, see, for example, Coeurdacier (2009), Devereux and Sutherland (2010), Devereux and Sutherland (2011), and Tille and Van Wincoop (2010). This class of models focuses on goods markets. It has had difficulty matching exchange rate dynamics. Bacchetta and Van Wincoop (2010) model agents who infrequently rebalance their portfolio in an overlapping generations (OLG) setting; Bacchetta, Davenport, and Van Wincoop (Forthcoming) introduce quadratic costs to portfolio adjustments. Sandulescu, Trojani, and Vedolin (2021) link proxies of financial intermediaries' risk-bearing capacity to international SDFs. Some recent papers such as Dou and Verdelhan (2015) seek to model gross capital flows; Caballero and Simsek (2020) and Jeanne and Sandri (2020) rationalize comovements of aggregate gross inflows and outflows via models in which risk diversification, scarcity of domestic safe assets, and the global financial cycle play important roles.

policy. Like us, they also assume that risky asset prices and exchange rates are jointly determined. Importantly, this allows for substitution effects across assets to affect the exchange rate. We build on Koijen and Yogo (2019), who estimate an entire demand system using cross-country aggregate holdings for 36 countries and decompose asset prices in three sources of variation: policy variables, macroeconomic factors, and latent demand. We focus instead on the interaction between equity portfolios and the differential in equity returns at the fund level and use a granular instrumental variable approach to estimate the effect of equity flows on currencies.

A key prediction of our model is that excess returns on the foreign equity market portion of the investor portfolio should be partially repatriated to maintain an optimal trade-off between international asset diversification and exchange rate exposure. The model also predicts that this trade-off is influenced by the level of exchange rate volatility.[7] From a macroeconomic point of view, our model generates home bias as an endogenous outcome and implies that the rebalancing behavior of international equity funds influences the exchange rate. We assume that the theoretical insights of the optimal competitive behavior of the two representative investors carry over to the granular investments of home and foreign equity funds. We use disaggregated fund-level holdings (quarterly frequency) for 7,940 internationally invested equity funds for the period 1999–2015 to test these predictions. The data comprise a total of 101,238 fund-quarters and 28,409,790 individual asset positions worldwide for funds domiciled in four major currency areas: the United States (U.S.), the United Kingdom (U.K.), the Eurozone (EZ), and Canada (CA). We can therefore observe portfolio-rebalancing behavior in a large cross-sectional panel with different investor locations and investment destinations. Our data show a high degree of heterogeneity in the portfolio composition of institutional investors, including significant differences in the degrees of home bias.[8] Importantly, we find strong evidence in favor of portfolio-rebalancing strategies at the fund level aimed at mitigating the risk exposure changes due to asset price and exchange rate changes. The key insights are summarized as follows:

1. At the fund level, we study the dynamics of the foreign value share of the portfolio. A higher equity return on the foreign portfolio share compared to the domestic share triggers capital repatriation, while the underperformance of foreign assets coincides with capital expatriation.
2. A high level of global FX volatility reinforces the rebalancing behavior of international equity funds.

7 Empirically, we also find, in accordance with intuition, that fund-level variables, such as the degree of fund diversification and its rebalancing costs, proxied by fund size, also have an impact on rebalancing behavior.

8 The determinants of home bias and static portfolio allocations have been extensively studied in the literature (see, e.g., the surveys of Lewis (1999) and Coeurdacier and Rey (2013)). For a detailed study of home bias at the fund level, see Hau and Rey (2008).

3. Quantile regressions show that the strength of the rebalancing dynamics is nonlinear in the return difference between a fund's foreign and domestic equity investments. The strength of the rebalancing increases more than proportionately as the performance difference between the foreign and domestic portfolio share increases. Transaction costs are a plausible explanation for this nonlinearity.
4. Stronger fund-level rebalancing is associated with more concentrated investment in fewer stocks, as measured by the Herfindahl-Hirschman index (HHI). Also, smaller funds exhibit stronger rebalancing, which is consistent with the transaction costs of dynamic portfolio adjustments increasing in fund size.
5. Aggregating the foreign equity investments of domestic funds and the domestic equity investments of foreign funds for each currency area, we show that net portfolio equity flows in response to differential equity returns are associated with an appreciation (a depreciation) of the domestic currency for net inflows (net outflows). The granular instrumental variable (GIV) estimator developed by Gabaix and Koijen (2020) allows us to estimate the causal effect of equity flows on exchange rate changes.

These empirical results are consistent with the predictions of our two-country model featuring equity market segmentation and limits to intertemporal FX arbitrage, optimal portfolio choice by mean-variance investors, and an equilibrium determination of the exchange rate. Our empirical study relies on more than 100,000 fund-quarter observations. This is unlike most of the existing empirical literature on capital flows, which uses aggregate data, where correlation evidence between flows and returns is difficult to interpret due to thorny endogeneity issues. Bohn and Tesar (1996) analyze return chasing and portfolio rebalancing in an Intertemporal Capital Asset Pricing Model (ICAPM) framework, while Brennan and Cao (1997) and Albuquerque, Bauer, and Schneider (2007) study the effect of information asymmetries on correlations between international portfolio flows and returns. A few studies have used more granular data. Evans and Lyons (2002) show a tight correlation between order flow and exchange rate. Broner, Gelos, and Reinhart (2006) focus on country allocations of emerging market funds and look at channels of crisis transmission; Raddatz, Schmukler, and Williams (2017) study empirically how capital flows and benchmarking of funds interact. Froot and Ramadorai (2005) explore links between asset prices and equity flows at a more granular level.[9] Our data allow us to get around the endogeneity issues associated with aggregate data because we observe the portfolio of each individual fund manager and estimate the portfolio weight changes induced by past realized valuation

[9] In a closed economy framework, Calvet, Campbell, and Sodini (2009) investigate whether Swedish households adjust their risk exposure in response to the portfolio returns they experience during the period 1999–2002.

changes in our sample of heterogeneous portfolios. Those valuation changes are plausibly exogenous to each fund. Furthermore, we exploit the idiosyncratic rebalancing shocks of the large funds (GIV) to identify the aggregate effects of flows on the exchange rate. Our findings on fund rebalancing can inform a burgeoning theoretical literature in macroeconomics and finance that aims at modeling financial intermediaries.[10]

1. Model

In this section, we outline a model of dynamic portfolio rebalancing in which representative home and foreign investors optimally adjust to the endogenously determined asset prices and exchange rate fluctuations. Both investors behave competitively and are price takers. The exchange rate is determined in equilibrium between the net currency demand from portfolio rebalancing motives and the price-elastic currency supply of a risk-averse global intermediary. The model builds on that of Hau and Rey (2002, 2006).

A key feature of the model is that the exchange rate and investors' rebalancing dynamics are driven by the fundamental value of two dividend processes (in local currency) for home (h) and foreign (f) equity. Innovations in the fundamental value of equity in each country change stock market valuations and trigger a desire for holdings changes because the home and foreign equity markets are segmented by imperfectly traded exchange rate risk. For the home investor, foreign equity is riskier, whereas the opposite is true for the foreign investor. Market incompleteness resides in the realistic feature that exchange rate risk cannot be traded directly and separately between the home and foreign investors. A global intermediary is the only counterparty to the net currency demand of home and foreign equity investors. Asymmetric rebalancing desires of home and foreign investors can generate a high degree of exchange rate volatility.

To give the model a simple structure, we assume that both home and foreign investors maximize an instantaneous and linear trade-off between the expected asset return and its risk. Home and foreign investors choose portfolio weights $H_t = (H_t^h, H_t^f)$ and $H_t^* = (H_t^{h*}, H_t^{f*})$ in equity markets, respectively. The superscripts h and f denote the home and foreign equity markets, and the foreign investors are distinguished by a star ($*$). Alternatively, both investors can invest in a riskless domestic bond at rate r. The bond supply is fully price elastic. Both representative investors solve the optimization problem

$$\begin{aligned} &\max_{H_t^h, H_t^f} \quad \mathcal{E}_t \int_{s=t}^{\infty} e^{-r(s-t)} \left[d\Pi_t - \tfrac{1}{2}\rho d\Pi_t^2 \right] ds \\ &\max_{H_t^{f*}, H_t^{h*}} \ \mathcal{E}_t \int_{s=t}^{\infty} e^{-r(s-t)} \left[d\Pi_t^* - \tfrac{1}{2}\rho d\Pi_t^{*2} \right] ds \end{aligned} \tag{1}$$

[10] See, e.g., Adrian, Etula, and Shin (2015), Vayanos and Woolley (2013), Dziuda and Mondria (2012), Basak and Pavlova (2013), and Bruno and Shin (2014).

where $\mathcal{E}_t$ denotes the expectation for the stochastic profit flow $d\Pi_t$ from t to $t+dt$ and its squared term $d\Pi_t^2$. For instantaneous excess returns $dR_t=(dR_t^h, dR_t^f)^T$ and $dR_t^*=(dR_t^{h*}, dR_t^{f*})^T$ expressed in terms of the currency of home and foreign investors, respectively, we can denote the stochastic profit flows as

$$\begin{aligned} d\Pi_t &= H_t dR_t \\ d\Pi_t^* &= H_t^* dR_t^*, \end{aligned} \tag{2}$$

respectively. The investor risk aversion is denoted by ρ, and the domestic riskless rate is given by r in each country. The linear asset demand functions abstract from intertemporal hedging motives that arise in a more general utility formulation. Investors do not take into account their price impact on asset prices or the exchange rate. The representative home and foreign investors can be thought of as aggregating a unit interval of identical atomistic individual investors without any individual price impact. Normalizing the asset supplies to one, market clearing in the equity market requires:

$$\begin{aligned} H_t^h + H_t^{h*} &= 1 \\ H_t^f + H_t^{f*} &= 1 \end{aligned} \tag{3}$$

Any selling of domestic equity by the foreign investor increases the holdings of the domestic investor. However, these purchases by domestic investors can be financed by the selling of local riskless bonds: they do not require a reduction of his foreign equity holdings. Similarly, the foreign investor may reinvest the proceeds of his equity sales in local riskless bonds and thus rebalance from equity to fixed income. Net equity flows are generally nonzero.

An additional market-clearing condition applies to the foreign exchange market and its exchange rate E_t. Let P_t^h and P_t^{f*} denote the home and foreign stock prices in local stock currency, and D_t^h and D_t^{f*} the corresponding dividend flows, also in local currency. We can measure the equity-related capital outflows dQ_t of the home country (in foreign currency terms) as

$$dQ_t = E_t H_t^{h*} D_t^h dt - H_t^f D_t^{f*} dt + P_t^{f*} dH_t^f - E_t P_t^h dH_t^{h*}. \tag{4}$$

The first two terms represent the outflow if all dividends are repatriated. But investors can also increase their holdings of foreign equity assets. The net capital outflow due to changes in the foreign holdings, dH_t^f and dH_t^{h*}, from t to $t+dt$ are captured by the third and fourth terms. If we denote the Eurozone as the home country, and the United States as the foreign country, then dQ_t represents the net capital outflow out of the Eurozone into the United States in dollar terms. An increase in E_t (denominated in dollars per euro) corresponds to a dollar depreciation against the euro. Capital outflows are identical to a net demand in foreign currency, as all investments are assumed to occur in the local currency.

The net demand for currency is met by a risk-averse global arbitrageur with a price-elastic excess supply curve with a supply elasticity parameter $\kappa > 0$.

For an equilibrium exchange rate E_t, the excess supply of foreign exchange is given by

$$Q_t^S = -\kappa(E_t - \overline{E}), \tag{5}$$

where $\overline{E}=1$ denotes the steady-state exchange rate level around which the exchange rate is mean reverting. An increase in E_t (dollar depreciation) decreases the excess supply of dollar balances. Currency speculators tend to sell dollars for euros if the dollar is expensive and buy dollars if it is cheap. The parameter κ reflects their risk aversion or their capital constraints. The reduced-form assumption in Equation (5) could be generalized to account for interest rate differentials by adding a foreign currency supply component that increases in the differences between the home and foreign (riskless) interest rates (i.e., a term $\kappa_2(r-r^*)$ with $\kappa_2>0$). We assume a zero interest rate differential ($r=r^*$) for simplicity. A higher exchange rate level $E_t>1$ generates a risky arbitrage opportunity if the expected long-run exchange rate is $\mathcal{E}_t(E_{t+h})\approx 1$ (for large h). In other words, risky arbitrage by bond investors with respect to uncovered interest parity violations also provides a justification for the reduced-form assumption in Equation (5). Lastly, we can relate the foreign currency supply to trade flows. Most macroeconomic models incorporate short-run nominal price rigidities, and a (nominal) dollar depreciation (i.e., a higher E_t) tends to decrease the foreign (dollar) currency supply through a foreign (U.S.) trade surplus. At a longer horizon, the parameter κ could also depend on the elasticity of substitution between domestic and foreign goods and the degree of nominal rigidity in the goods markets.

Combining Equations (4) and (5), and putting aside net dividend income $NDI_t = E_t H_t^{h*} D_t^h - H_t^f D_t^{f*}$, it follows that the foreign exchange rate appreciation $-dE_t$ (or home currency depreciation) is proportional to the foreign holding changes dH_t^f by domestic funds minus the domestic holding changes dH_t^{h*} of foreign funds as

$$-\kappa dE_t = NDI_t dt + P_t^{f*} dH_t^f - E_t P_t^h dH_t^{h*}. \tag{6}$$

In Section 4 of the paper, we explore this aggregate relationship empirically.[11] Before we can solve this simple model, two more assumptions are needed. First, we have to specify the exogenous dividend dynamics in local currency. For tractability, we assume two independent Ornstein-Uhlenbeck processes with identical variance and mean reversion to a steady-state value $\overline{D}$; hence,

$$\begin{aligned} dD_t^h &= \alpha_D(\overline{D}-D_t^h)dt + \sigma_D dw_t^h \\ dD_t^{f*} &= \alpha_D(\overline{D}-D_t^{f*})dt + \sigma_D dw_t^{f*}. \end{aligned} \tag{7}$$

We note that the model dynamics are invariant to the particular payout policy of firms as long as investors can reinvest dividend payouts instantaneously

[11] The active rebalancing of bond funds could induce additional confounding currency demands ignored in our model. However, bond investments are usually hedged in derivative markets, which mutes their effect on exchange rates.

so that share-buybacks and reinvestments imply the same investment positions. Second, we linearize Equation (4) as well as the foreign excess return expressed in the home currency. The model features a unique equilibrium for the joint equity price, exchange rate, and portfolio holding dynamics under these linearizations and reasonable parameter values.[12]

1.1 Model solution

The linearized version of the model defines a system of linear stochastic differential equations in seven endogenous variables—namely, the home and foreign asset prices P_t^h and P_t^{f*}, the exchange rate E_t, and the home and foreign equity holdings of both investors $H_t=(H_t^h, H_t^f)$ and $H_t^*=(H_t^{f*}, H_t^{h*})$, respectively. These seven variables are functions of past and current stochastic innovations dw_t^h and dw_t^f of the dividend processes. To characterize the equilibrium, it is useful to define a few auxiliary variables. We denote the fundamental value of equity as the expected present value of future discounted local currency dividends given by

$$\begin{aligned} F_t^h &= \mathcal{E}_t \int_{s=t}^{\infty} D_t^h e^{-r(s-t)} ds &= f_0 + f_D D_t^h \\ F_t^{f*} &= \mathcal{E}_t \int_{s=t}^{\infty} D_t^{f*} e^{-r(s-t)} ds &= f_0 + f_D D_t^{f*}, \end{aligned} \tag{8}$$

with constant terms defined as $f_D = 1/(\alpha_D + r)$ and $f_0 = (r^{-1} - f_D)\overline{D}$. Investor risk aversion and market incompleteness with respect to exchange rate risk trading imply that asset prices generally deviate from this fundamental value. We define two variables Δ_t and Λ_t that embody the asset price dynamics around the fundamental value—that is,

$$\Delta_t = \int_{-\infty}^{t} \exp[-\alpha_D(t-s)]\sigma_D dw_s \quad \text{and} \quad \Lambda_t = \int_{-\infty}^{t} \exp[-\alpha_\Lambda(t-s)] dw_s, \tag{9}$$

where $dw_s = dw_t^h - dw_t^{f*}$ and $\alpha_\Lambda > 0$. The variable $\Delta_t = D_t^h - D_t^{f*}$ simply represents the difference in the dividend level between the home and foreign equity markets, whereas Λ_t aggregates past dividend innovations with a different decay factor α_Λ.[13]

We are interested in an equilibrium for which both the home and foreign investors hold positive (steady-state) amounts of home and foreign equity. For such an equilibrium to exist, we impose a lower bound on the elasticity of currency ($\kappa > \underline{\kappa}$) and an upper bound on investor risk aversion ($\rho < \overline{\rho}$). Under these conditions, the following unique equilibrium exists:

[12] More precisely, the risk aversion of the investors needs to be sufficiently low and the currency supply by the global intermediary sufficiently elastic to maintain an equilibrium where investors diversify their portfolios internationally. Otherwise, we revert to a corner solution of domestic investment only.

[13] We note that the variance of the process Λ_t can be normalized without loss of generality as parameters p_Λ and e_Λ in Proposition 1 (defined later) already scale the variance of the process.

Proposition 1 (Portfolio Rebalancing Equilibrium). The unique equilibrium for the linearized model features asset prices (expressed in local currency) and an exchange rate characterized by

$$P_t^h = p_0 + F_t^h + p_\Delta \Delta_t + p_\Lambda \Lambda_t \tag{10}$$

$$P_t^{f*} = p_0 + F_t^{f*} - p_\Delta \Delta_t - p_\Lambda \Lambda_t \tag{11}$$

$$E_t = 1 + e_\Delta \Delta_t + e_\Lambda \Lambda_t \tag{12}$$

and dynamic portfolio holdings

$$\begin{pmatrix} H_t^h & H_t^f \\ H_t^{f*} & H_t^{h*} \end{pmatrix} = \begin{pmatrix} 1-\overline{H} & \overline{H} \\ 1-\overline{H} & \overline{H} \end{pmatrix} + \begin{pmatrix} -1 & -1 \\ 1 & 1 \end{pmatrix} \frac{1}{2\rho}(m_\Delta \Delta_t + m_\Lambda \Lambda_t), \tag{13}$$

where $0 < \overline{H} \leq 0.5$ denotes the steady-state holding of foreign assets and the coefficients $p_0 < 0$, p_Δ, p_Λ, e_Δ, e_Λ, m_Δ, and m_Λ are defined implicitly by the first-order and market-clearing conditions stated in Appendix A. These parameters are functions of the six exogenous parameters α_D, σ_D, $\overline{D}$, r, κ, and ρ.

Proof. See Appendix A. ∎

The home and foreign equity prices in Equations (10–11) deviate from their fundamental values F_t^h and F_t^{f*}, and a constant risk premium $p_0 < 0$ by the additional stochastic term $p_\Delta \Delta_t + p_\Lambda \Lambda_t$, which moves the respective home and foreign asset prices in opposite directions. Under market incompleteness and limited international risk sharing, asset prices deviate from their fundamental values. The same stochastic processes Δ_t and Λ_t composed of past dividend innovations also drive the exchange rate in Equation (12) and the asset rebalancing dynamics in Equation (13). The second 2×2 matrix in Equation (13) describes the steady-state equity holdings with the endogenous home bias $1 - \overline{H} > 0.5$;[14] the third term in Equation (13) characterizes the dynamic adjustment of the equity portfolios. As the diagonal elements add up to unity, market-clearing is trivially assured. Each representative investor adjusts his home and foreign equity positions by the same increment $\frac{1}{2\rho}(m_\Delta d\Delta_t + m_\Lambda d\Lambda_t)$, but in the opposite direction of each other, which means that their rebalancing from equity into the local riskless asset occurs in opposite directions.

Limited currency supply elasticity plays a crucial role in the equilibrium. To appreciate this aspect, consider the limit case of an infinitely price elastic foreign currency supply with $\kappa \to \infty$. In this special case, all exchange rate

[14] For a model in which infrequent portfolio adjustment and exchange rate volatility generate home bias, see Lee (2021).

volatility disappears ($E_t = 1$) as $e_\Delta \rightarrow 0$, and $e_\Lambda \rightarrow 0$. Moreover, the home and foreign asset prices converge to $P_t^h = p_0 + F_t^h$ and $P_t^{f*} = p_0 + F_t^{f*}$, respectively, as $p_\Delta \rightarrow 0$, and $p_\Lambda \rightarrow 0$. The limit case features perfect global risk sharing with both home and foreign investors holding half of the equity risk in each market; thus, $\overline{H} \rightarrow 0.5$ and $m_\Delta \rightarrow 0$, $m_\Lambda \rightarrow 0$. Both equity prices are then determined only by their domestic fundamentals.

1.2 Model implications for rebalancing

The model solution in Proposition 1 implies a unique covariance structure for the joint dynamics of international equity holdings, equity returns, and exchange rate. In this section, we highlight the empirical implications and outline the empirical strategy for testing the model predictions.

Corollary 1 (Rebalancing and Equity Return Differences). The domestic investor rebalances her foreign investment portfolio toward home country equity if the return on her foreign equity holdings exceeds the return on her home equity investments. Formally, the foreign equity holding change dH_t^f and the excess return of the foreign equity over home equity $dr_t^f - dr_t^h = (dR_t^f - dR_t^h)/\overline{P}$ expressed in domestic currency feature a negative covariance given by

$$Cov(dH_t^f, dr_t^f - dr_t^h)$$
$$= \kappa \frac{1}{\overline{P}} \left[\frac{1}{\overline{P}} f_D \sigma_D + 2 p_\Delta \sigma_D + 2 p_\Lambda + e_\Delta \sigma_D + e_\Lambda \right] (e_\Delta \sigma_D + e_\Lambda) dt < 0 \qquad (14)$$

Proof. See Appendix A. ■

Corollary 1 characterizes the rebalancing behavior dH_t^f in foreign equity by the representative home investor under the assumption of competitive price-taking behavior. Undertaking the regression analysis at the fund level considerably increases the statistical power of any test. We measure the fund-specific foreign excess return $r_{j,t}^f - r_{j,t}^h$, which can feature cross-sectional heterogeneity if, for example, individual investment strategies deviate from the representative holdings due to fund-specific beliefs about future stock returns. We pursue this analysis in Section 3.1 based on a linear regression model where we regress fund j rebalancing $\Delta h_{j,t}^f$ on its fund-specific return differential $(r_{j,t}^f - r_{j,t}^h)$ controlling for country-time $\eta_{c,t}$ and fund fixed effects ε_j ($\mu_{j,t}$ is the error term).

$$\Delta h_{j,t}^f = \beta (r_{j,t}^f - r_{j,t}^h) + \varepsilon_j + \eta_{c,t} + \mu_{j,t} \qquad (15)$$

Our theory predicts a rebalancing coefficient $\beta < 0$.

1.3 Comparative statics FX supply elasticity

The model yields additional insights into the level of FX volatility under different parameter conditions. We can derive the instantaneous volatility as

$$Vol^{FX} = \sqrt{\frac{\mathcal{E}_t(dE)^2}{dt}} = \sqrt{2}|e_\Delta \sigma_D + e_\Lambda|. \quad (16)$$

Figure 1, panel A, plots the instantaneous volatility Vol^{FX} for varying scaled FX supply elasticities $\frac{\kappa}{PH} \in [10, 200]$ (corresponding to $\kappa \in [100, 5000]$). We use a risk aversion $\rho = 0.02$, and the parameters of the dividend process are set at $\overline{D} = 1, r = 0.04$, $\alpha_D = 0.015$. We show the results for four different levels of stock market volatility $\sigma_D \in [0.15, 0.2, 0.25, 0.3]$. For any given level of stock market volatility σ_D and risk aversion ρ, a lower FX supply elasticity κ implies a larger level of FX volatility, as capital flows have an increasing impact on the FX price. A lower FX market liquidity due to a decrease in available arbitrage capital at dealer banks, for example, can thus generate a higher level of FX volatility and increase the degree of equity market segmentation. We note for the empirical section that our model can generate observable levels of FX volatility if the (scaled) currency supply elasticity $\frac{\kappa}{PH}$ drops below a value of 20.

Our model does not feature any dynamic time variation in the parameter κ. Any such time variation—either deterministic or stochastic—implies that all the variance and covariance parameters of the rebalancing flows, the stock prices, and the exchange rate also become time dependent. Such an extended model is beyond the scope of this paper. But, we can nevertheless point out the results of a simple comparative statics exercise in the parameter κ for the homoscedastic model. This solution describes a good approximation to a heteroscedastic model if the transition dynamics between different levels of volatility is slow relative to the dividend dynamics governing the system.[15]

Corollary 2 (Comparative Statics in FX Supply Elasticity). The home investor rebalances the foreign investment portfolio toward the home country more strongly under higher foreign excess return $dr_t^f - dr_t^h$ if the level of FX volatility is larger due to a lower elasticity parameter κ. Formally, the rebalancing coefficient β decreases in FX volatility, that is,[16]

$$\frac{d\beta}{dVol^{FX}} < 0, \quad \text{where } \beta = \frac{Cov\left[dH_t^f, dr_t^f - dr_t^h\right]}{Var\left[dr_t^f - dr_t^h\right]}. \quad (17)$$

Numerical simulation. See Appendix A.

Figure 1, panel B, plots the rebalancing coefficient β as a function of the instantaneous FX volatility for variations of the supply elasticity parameter

15 The effect of changing volatility levels on the equilibrium characteristics tends to be small if changes in $\kappa(t)$ occur slowly relative to the short (myopic) horizon of the investors.

16 We compute β in Appendix A.

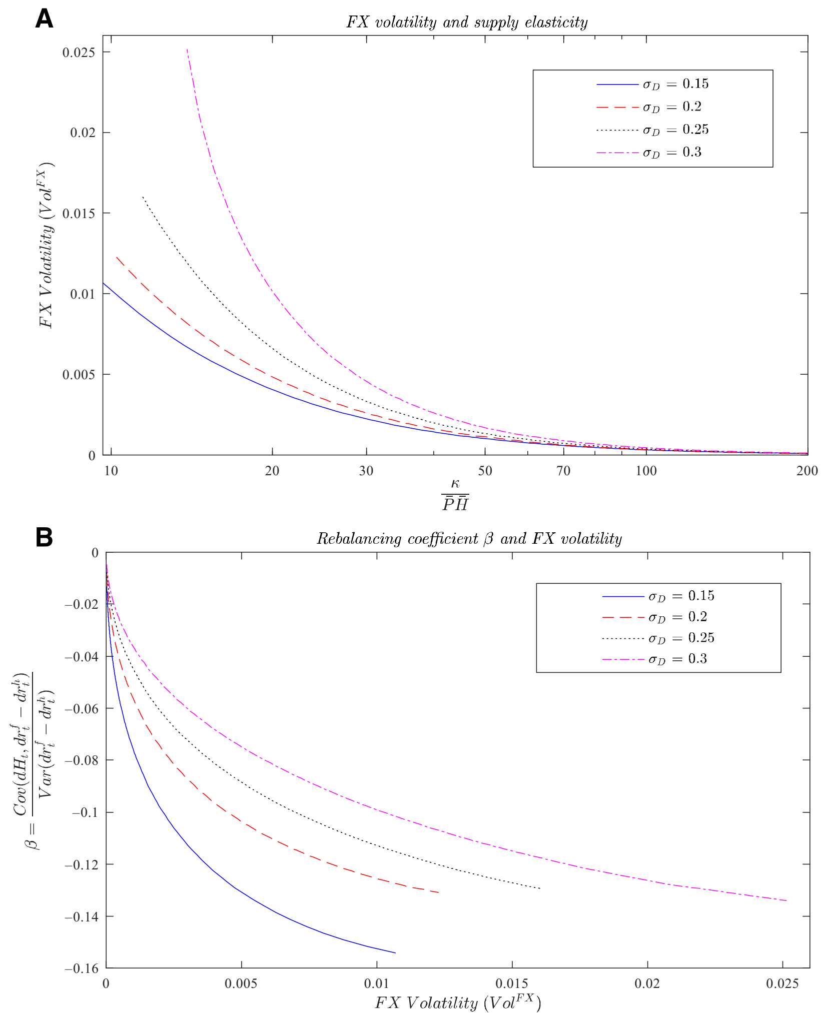

Figure 1
FX volatility and rebalancing as a function of the supply elasticities and stock volatility
In panel A, we plot FX volatility as a function of the scaled supply elasticity parameter $\frac{\kappa}{\overline{PH}}$ for different stock volatility values $\sigma_D \in \{0.15, 0.20, 0.25, 0.30\}$ and the parameter range $\kappa \in [100, 5000]$. In panel B, we plot the rebalancing coefficient $\beta = \frac{Cov(H_t^f, dr_t^f - dr_t^h)}{Var(dr_t^f - dr_t^h)}$ as a function of FX volatility for different stock volatility values $\sigma_D \in \{0.15, 0.20, 0.25, 0.30\}$. For both panels, we use parameters $\rho = 0.02$, $r = 0.04$, $\alpha_D = 0.015$, and $\overline{D} = 1$.

$\kappa \in [100, 5000]$. Lower supply elasticities—equivalent to higher FX volatility in panel B—imply ceteris paribus a higher FX volatility level and a more negative rebalancing coefficient. In other words, we predict more intense rebalancing under higher FX volatility. We show the results for four different levels of stock market volatility $\sigma_D \in [0.15, 0.2, 0.25, 0.3]$.

Corollary 2 suggests that episodes of higher FX volatility should coincide with a stronger and more negative rebalancing coefficient β. We can explore this prediction at the fund level by regressing foreign holding changes $\Delta h^f_{j,t}$ over period t of fund j on the interaction terms $(r^f_{j,t} - r^h_{j,t}) \times Vol^{FX}_t$ between a fund foreign excess return $r^f_{j,t} - r^h_{j,t}$ and the the level of FX volatility Vol^{FX}_t. Controlling for fund fixed effects and time-country fixed effects, we expect the linear regression

$$\Delta h^f_{j,t} = \beta(r^f_{j,t} - r^h_{j,t}) + \gamma Vol^{FX}_t + \delta(r^f_{j,t} - r^h_{j,t}) \times Vol^{FX}_t + \varepsilon_j + \eta_{c,t} + \mu_{j,t} \qquad (18)$$

to yield a negative rebalancing/volatility interaction coefficient $\delta < 0$. In other words, rebalancing toward home equity increases in periods of higher FX volatility. Intuitively, higher exchange rate volatility renders foreign equity positions more risky in domestic currency terms and strengthens the profit repatriation motive for any foreign excess return. We pursue this analysis in Section 3.2.

2. Data

For data on global equity holdings, we use FactSet/LionShares.[17] The data report individual mutual fund and other institutional holdings at the stock level. For investors in the United States, the data are collected by the Securities and Exchange Commission (SEC) based on 13-F filings (fund family level) and N-SAR filings (individual fund level). Outside the United States, the sources are national regulatory agencies, fund associations, and fund management companies. The sample period covers the 17 years from 1999 to 2015 and has therefore not only a large cross-sectional coverage, but also a reasonably long time dimension to investigate portfolio dynamics.[18]

The FactSet/LionShares dataset comprises fund identifier, stock identifier, country code of the fund incorporation, management company name, stock position (number of stocks held), reporting dates for which holding data are available, and security prices on the reporting date. We complement these data with the total return index (including the reinvested dividends) in local currency for each stock using CRSP (for U.S./Canadian stocks) and Datastream (for

[17] Ferreira and Matos (2008) examine the representativeness of the FactSet/LionShares dataset, by comparing the cross-border equity holdings in it with the aggregate cross-country holdings data of the Coordinated Portfolio Investment Survey (CPIS) of the IMF. The CPIS data have been systematically collected since 2001 and constitute the best measures of aggregate cross-country asset holdings. The values reported in FactSet are lower than those in the CPIS but still representative of foreign equity positions in the world economy.

[18] Other papers use disaggregated data on international institutional investors holdings, albeit with a different focus. Chan, Covrig, and Ng (2005) look at the determinants of static allocations at the country level. The high-frequency study by Froot, O'Connell, and Seasholes (2001) is based on the transaction data of one global custodian (State Street Bank & Trust). The authors look at the effect of aggregate cross-country flows on MSCI country returns. For a high-frequency study linking exchange rates to aggregated institutional investors flows using State Street Bank & Trust data, see Froot and Ramadorai (2005). Our study focuses on a different time scale (quarterly instead of daily) and uses a whole cross-section of fund-specific investment decisions and stock-level data.

non-U.S./non-Canadian stocks). Most funds report quarterly, which suggests that the analysis is best carried out at a quarterly frequency. Reporting dates differ somewhat, but more than 90% of the reporting occurs in the last 30 days of each quarter. A limitation of the data is that they do not include any information on a fund's cash holdings, financial leverage, investments in fixed income instruments, or investments in derivative contracts. All the portfolio characteristics we calculate therefore concern only the equity proportion of a fund's investment. We believe that missing cash holdings in home currency or financial leverage is not a major concern for our analysis, since (positive or negative) leverage simply implies a scaling of the absolute risk by a leverage factor. All our analysis is based on portfolio shares and therefore not affected by constant leverage or time variations in leverage, as long as these are independent of the excess return on foreign assets.[19] A more serious concern is that funds may carry out additional hedging operations that escape our inference. However, as documented in previous surveys (Levich, Hayt, and Ripston (1998)), most equity funds do not engage in any derivative trading, and their equity position may therefore represent an accurate representation of their risk-taking. We also note that any additional hedging is likely to attenuate rebalancing and therefore bias the predicted negative correlation toward zero.

We focus our analysis on funds domiciled in four geographic regions—namely, the United States (U.S.), the United Kingdom (U.K.), the Eurozone, and Canada.[20] These fund locations represent 92% of all quarterly fund reports in our data and constitute 97% of all reported positions by value. Funds in the Eurozone are pooled because of their common currency after 1999. To reduce data outliers and limit the role of reporting errors, a number of data filters are employed:

- We retain holding data only from the last reporting date of a fund in each quarter. A fund has to feature in two consecutive quarters to be retained. Consecutive reporting dates are a prerequisite for the dynamic inference in this paper. Our sample starts at the first quarter of 1999.
- Funds are retained if their total asset holding exceeds \$10 million. Smaller funds might represent incubator funds and other nonrepresentative entities.
- We retain only international funds that hold at least five stocks in the domestic currency and at least five stocks in another currency area. This excludes all fund-quarters with fewer than 10 stock positions and also funds with only domestic or only international positions. Our focus on international rebalancing between foreign and domestic stocks

19 This argument is only valid for home currency cash and cannot be maintained if cash is held in foreign currency. In the latter case, the exchange rate risk alters the risk features of the portfolio.

20 The Eurozone countries included in the sample are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain.

renders funds with a narrow foreign or domestic investment mandate less interesting.

- Nondiversified funds with extreme investment biases in very few stocks are also ignored. We consider a fund diversified if fund stock weights produce a Herfindahl-Hirschman index below 20%.
- We discard funds if their returns on combined equity holdings exceed 200% or if they lose more than 50% of their equity holdings value over a quarter. Individual stock observations are ignored if they feature extreme quarterly returns that exceed 500% or are below −80%.[21]
- We trim the percentage fund rebalancing statistics at the 2.5^{th} and 97.5^{th} percentiles.[22]

In Table 1, panel A, we report summary statistics on fund holdings at the fund-quarter level for the sample period 1999–2015. An international fund has on average $1 billion in total equity assets, out of which $677 million is invested in home equity and $325 million in foreign equity. The data on internationally invested funds show a modest home bias, as the average domestic share of a fund portfolio is 54.0%. While the average quarterly rebalancing between foreign and domestic equity investments is small at 0.064%, its standard deviation is substantial at 4.6% of the total (equity) value of the portfolio. The number of international funds in the raw sample increases steadily over time from only 167 funds reporting at the end of 1999 to 5,683 funds reporting at the end of 2014. While the European fund sample comprises a larger number of fund periods and stock positions than the U.S. fund sample, the latter amounts to a larger aggregate value throughout the sample period. For example, at the end of 2006, we count 889 (international) equity funds domiciled in the United States with a total of 156,086 stock positions valued at $1,690 billion. For the same quarter, the European equity fund sample comprises 2,744 funds with a total of 293,718 stock positions and an aggregate value of $732 billion. Table 1, panel B, presents the aggregate statistics at the quarterly level. The variables are the (effective) exchange rate change of currency area c relative to the 10 other most important investment destinations, the aggregate rebalancing $\Delta H^{f}_{c,t}$ from home to foreign investments for all funds domiciled within currency area c, and the reciprocal aggregate rebalancing $\Delta H^{h*}_{c,t}$ into currency area c for funds domiciled outside currency area c. It also reports the summary statistics for the FX volatility variable and for the granular instrumental variables used to identify the causal effect of portfolio flows on the exchange rate in Section 4.

21 We discard very few observations this way. Extreme return values may be attributable to data errors.

22 Extreme rebalancing is concentrated in very small equity funds, and its trimming has only a small impact on aggregate portfolio flows. We check robustness of our results using alternative trimming assumptions.

Table 1
Summary statistics

		Obs.	Mean	STD	Min	10th	50th	90th	Max
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
A. Pooled fund-level statistics									
Fund assets	Mio USD	101,238	1,002	4,794	10	19	130	1,489	145,289
Fund assets at home	Mio USD	101,238	677	3,679	0	7	53	902	109,235
Fund assets abroad	Mio USD	101,238	325	1,966	0	6	45	489	122,816
Home asset share	w_j^h	101,238	0.540	0.290	0.000	0.123	0.546	0.932	1.000
Foreign asset share	w_j^f	101,238	0.460	0.290	0.000	0.068	0.454	0.877	1.000
Fund rebalancing	$\Delta h_{j,t}^f$	101,238	0.064	4.557	−89.015	−3.495	0.017	3.686	72.833
Excess returns (expressed in the fund domicile currency)									
$r_{j,t}^f - r_{j,t}^h$	(quarterly)	101,238	−0.001	0.070	−0.554	−0.082	−0.002	0.082	0.766
$(r_{j,t}^f - r_{j,t}^h) \times 1_{<0}$	(quarterly)	101,238	−0.026	0.041	−0.554	−0.082	−0.002	0.000	0.000
$(r_{j,t}^f - r_{j,t}^h) \times 1_{\geq 0}$	(quarterly)	101,238	0.026	0.043	0.000	0.000	0.000	0.082	0.766
B. Aggregate statistics									
Exchange rate change	$\Delta E_{c,t}$	143	0.001	0.036	−0.082	−0.045	−0.004	0.047	0.102
Observed rebalancing									
All fund in c	$\Delta H_{c,t}^f$	143	−0.024	0.582	−2.270	−0.749	−0.052	0.571	2.230
All funds outside c	$\Delta H_{c,t}^{h*}$	143	−0.081	0.549	−3.840	−0.630	−0.026	0.419	1.380
Net flows	$\Delta H_{c,t}^{Net}$	143	0.070	0.813	−1.910	−0.768	0.017	0.920	5.500
FX volatility	$Vol_{c,t}^{FX}$	259	4.050	1.730	1.560	2.440	3.690	5.940	16.200
GIV1	$z_{c,t}$	143	−0.015	0.448	−1.330	−0.455	−0.016	0.486	2.230
GIV2	$z_{c,t}$	143	0.102	0.446	−1.122	−0.346	0.085	0.573	2.248

We use the FactSet dataset (available at WRDS) to calculate in panel A fund-level statistics for 101,238 fund-quarter observations for the period 1999–2015. We consider all funds domiciled in four different currency areas c—namely, the United States, the United Kingdom, the Eurozone, and Canada. Reported are total fund assets, the fund assets invested in equity at home (h) (i.e., the fund domicile) and in any foreign country (f) (i.e., anywhere outside the fund domicile), respectively; the portfolio shares held in the home (w_j^h) and foreign country (w_j^f) equity, respectively; the active equity rebalancing ($\Delta h_{j,t}^f$) in quarter t of the foreign investment share toward the home country by fund j domiciled in c (scaled by the factor of 100); the fund-level excess returns on foreign minus home-country investment positions ($r_{j,t}^f - r_{j,t}^h$) (expressed in fund domicile currency) in quarter t; and the positive ($\times 1_{\geq 0}$) or negative ($\times 1_{<0}$) component of these foreign excess returns. Panel B provides aggregate summary statistics for the four currency areas. The effective quarterly home currency appreciation ($\Delta E_{c,t}$) of currency area c is based on weights calculated from the aggregate foreign investment position of domestic funds in the 10 most important foreign investment destinations. The aggregate rebalancing flows $\Delta H_{c,t}^f$ ($\Delta H_{c,t}^{h*}$) measure the aggregate change in foreign (domestic) investment positions held by all domestic (foreign) equity funds domiciled in (outside) currency area c. The aggregate net equity flows $H_{c,t}^{Net} = 2\mu_{c,t-1}\Delta H_{c,t}^f - 2(1-\mu_{c,t-1})\Delta H_{c,t}^{h*}$ are calculated based on the ratio $\mu_{c,t-1}$ of aggregate outbound equity holdings relative to the sum of outbound and inbound equity holdings. We denote $Vol_{c,t}^{FX}$ the quarterly realized volatility of the effective exchange rate in currency c. Following Gabaix and Koijen (2020), we report in the last three rows different "granular instrument variables" defined as either the fund-size weighted net equity flows minus equally weighted net flows (GIV1), or fund-size weighted filtered net flows minus equally weighted filtered net flows (GIV2).

3. Evidence on Portfolio Rebalancing

The model in Section 1 illustrates that imperfect exchange rate risk trading can generate exchange rate volatility that segments the foreign and domestic equity markets. The foreign investment component of an international portfolio is exposed to additional exchange rate risk and generates a rebalancing motive whenever its value grows relative to the domestic equity share in the portfolio. Such differential exposure to exchange rate risk implies that equity investments are repatriated to the home country whenever the foreign equity market outperforms the domestic market. The rebalancing behavior reflects the investor's desire to partly offset exogenous changes in exchange rate risk exposure. These rebalancing flows in turn create a feedback effect on exchange rate volatility. The repatriated equity investments lead to appreciation of the domestic currency. We explore the role of FX volatility in Section 3.2, plausible nonlinearities in rebalancing in Section 3.3, and the role of fund heterogeneity in Section 3.4. Our fund-level rebalancing variable $\Delta h^f_{j,t}$ compares the observed foreign equity weights $w^f_{j,t}$ of fund j at the end of period (quarter) t to the implied weights $\widehat{w}^f_{j,t}$ from a simple holding strategy that does not engage in any buy or sell activity with respect to foreign equity investment. Formally, we define rebalancing of foreign asset holdings as any deviation from the simple holding strategy given by

$$\Delta h^f_{j,t} = w^f_{j,t} - \widehat{w}^f_{j,t} \qquad \text{with} \qquad \widehat{w}^f_{j,t} = w^f_{j,t-1}\left[\frac{1+r^f_{j,t}}{1+r^P_{j,t}}\right], \tag{19}$$

where $r^P_{j,t}$ represents the total portfolio return and $r^f_{j,t}$ the return on the foreign component of the portfolio of fund j between dates $t-1$ and t, all expressed in the currency of the fund domicile. Furthermore,

$$w^f_{j,t} = \sum_{s=1}^{N_j} 1_{s=f} \times w_{s,j,t}, \tag{20}$$

where $1_{s=f}$ is a dummy variable that is 1 if stock s is a foreign stock and 0 otherwise.

Figure 2 illustrates the distribution of the rebalancing measure for each of the four fund domiciles. We graph the realized foreign portfolio share $w^f_{j,t}$ of each fund on the y-axis against the implied share $\widehat{w}^f_{j,t}$ under a passive holding strategy on the x-axis. The dispersion of points along the 45-degree line shows the difference in the foreign investment share across funds in the different domiciles. The vertical distance of any fund observation from the 45-degree line measures active portfolio rebalancing of foreign asset holdings $\Delta h^f_{j,t} = w^f_{j,t} - \widehat{w}^f_{j,t}$ in percent of total assets for the respective fund. Fund rebalancing at the quarterly frequency has a standard deviation of 4.6% for the full sample of 101,238 fund periods, as stated in Table 1. It is highest for Eurozone funds at 5.2% and lowest for the U.K. and U.S. funds at 3.9% and 3.8%, respectively. We also highlight a larger average foreign investment share for U.K. funds and the stronger home bias for U.S. funds. By contrast, the Eurozone fund sample is more uniformly distributed in terms of its foreign investment share.

The total portfolio return $r^P_{j,t}$ on fund j is defined as

$$r^P_{j,t} = \sum_{s=1}^{N_j} w_{s,j,t-1} r_{s,t}, \tag{21}$$

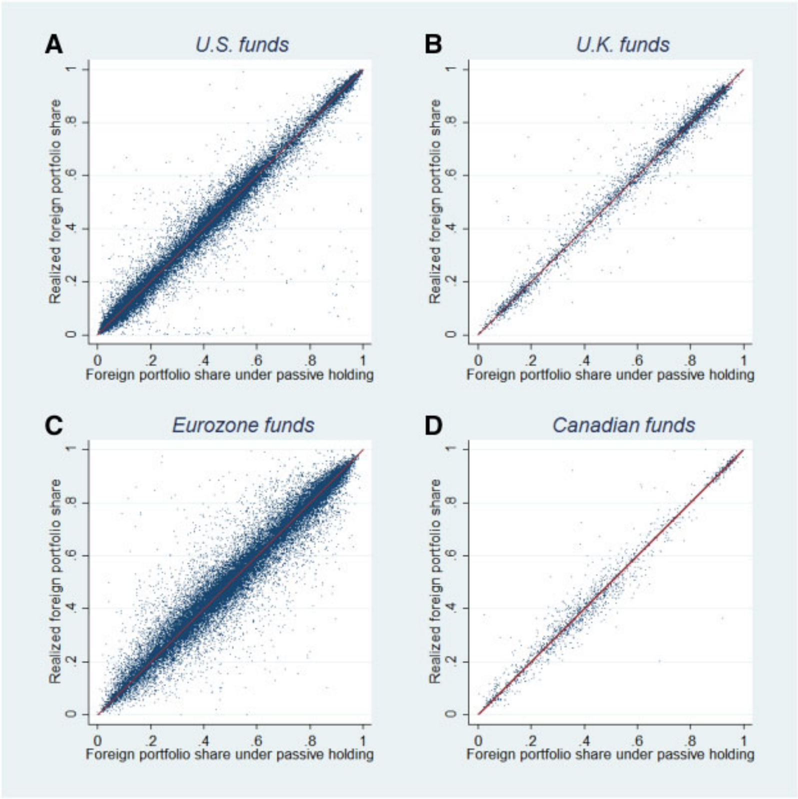

Figure 2
Active rebalancing
We plot the realized foreign portfolio share $w^f_{j,t}$ (y-axis) relative to the portfolio share implied by a passive holding strategy $\widehat{w}^f_{j,t}$ (x-axis) of funds domiciled in the United States (panel A), the United Kingdom. (panel B), the Eurozone (panel C), and Canada (panel D). The vertical distance to the 45-degree line is proportional to the active rebalancing measure $\Delta h^f_{j,t} = w^f_{j,t} - \widehat{w}^f_{j,t}$.

where $r_{s,t}$ is the return on security s expressed in the currency of the fund domicile and N_j is the total number of stocks in the portfolio of fund j. The foreign and domestic return components of the portfolio expressed in the currency of the fund domicile are given by

$$r^f_{j,t} = \sum_{s=1}^{N_j} \frac{w_{s,j,t-1}}{w^f_{j,t-1}} r_{s,t} \times 1_{s=f} \qquad r^h_{j,t} = \sum_{s=1}^{N_j} \frac{w_{s,j,t-1}}{w^h_{j,t-1}} r_{s,t} \times 1_{s=h}. \qquad (22)$$

3.1 Main results

As a test of the rebalancing hypothesis, we regress the portfolio rebalancing measure on the excess return of the foreign part of the portfolio over the home part of the portfolio—that is,

$$\Delta h^f_{j,t} = \sum_{l=0,1,2} \beta_l (r^f_{j,t-l} - r^h_{j,t-l}) + \eta_{c,t} + \varepsilon_j + \mu_{j,t}, \tag{23}$$

where $\beta_l < 0$ with $l=0$ captures instantaneous rebalancing and $\beta_l < 0$ with $l = 1,2$ captures delayed portfolio reallocations with a time lag of l quarters.[23] The specification includes interacted investor country and time fixed effects $\eta_{c,t}$ to capture common (macro-economic) reallocations between home and foreign equity pertaining to all funds domiciled in the same country. To allow for a time trend in the foreign portfolio allocation of funds, we also include fund fixed effects ε_j in most specifications. We note that a passive buy and hold strategy of an index produces $\Delta h^f_{j,t} = 0$ and should imply a zero coefficient. Passive index investment will bias the coefficients β_l toward zero.

Table 2 reports the baseline results on the rebalancing behavior of international equity funds. Column (1) includes only the contemporaneous excess return $r^f_{j,t} - r^h_{j,t}$ and does not include any fixed effects. The 101,238 fund-quarters yield the predicted negative coefficient at -1.839, which is statistically highly significant. As some of the rebalancing is likely to occur only with a time lag, we include in column (2) the lagged excess return on foreign equity. The inclusion of lagged excess returns also presents a useful control of reverse causality. If a fund increases (decreases) its positions in illiquid foreign stocks, this may increase (decrease) their stock price, generate a positive (negative) foreign excess return $r^f_{j,t} - r^h_{j,t}$, and thus bias the contemporaneous coefficient toward a positive value $\beta_0 > 0$. The same logic does not apply to lagged foreign excess returns. Column (2) also includes interacted time and investor country fixed effects that control for all macroeconomic effects, such as common equity fund inflows in the investor domicile. The contemporaneous coefficient β_0 and the lagged coefficient β_1 are both negative at high levels of statistical significance. Adding fund fixed effects in column (3) can absorb any positive or negative growth trend in a fund's foreign equity position, but their inclusion does not qualitatively affect the rebalancing evidence. Column (4) shows that even the second quarterly lag of foreign excess returns $r^f_{j,t-2} - r^h_{j,t-2}$ has some explanatory power for fund rebalancing, although the economic magnitude is weaker at -0.998.

Adding the three coefficients in column (4) implies a combined rebalancing effect of -5.099. A relative quarterly excess return of two standard deviations (or 0.140) therefore implies a reduction in the foreign equity weight by 0.714 percentage points for the representative (foreign-invested) institutional investor.[24] In light of the large size of foreign equity positions valued

23 The excess return of the foreign part of the portfolio over the home part of the portfolio $r^f_{j,t-l} - r^h_{j,t-l}$ is measured in the currency of the fund domicile. Results are robust to an alternative specification where $r^f_{j,t-l} - r^h_{j,t-l}$ is measured in local stock currency.

24 We note that the dependent variable $\Delta h^f_{j,t}$ is scaled by a factor of 100.

Table 2
Equity fund rebalancing

	Fund-Level Rebalancing $\Delta h^{f}_{j,t}$						
Dependent variable:	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$r^{f}_{j,t}-r^{h}_{j,t}$	−1.839***	−2.463***	−2.405***	−2.461***		−1.995***	−2.435***
	(0.239)	(0.250)	(0.263)	(0.278)		(0.554)	(0.305)
$r^{f}_{j,t-1}-r^{h}_{j,t-1}$		−1.595***	−1.439***	−1.640***		−1.651***	−1.355***
		(0.249)	(0.262)	(0.276)		(0.578)	(0.301)
$r^{f}_{j,t-2}-r^{h}_{j,t-2}$				−0.998***			
				(0.274)			
$(r^{f}_{j,t}-r^{h}_{j,t})\times 1_{\geq 0}$					−3.567***		
					(0.454)		
$(r^{f}_{j,t}-r^{h}_{j,t})\times 1_{<0}$					−1.196**		
					(0.468)		
$(r^{f}_{j,t-1}-r^{h}_{j,t-1})\times 1_{\geq 0}$					−0.295		
					(0.447)		
$(r^{f}_{j,t-1}-r^{h}_{j,t-1})\times 1_{<0}$					−2.702***		
					(0.471)		
Time×Fund Domicile FEs	No	Yes	Yes	Yes	Yes	Yes	Yes
Fund FEs	No	No	Yes	Yes	Yes	Yes	Yes
F-statistic	59.105	10.865	10.294	10.267	10.297	4.300	12.888
Observations	101,238	89,175	89,175	79,432	89,175	15,984	73,191
Adjusted R^2	0.001	0.066	0.134	0.143	0.134	0.170	0.142
Sample	Full	Full	Full	Full	Full	Until June 2008	After June 2008

Fund rebalancing of the foreign investment share $\Delta h^{f}_{j,t}$ of fund j in quarter t (measured in percentages) is regressed on the excess return of the foreign over the domestic investment share, $r^{f}_{j,t}-r^{h}_{j,t}$, and its lagged values $r^{f}_{j,t-l}-r^{h}_{j,t-l}$ for lags $l=1,2$. In column (1), we report OLS regression results without fixed effects, columns (2–7) add interacted time and fund domicile fixed effects, and Columns (3–7) add additional fund fixed effects. Column (5) splits the excess return on the foreign portfolio share into positive and negative realizations to test for symmetry of the rebalancing behavior. In columns (6–7), we report the baseline regression of column (3) for the subsample until June 2008 (Period I) and thereafter (Period II). We report robust standard errors clustered at the fund level for specification (1). *p < .1; **p <.05; ***p <.01.

at \$6.7 trillion for U.S. investors in December 2015, this amounts to economically significant equity flows of \$48 billion per quarter for U.S. equity investors alone.[25] We also explore asymmetries in the rebalancing behavior of international investors by splitting the sample into negative and positive excess returns. Formally, we have

$$\Delta h^{f}_{j,t}=\sum_{l=0,1}\beta^{+}_{l}(r^{f}_{j,t-l}-r^{h}_{j,t-l}) \times 1_{\Delta r\geq 0}+\sum_{l=0,1}\beta^{-}_{l}(r^{f}_{j,t-l}-r^{h}_{j,t-l})\times 1_{\Delta r<0}+\eta_{c,t}+\varepsilon_{j}+\mu_{j,t}, \qquad (24)$$

where $1_{\Delta r\geq 0}$ represents a dummy that is equal to 1 whenever the foreign excess return $\Delta r=r^{f}_{j,t}-r^{h}_{j,t}\geq 0$ and 0 otherwise. The complementary dummy marking

25 Source: U.S. Portfolio Holdings of Foreign Securities as of December 3, 2015, U.S. Department of Treasury.

negative foreign excess returns is given by $1_{\Delta r<0}$. The regression coefficients for the positive and negative components of the excess returns reported in column (5) show similar overall rebalancing for positive and negative excess returns when the significant coefficients for the contemporaneous and lagged rebalancing behavior are summed up. We conclude that rebalancing occurs symmetrically for both positive and negative foreign excess returns. We also split the excess return into separate foreign and home market return components—namely, $r^f_{j,t-l}$ and $r^h_{j,t-l}$. Again, no evidence for an asymmetric rebalancing is found in these unreported regression results. Finally, we split the sample into a precrisis period up to June 2008 (Period I) and a crisis and postcrisis period (Period II) thereafter. Columns (6) and (7) show the respective regression results and suggest that portfolio rebalancing in response to foreign excess returns is of roughly similar economic significance in the pre-crisis period 1999–2008 and thereafter.

3.2 Rebalancing and FX market volatility

Higher FX market volatility increases segmentation between the domestic and foreign equity markets. This reinforces portfolio rebalancing under incomplete FX risk trading in accordance with Corollary 2. To obtain measures of exchange rate volatility at a quarterly frequency, we first calculate the effective daily exchange rate $E_{c,d}$ for currency area c on trading day d as the weighted average of bilateral exchange rates $E_{c,i,d}$ with the N most important investment destinations indexed by i. Formally,

$$E_{c,d} = \sum_{i=1}^{N} \omega_{c,i} E_{c,i,d}, \tag{25}$$

where the weights $\omega_{c,i}$ are chosen to be the average foreign portfolio shares of all domestic funds in currency area c. For simplicity, we limit N to the 10 most important equity investment destinations, which account for more than 95% of foreign equity investment of all funds in each of the four currency areas c. The (realized) exchange rate volatility $VOL^{FX}_{c,t}$ for quarter t is defined as the standard deviation of the daily return $r^{FX}_{c,d} = \ln E_{c,d} - \ln E_{c,d-1}$ calculated for all trading days d of quarter t.[26] Figure 3 shows the realized effective exchange rate volatility of the four fund locations for the period January 1999–December 2015. To test for the FX volatility sensitivity of portfolio rebalancing, we interact the excess return on foreign equity $r^f_{j,t} - r^h_{j,t}$ with the contemporaneous

[26] For a total of D trading days in a given quarter t, realized volatility is calculated as follows:

$$VOL^{FX}_{c,t} = 100 \times \sqrt{\frac{66}{D} \sum_{d=1}^{D} \left(r^{FX}_{c,d} \right)^2}.$$

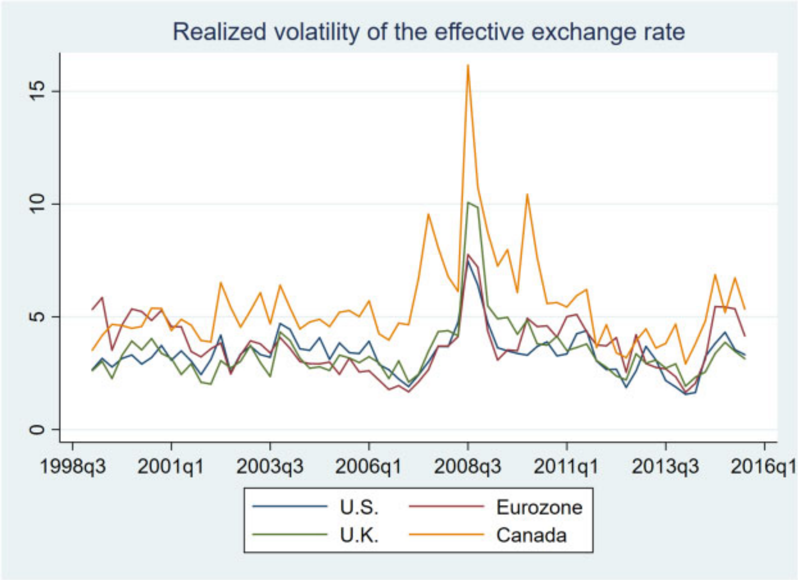

Figure 3
Realized volatility of the effective exchange rate
We plot the quarterly realized volatility $VOL_{c,t}^{FX}$ of the effective exchange rate for the United States, the United Kingdom, the Eurozone, and Canada, respectively for the period January 1999–December 2015. For a total of D trading days in a given quarter t, realized volatility is calculated as

$$VOL_{c,t}^{FX} = 100 \times \sqrt{\frac{66}{D}\sum_{d=1}^{D}\left(r_{c,d}^{FX}\right)^2},$$

where $r_{c,d}^{FX}$ is the log daily return of the effective exchange rate of currency area c.

measure of realized exchange rate volatility $VOL_{c,t}^{FX}$. The extended regression specification follows as

$$\Delta h_{j,t}^{f} = \sum_{l=0,1}\beta_l(r_{j,t-l}^{f} - r_{j,t-l}^{h}) + \gamma\, VOL_{c,t}^{FX}$$
$$+\sum_{l=0,1}\delta_l(r_{j,t-l}^{f} - r_{j,t-l}^{h}) \times VOL_{c,t}^{FX} + \eta_{c,t} + \varepsilon_j + \mu_{j,t}, \qquad (26)$$

where β_l captures the volatility-independent component of fund rebalancing at lags $l = 0, 1$ and δ_l the sensitivity of rebalancing to changes in FX volatility. The coefficient γ measures any increase in the foreign bias of fund allocation related to changes in the level of FX volatility. We include fund fixed effects ε_j in the regression, and for specifications (3) and (4) only (where the level of volatility is not included as a regressor), we also include the interacted time and investor country fixed effects, as we seek to identify the role of time variation in the rebalancing channel.

Table 3
Fund rebalancing and exchange rate volatility

	Fund-Level Rebalancing $\Delta h^{f}_{j,t}$			
Dependent variable:	(1)	(2)	(3)	(4)
$Vol^{FX}_{c,t}$	0.001	−0.009		
	(0.013)	(0.013)		
$r^{f}_{j,t}-r^{h}_{j,t}$	−0.025	−0.148	0.259	0.102
	(0.904)	(0.953)	(0.743)	(0.786)
$(r^{f}_{j,t}-r^{h}_{j,t})\times Vol^{FX}_{c,t}$	−0.434*	−0.397	−0.728***	−0.680***
	(0.246)	(0.261)	(0.184)	(0.195)
$r^{f}_{j,t-1}-r^{h}_{j,t-1}$		0.944		0.501
		(0.760)		(0.798)
$(r^{f}_{j,t-1}-r^{h}_{j,t-1})\times Vol^{FX}_{c.t}$		−0.610***		−0.525***
		(0.193)		(0.201)
Time FEs×Fund Domicile FEs	No	No	Yes	Yes
Fund FEs	Yes	Yes	Yes	Yes
F-statistic	13.830	16.139	20.889	22.781
Observations	101,238	89,175	101,238	89,175
Adjusted R^2	0.079	0.074	0.119	0.121

Fund rebalancing of the foreign investment share $\Delta h^{f}_{j,t}$ of fund j in quarter t (measured as percentage) is regressed on the excess return of the foreign over the domestic investment share, $r^{f}_{j,t}-r^{h}_{j,t}$, the realized (daily) FX volatility $Vol^{FX}_{c,t}$ of the effective exchange rate of the fund domicile country in the current quarter t, and the interaction between foreign excess return and volatility, $(r^{f}_{j,t}-r^{h}_{j,t})\times Vol^{FX}_{c,t}$. In columns (2) and (4), we also add lagged excess returns, $r^{f}_{j,t-1}-r^{h}_{j,t-1}$, and their interaction with the volatility measure as additional regressors. We report robust standard errors clustered at the fund level for specifications (1) and (2). *p <.1; **p <.05; ***p <.01.

Table 3 presents the regression results for the extended specification. Column (1) includes only the contemporaneous component of excess returns (lag $l=0$) and its interaction with exchange rate volatility $VOL^{FX}_{c,t}$, whereas column (2) also includes lagged excess returns (lag $l=1$). In columns (3)–(4), we also add interacted time-country fixed effects, which absorb any portfolio rebalancing related to macroeconomic phenomena and unrelated to fund-specific excess return on foreign equity holdings.

We find that the rebalancing behavior in response to differential equity returns is stronger under higher levels of exchange rate volatility, as predicted in Corollary 2. For a quarterly foreign excess return of 10%, any increase of the contemporaneous FX volatility by one standard deviation (=1.73) generates an additional rebalancing flow toward home equity of 0.126% of funds under management ($=-0.728\times 0.1\times 1.73$). The insignificant coefficient for the term $r^{f}_{j,t}-r^{h}_{j,t}$ suggests that the intensity of rebalancing is approximately proportional to the realized volatility measure $VOL^{FX}_{c,t}$. Higher FX volatility increases the riskiness of the foreign equity share in the fund portfolio and thus strengthens the rebalancing motive. In column (4), the interaction term $(r^{f}_{j,t-1}-r^{h}_{j,t-1})\times VOL^{FX}_{c,t}$ for lagged excess returns is also statistically significant and adds to the overall rebalancing flow. As noted before, fund rebalancing can

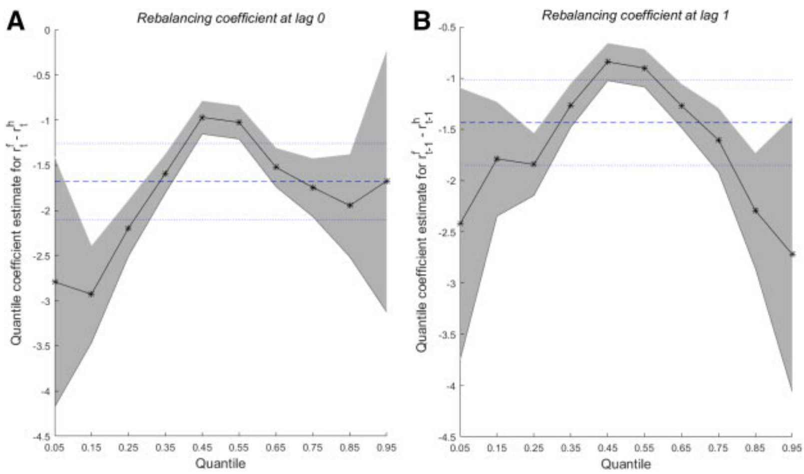

Figure 4
Quantile rebalancing regression
Panels A and B show the rebalancing coefficients β_0 and β_1 in the regression

$$\Delta h^f_{j,t} = \alpha + \beta_0 (r^f_{j,t} - r^h_{j,t}) + \beta_1 (r^f_{j,t-1} - r^h_{j,t-1}) + \mu_{j,t}$$

for the foreign excess return and the lagged foreign excess return, respectively, for the 10 quantile regressions at quantiles $\tau = 0.05,\ 0.15,\ 0.25, ..., 0.95$ together with a confidence interval of two standard deviations. The horizontal dashed blue line represents the point estimate of the OLS coefficient surrounded by its 95% confidence interval (dotted blue lines). We do not include time interacted with investor country fixed effects in the quantile regression specifications.

occur with some time delay. We conclude that higher exchange rate volatility reinforces the rebalancing channel of international equity investment.

3.3 Rebalancing by quantiles

The linear regression model captures an average effect for the rebalancing channel. Yet the propensity to rebalance could be heterogeneous across fund characteristics. The elasticity of fund flows to differentials in returns could be different, for example, for large and small rebalancing flows, which could in turn reflect more active or passive strategies. We allow for a nonlinear relationship between foreign excess returns and the intensity of rebalancing by using quantile regressions. The slope coefficient of the quantile regression represents the incremental change in rebalancing for a one-unit change in returns differentials at the quantile of the rebalancing variable. For the baseline regression in Table 2, column (2), we undertake 10 different quantile regressions at the (interior) quantiles $\tau = 0.05,\ 0.15,\ 0.25, ...,\ 0.85,\ 0.95$ of the distribution of holding changes.[27] Figure 4 plots the quantile coefficients β_0^τ and β_1^τ at lags

[27] We do not include time interacted with investor country fixed effects in the quantile regression specifications.

0 and 1, respectively. The gray shaded area shows a 95% confidence interval around the point estimate. Both the contemporaneous and delayed rebalancing reactions show an inverted U-shaped pattern where the edges of the distribution show more negative and therefore stronger rebalancing behavior. All quantiles have both $\beta_0^\tau < 0$ and $\beta_1^\tau < 0$; hence, funds across all quantiles rebalance their portfolios.

Figure 4 shows that the propensity to rebalance as a function of returns differentials is strongest whenever we observe large absolute rebalancing. Modest (positive or negative) rebalancing at more central quantiles features a weaker association between rebalancing and the returns differentials $r^f_{j,t-l} - r^h_{j,t-l}$, whereas strong rebalancing in absolute terms at low quantiles $\tau = 0.05$, 0.15, 0.25 or high quantiles $\tau = 0.75$, 0.85, 0.95 covaries more negatively with the returns differentials on foreign and domestic equity positions. Hence, particularly large changes $\Delta h^f_{j,t}$ at the edge of the rebalancing distribution contribute most to the average rebalancing effect captured by the ordinary least squares (OLS) regressions. For comparison, we add the OLS estimate as a blue dashed line together with its 95% confidence interval (dotted line). This evidence is consistent with periodic (rather than continuous) fund rebalancing where the likelihood of rebalancing increases as the discrepancy between desired and actual fund holdings grows. Similar to index funds pursuing a trade-off between tracking error and transaction costs, international funds rebalance more vigorously if the imbalance relative to the desired equity position becomes large.

3.4 Fund heterogeneity

We now investigate potential factors behind the heterogeneous rebalancing responses of funds reported in Section 3.3. Could the stronger rebalancing behavior shown in the tails of the $\Delta h^f_{j,t}$ distribution be explained by differences in fund characteristics? The three dimensions of fund heterogeneity we examine more closely are (i) fund size measured as log assets under management, (ii) a fund's foreign investment share $w^f_{j,t}$, and (iii) the fund investment concentration as measured by the Herfindahl-Hirschman index (HHI) of all fund stock position weights $w_{s,j,t}$. Fund size may represent an obstacle to frequent rebalancing if average transaction costs increase with the size of the position change. Large funds are also likely to be more diversified so that large differences between foreign and domestic equity returns occur less frequently. Greater fund diversification is likely to attenuate the need for rebalancing. We therefore expect funds with more concentrated holdings to feature stronger rebalancing behavior.

We calculate the average and median values of these three fund characteristics for all observations in the direct vicinity of the regression line for 10 quantiles $\tau = 0.05, 0.15, 0.25, ..., 0.85, 0.95$. Vicinity means that observations associated with quantile τ fall into a space around the quantile slope $\beta(\tau)$ delimited from above by the quantile slope $\beta(\tau - .05)$ and from below by the quantile slope $\beta(\tau+.05)$. Formally, such observations $(x_{j,t}, \Delta h^f_{j,t})$ fulfill the conditions $\Delta h^f_{j,t} - x_{j,t}\beta(\tau-.05) < 0$ and $\Delta h^f_{j,t} - x_{j,t}\beta(\tau+.05) \geq 0$. The regressors $x_{j,t}$ are the same as in the quantile regressions in Section 3.3 and include the excess return at lags $l=0,1$; that is, $x_{j,t} = (r^f_{j,t} - r^h_{j,t}, r^f_{j,t-1} - r^h_{j,t-1}) \in \mathbb{R}^2$. In other words, the vicinity space for each quantile τ is delimited by the two (two-dimensional) hyperplanes $y_{j,t} = x_{j,t}\beta(\tau-.05)$ and $y_{j,t} = x_{j,t}\beta(\tau+.05)$ through the origin of the space $\mathbb{R}^3$.

Figure 5, panels A and B, characterizes the average and median fund size, foreign portfolio share and portfolio concentration along the various quantile regressions lines, respectively. The average (median) fund size is less than one-third (one-half) at the edge of the distribution for the rebalancing statistics $\Delta h^f_{j,t}$ than at its center. The strongest propensity to rebalance in reaction to returns differentials is therefore observed for smaller funds. The smaller price impact makes portfolio adjustment less costly for these smaller institutional investors, which seems to make them more sensitive to returns differentials. The foreign portfolio share plotted in panels C and D does not suggest any strong heterogeneity in the intensity of rebalancing behavior across funds with different home biases. Only a slightly larger foreign investment share is associated with larger rebalancing propensities at low quantiles (large repatriation flows). By contrast, the intensity of rebalancing is strongly related to the HHI of a fund's investment stock concentration. Its median value in panel F is almost twice as large at the edges of the rebalancing distribution in which the portfolio adjustment to excess returns is most pronounced. Unlike index tracking funds, concentrated equity funds contribute strongly to the rebalancing evidence. This is not surprising, as these funds are also more likely to feature diverging performance on their domestic and foreign equity portfolios. Funds with concentrated equity positions feature stronger rebalancing behavior. The more diversified and largest funds tend, in contrast, to be associated with moderate rebalancing levels and low rebalancing propensities. They are more likely to follow more passive strategies.

4. Exchange Rate Effects of Portfolio Rebalancing

A key element of the equilibrium model developed in Section 1 is that equity portfolio rebalancing influences a country's exchange rate. While foreign productivity gains relative to the home country should depreciate the home currency in a real business cycle model, the associated higher foreign equity returns can reinforce rebalancing toward the home country, with the opposite effect on the exchange rate. To what extent the portfolio flow effect dominates at a given horizon is largely an empirical matter. We start by exploring the correlation structure between rebalancing flows and exchange rate in Section 4.1. We then proceed to estimate the causal effect of flows on the currency in Section 4.2 using a granular instrumental variable approach.

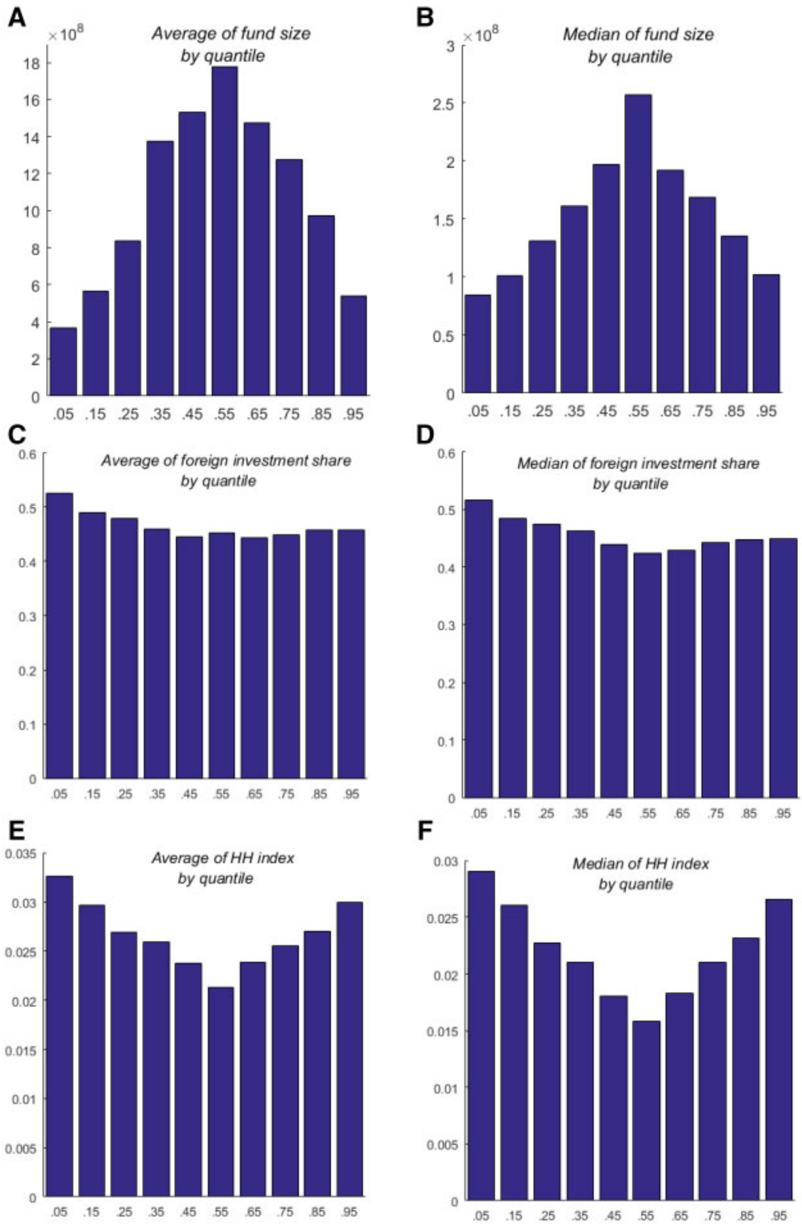

Figure 5
Fund characteristics by rebalancing quantile
Panels A and B characterize the mean and median fund size around a quantile regression at the quantiles $\tau = 0.05$, 0.15, 0.25, ..., 0.95, where the interquantile range of mean and median calculation is from $\tau - 0.05$ to $\tau + 0.05$. Panels C and D show the mean and median estimates for the foreign fund share, and panels E and F for the Herfindahl-Hirschman index (HHI) of investment shares concentration across stocks.

4.1 Aggregate flow measurement

To explore the links between aggregate equity fund flows and exchange rate dynamics, we define as D_c the set of all home funds domiciled in one of four currency areas $c \in$ {U.S., U.K., Eurozone, Canada}, and F_c as the complementary set of all foreign funds domiciled in currency areas $c' \in$ {U.S., U.K., Eurozone, Canada}$\setminus\{c\}$, but with equity investment in currency area c. Let the market value of all foreign equity positions of fund $j \in D_c$ at the end of quarter $t-1$ be denoted by $a^f_{j,t-1}$ and the value of all equity positions in currency area c by a foreign fund $j \in F_c$ be given by $a^{h*}_{j,t-1}$. We can then define the value-weighted (average) aggregate rebalancing (in terms of portfolio shares) of all home and foreign domiciled funds with respect to currency area c as

$$\begin{aligned} \Delta H^f_{c,t} &= \frac{1}{A^f_{c,t-1}} \sum_{j \in D_c} \Delta h^f_{j,t} \times a^f_{j,t-1} \quad \text{with} \quad A^f_{c,t-1} = \sum_{j \in D_c} a^f_{j,t-1} \\ \Delta H^{h*}_{c,t} &= \frac{1}{A^{h*}_{c,t-1}} \sum_{j \in F_c} \Delta h^{h*}_{j,t} \times a^{h*}_{j,t-1} \quad \text{with} \quad A^{h*}_{c,t-1} = \sum_{j \in F_c} a^{h*}_{j,t-1} \end{aligned}, \tag{27}$$

respectively, where $\Delta h^f_{j,t}$ denotes the fund-level rebalancing of home funds (domiciled in currency area c) toward foreign equity (i.e., portfolio outflows from currency area c) and $\Delta h^{h*}_{j,t}$ the rebalancing of foreign domiciled funds from foreign equity positions into equity in currency area c (i.e., portfolio inflows into currency area c). Similar to the fund-level terms Δh, the aggregate rebalancing flows ΔH represent percentage changes in the aggregate foreign equity position and therefore are not denominated in any currency.[28] Our model captures net aggregate flows as the last two terms in Equation (6). For percentage aggregate holding changes $\Delta H^f_{c,t+dt} = dH^f_{c,t}/H^f_{c,t}$ and $\Delta H^{h*}_{c,t+dt} = dH^{h*}_{c,t}/H^{h*}_{c,t}$, and asset positions $A^f_{c,t} = P^{f*}_{c,t} H^f_t$ and $A^{h*}_{c,t} = E_{c,t} P^h_{c,t} H^{h*}_{c,t}$, respectively, we restate net aggregate equity flows as

$$\begin{aligned} &P^{f*}_{c,t} dH^f_{c,t} - E_{c,t} P^h_{c,t} dH^{h*}_{c,t} \\ &= A^f_{c,t} \Delta H^f_{c,t+dt} - A^{h*}_t \Delta H^{h*}_{c,t+dt} \\ &= \frac{1}{2}\left[A^f_{c,t} + A^{h*}_{c,t}\right]\left[2\mu_{c,t} \Delta H^f_{c,t+dt} - 2(1-\mu_{c,t}) \Delta H^{h*}_{c,t+dt}\right] \approx \overline{PH} \Delta H^{Net}_{c,t+dt}, \end{aligned} \tag{28}$$

with percentage net flows defined as $\Delta H^{Net}_{c,t+dt} \equiv 2\mu_{c,t} \Delta H^f_{c,t+dt} - 2(1-\mu_{c,t}) \Delta H^{h*}_{c,t+dt}$.[29] The parameter $\mu_{c,t} \equiv A^f_{c,t}/(A^f_{c,t} + A^{h*}_{c,t})$ denotes the size of the

[28] We ignore rebalancing events below the 2.5^{th} and above the 97.5^{th} percentiles of the rebalancing statistics. This filter eliminates extremely large position changes that could originate in data errors. As extreme rebalancing events concern mostly smaller funds, we effectively discard only 1.58% of the aggregate asset value under management. We check robustness of the results with respect to 1%, 2%, 3%, 4%, and 5% trimming thresholds in Internet Appendix Table A2. Our estimates are qualitatively robust.

[29] In the discrete time framework, we give the percentage rebalancing Δh and ΔH from (the end of) period $t-1$ to t the time index t, which corresponds to $t+dt$ in continuous time.

Table 4
Aggregate equity rebalancing and the exchange rate

	Effective Quarterly Foreign Currency Appreciation, $-\Delta E_{c,t}$					
	Full Sample		Period 1999–2007		Period 2008–2015	
	OLS	OLS	OLS	OLS	OLS	OLS
Dependent var.:	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta H^{f}_{c,t}$	0.547		1.363		0.196	
	(0.541)		(0.906)		(0.660)	
$\Delta H^{h*}_{c,t}$	−1.085*		−0.214		−2.097**	
	(0.574)		(0.711)		(0.906)	
$\Delta H^{Net}_{c,t}$		1.046***		0.538		1.700***
		(0.357)		(0.438)		(0.551)
F-statistic	3.458	8.567	1.818	1.508	3.206	9.532
Observations	143	143	36	36	107	107
Adjusted R^2	0.047	0.057	0.099	0.042	0.058	0.083

The effective (log) foreign currency appreciation $-\Delta E_{c,t}$ in quarter t (scaled by a factor of 100) for the four currency areas c (i.e., U.S., U.K., Eurozone, Canada) is regressed on the net equity rebalancing flows (expressed in percentages of the average foreign equity positions). In columns (1–2), we use the full sample, and in columns (3–6), we present subsample results. In column (1), we report OLS regression coefficients for the aggregate rebalancing $\Delta H^{f}_{c,t}$ of the foreign portfolio share of all funds domiciled in c and the aggregate rebalancing $\Delta H^{h*}_{c,t}$ of the portfolio share invested in c by equity funds domiciled outside c. Column (2) combines both terms to the net aggregate equity outflow $\Delta H^{Net}_{c,t} = 2\mu_{c,t-1}\Delta H^{f}_{c,t} - 2(1-\mu_{c,t-1})\Delta H^{h*}_{c,t}$ from currency area c, where $\mu_{c,t-1}$ denotes the ratio of aggregate outbound to the sum of aggregate outbond and inbound equity investments. Columns (3–6) repeat the regressions in columns (1–2) for a precrisis 1999–2007 subsample amd a crisis/postcrisis 2008–2015 subsample. *p < .1; **p < .05; ***p <.01.

outbound equity investments relative to the sum of outbound and inbound investments. Empirically, the time-averaged value of $\mu_{c,t}$ is 84.6%, 17.1%, 42.3%, and 18.9% for the United States, the United Kingdom, the Eurozone, and Canada, respectively. The correlation between aggregate equity rebalancing outflows and inflows and the quarterly effective (log) foreign currency appreciation $-\Delta E_{c,t} = -\left[\ln E_{c,t} - \ln E_{c,t-1}\right]$ can be evaluated by the linear regressions

$$-\Delta E_{c,t} = \alpha \Delta H^{Net}_{c,t} + \epsilon_{c,t}, \qquad (29)$$

where we pool observations across the four currency areas: the United States, the United Kingdom, the Eurozone, and Canada. We only include quarterly observations for a currency area if at least 20 fund observations are recorded.[30] Each currency area is in turn considered the home country, with home funds accounting for aggregate rebalancing flows $\Delta H^{f}_{c,t}$ and overseas funds contributing an aggregate rebalancing flow $\Delta H^{h*}_{c,t}$. The effective foreign currency appreciation $-\Delta E_{c,t}$ (i.e., the relative depreciation of currency area c) is calculated based on fixed weights for the 10 most important outbound equity investment destinations as stated by Equation (25).

In Table 4, column (1), we pool the data over the four currency areas and show the OLS coefficients separately for the aggregate foreign holding change $\Delta H^{f}_{c,t}$

[30] As a consequence, we record 36 currency area quarters with aggregate inflow and outflow data for the period 1999–2007, and 107 currency area quarters for the period 2008–2015.

of funds incorporated in the home country and for the home country holding change $\Delta H^{h*}_{c,t}$ of foreign funds. Column (2) reports corresponding results for the net flows $\Delta H^{Net}_{c,t}$, which takes into account the relative size of inbound and outbound equity markets by currency area. The aggregate foreign holding increase $\Delta H^{f}_{c,t} > 0$ (or investment expatriation) indeed correlates with an appreciation of the foreign currency, and a decrease in foreign fund investment at home $\Delta H^{h*}_{c,t} < 0$ also correlates with an appreciation of the foreign currency. However, statistical significance at the conventional 1% level is obtained only for the net flows in column (2) with a point estimate of 1.046. The overall explanatory power of the regression is modest, as illustrated by the regression R^2 of approximately 5.7%.[31]

Comparing the data period 1999–2007 to 2008–2015, we find that the regression fit almost doubles from an R^2 of 0.042 in column (4) to 0.083 in column (6). This increase in explanatory power is likely to reflect the more comprehensive reporting of institutional fund positions in the later subsample. We also note that a subsample of U.S. and U.K. observations features a higher R^2 of 8.0% compared to 4.4% for Canada and the Eurozone, which may also be explained by a more comprehensive reporting by institutional investors in the former countries.[32]

Lilley et al. (2020) use quarterly portfolio flows from the International Monetary Fund's balance of payments data (BPM6), which includes investor types other than the institutional investors we focus on. They focus on the 2007–2019 period. Using their data, simple correlations between equity flows and exchange rate tend to be unstable over subsamples. But correlations between bond flows (particularly U.S. purchases of foreign bonds) and the exchange rate are very strong on any subsample where the financial crisis dominates. As argued by Lilley et al. (2020), during the 2007–2012 period, the status of the dollar as a safe haven currency drives exchange rate correlations. For the crisis period, they capture a very strong link between U.S. bond outflows and the exchange rate (with an R^2 of 32%). This correlation weakens as the sample increases. In contrast, we capture the long-run phenomenon of equity rebalancing behavior by institutional investors, which entails a more stable relationship with exchange rates. Yet, all OLS regressions suffer from endogeneity issues, and this motivates our use of a granular instrument.

There are three considerations for why equity flows should generally move exchange rates more than bond flows: (i) the higher volatility of relative equity returns; (ii) the generally unhedged investment character of equity positions, whereas bond positions tend to be hedged; and (iii) the larger size of foreign equity positions in developed markets. For example, using CPIS data, we

31 The equity flows constructed from the FactSet dataset used in Table 4 are included and represented in Figure 3 of the Internet Appendix. We also compare them with equity flows constructed from the Coordinated Portfolio Investment Survey (CPIS), provided by the IMF.

32 For the respective subsample analysis, we refer to Table A4 in the Internet Appendix.

calculate that of all foreign equity and debt held by U.S. institutional investors in 2015, the share of equity is 72% and the share of debt is 28%, respectively.

The strong correlation between exchange rates and some bond flows during the crisis is interesting and requires more analysis. Conceptually, hedged bond flows should matter far less for the exchange rate dynamics, as spot rate transactions are offset by forward rate transactions. However, recent work by Liao and Zhang (2020) on the "hedging channel" of exchange rate dynamics suggests that the hedge ratio on foreign bond positions itself may undergo large variations depending on the investor type, and thereby influences the exchange rates. A more integrated analysis of bond and FX derivative transactions represents a promising avenue for future research.

Lastly, we highlight that simple OLS regressions do not control for any of the common factors that may be driving equity flows and exchange rates. This certainly limits their meaningful interpretation of supply elasticities. We take up this challenge in the next section.

4.2 A granular instrumental variables approach

The assumption of a price-elastic supply of foreign exchange is at the heart of our theoretical model and embodied in the positive parameter κ. To quantify this supply elasticity, we use our disaggregate fund-level data and the granular instrumental variable (GIV) methodology proposed by Gabaix and Koijen (2020). While the theoretical model in Section 1 adopts a representative agent perspective and features no exogenous aggregate currency demand shocks, such shocks arise naturally in an empirical model of fund-level rebalancing. In such a model, rebalancing can be characterized not only by the fund's response to its own foreign excess return, but also by common and idiosyncratic rebalancing shocks originating in belief changes about future stock returns. A fund-level framework implies that the quantitatively most important portfolio flows can be traced to large funds. If net aggregate flows and their exchange rate impact are mostly influenced by the rebalancing of large funds, we can construct GIV instruments, which extract the idiosyncratic component of rebalancing by large funds relative to the average rebalancing of all funds and use it as an instrument.

For the aggregate currency supply change, we build on Equation (5) and assume

$$\Delta Q^S_{c,t} = -\kappa \Delta E_{c,t} + \varepsilon_t. \tag{30}$$

The error term ϵ_t allows for additional (liquidity) supply shocks that are not part of the theoretical model in Section 1. The currency demand is generated by the rebalancing behavior of individual funds domiciled at home ($j \in D_c$) or abroad ($j \in F_c$) given by

$$\begin{aligned} \Delta h^f_{j,t} &= \beta(r^f_{j,t} - r^h_{j,t}) + \eta_{c,t} + u_{j,t} \quad \text{for } j \in D_c \\ \Delta h^{h*}_{j,t} &= \beta(r^{h*}_{j,t} - r^{f*}_{j,t}) + \eta^*_{c,t} + u^*_{j,t} \quad \text{for } j \in F_c \end{aligned}, \tag{31}$$

respectively. The terms $\eta_{c,t}$ and $u_{j,t}$ embody the common and idiosyncratic belief shocks at the fund level, respectively. We assume that the idiosyncratic fund-level errors are orthogonal to the common error and the supply shock—that is, $\mathcal{E}_t[u_{j,t}\eta_{c,t}]=\mathcal{E}_t[u^*_{j,t}\eta^*_{c,t}]=\mathcal{E}_t[u_{j,t}\varepsilon_t]=\mathcal{E}_t[u^*_{j,t}\varepsilon_t]=0$. In Appendix C, we then provide the conditions under which fund-level rebalancing aggregates to a net currency demand

$$\Delta Q^D_{c,t}=\overline{PH}\ \Delta H^{Net}_{c,t}=\overline{PH}\ \beta\overline{\theta}\Delta E_{c,t}+\overline{PH}\ \widetilde{\eta}^{Net}_{c,t}+\overline{PH}\ \widetilde{u}^{Net}_{j,t}, \tag{32}$$

where $\widetilde{\eta}^{Net}_{c,t}$ represents an aggregate error term, $\widetilde{u}^{Net}_{j,t}$ the linear combination of idiosyncratic fund-level error terms, $\beta<0$ the rebalancing parameter, and $\overline{\theta}>0$ a constant. Identification of the supply elasticity via granular instruments relies on the orthogonality of the error term $\widetilde{u}^{Net}_{j,t}$ capturing only idiosyncratic rebalancing with the aggregate error terms $\widetilde{\eta}^{Net}_{c,t}$ and with the FX supply shocks ε_t—that is,

$$\mathcal{E}_t[\widetilde{u}^{Net}_{j,t}\widetilde{\eta}^{Net}_{c,t}]=\mathcal{E}_t[\widetilde{u}^{Net}_{j,t}\varepsilon_t]=0. \tag{33}$$

Following Gabaix and Koijen (2020), our instrument is based on netting the fund-size-based idiosyncratic variation of both equity fund outflows and inflows from their common components. Let $z^{Outflows}_{c,t}$ denote the granular instrumental variable for the foreign investments of funds domiciled in currency area c, and $z^{Inflows}_{c,t}$ represent the granular instrumental variable for the domestic investments by funds domiciled outside currency area c:

$$\begin{aligned} z^{Outflows}_{c,t} &= \frac{1}{A^f_{c,t-1}}\sum_{j\in D_c}\Delta h^f_{j,t}\times a^f_{j,t-1}-\frac{1}{N_{D_c}}\sum_{j\in D_c}\Delta h^f_{j,t} \\ z^{Inflows}_{c,t} &= \frac{1}{A^{h*}_{c,t-1}}\sum_{j\in F_c}\Delta h^{h*}_{j,t}\times a^{h*}_{j,t-1}-\frac{1}{N_{F_c}}\sum_{j\in F_c}\Delta h^{h*}_{j,t} \end{aligned}. \tag{34}$$

In other words, $z^{Outflows}_{c,t}$ is defined as the difference between the fund-size weighted and average weighted equity outflows by domestic funds in currency area c, and $z^{Inflows}_{c,t}$ is defined analogously as the difference between fund-size weighted and average equity inflows from the foreign funds into currency area c. As the rebalancing terms $\Delta h_{j,t}$ are expressed in terms of percentages of total assets, we still have to account for differences in the relative importance of inflows and outflows for each currency area c by using $\mu_{c,t}$ as the proportion of outflows relative to the sum of outflows and inflows. This allows us to define the granular instrument for the net equity flows $\Delta H^{Net}_{c,t}$ as

$$z^{Net}_{c,t}\equiv 2\mu_{c,t-1}z^{Outflows}_{c,t}-2(1-\mu_{c,t-1})z^{Inflows}_{c,t}. \tag{35}$$

The parameters $\mu_{c,t-1}\equiv A^f_{c,t-1}/(A^f_{c,t-1}+A^{h*}_{c,t-1})$ and $1-\mu_{c,t-1}$ denote again the relative size of outbound and inbound equity investments. The instrument $z^{Net}_{c,t}$ captures the idiosyncratic flows of large funds relative to general rebalancing flows of the average fund; it has at 0.448 a 45% lower standard deviation than the aggregate net flows $\Delta H^{Net}_{c,t}$. However, this idiosyncratic net flow component is still highly variable and represents a strong instrument for the aggregate net flows in the first-stage regression

$$\Delta H^{Net}_{c,t}=\alpha\ z^{Net}_{c,t}+\epsilon_{c,t}. \tag{36}$$

The predicted component $\Delta \widehat{H}_{c,t}^{Net}$ from the first-stage regression then identifies in the second-stage regression

$$-\Delta \widehat{E}_{c,t} = \frac{\overline{PH}}{\kappa} \Delta \widehat{H}_{c,t}^{Net} + \zeta_{c,t} \tag{37}$$

the inverse of the supply elasticity parameter given by $\frac{\overline{PH}}{\kappa} > 0$.[33]

In our baseline approach, called GIV1, we use the portfolio rebalancing flows $\Delta h_{j,t}^{f}$ and $\Delta h_{j,t}^{h*}$ to construct our instrument $z_{c,t}^{Net}$ according to Equations (34–35). The differencing of value- and equally weighted flows eliminates all rebalancing components $\eta_{c,t}$ and $\eta_{c,t}^{*}$ in Equation (31), which influence fund flows independently of fund characteristics. However, the evidence in Section 3.4 shows fund heterogeneity in rebalancing that may not be purged by simple differencing based on granularity. This motivates an augmented approach called GIV2, which filters additional predictable components based on fund characteristics $C_{j,t}$ and fund fixed effects α_j from the raw fund flows. We then use the residual portfolio flows $\Delta h_{j,t}^{f} - C_{j,t}\beta - \alpha_j$ and $\Delta h_{j,t}^{h*} - C_{j,t}\beta - \alpha_j$, to construct our instrument. As control variables $C_{j,t}$, we use the log fund size, the HHI of fund concentration, and their interaction with a fund's foreign excess return $r_{j,t}^{f} - r_{j,t}^{h}$. The fund fixed effects α_j take out all trend growth in foreign investment shares.

As an additional robustness check, we extract from the fund flows principal components and include them as additional control variables in the two-stage least squares estimation. For GIV1, we use the raw portfolio rebalancing flows $\Delta h_{j,t}^{f}$ and $\Delta h_{j,t}^{h*}$ and extract the first 10 principal components η_t^{Net}.[34] As our initial panel is unbalanced, we select for the principal component extraction only funds with at most seven missing time observations. We then use the alternating least squares algorithm to obtain a balanced panel for the principal component analysis.[35] For GIV2, we proceed along the same lines, but use the residual portfolio flows $\Delta h_{j,t}^{f} - C_{j,t}\beta - \alpha_j$ and $\Delta h_{j,t}^{h*} - C_{j,t}\beta - \alpha_j$ to extract the principal components. As an illustration, we present in Table A5 of the Internet Appendix the time series of GIV1 for the United States and the Eurozone. We check that the largest shocks correspond to underlying idiosyncratic inflows and outflows shocks of certain large funds. We then go further and look for narratives behind the biggest idiosyncratic shocks. Following the methodology described in Gabaix and Koijen (2020), we run regressions of the rebalancing

33 Using $z_{c,t}$ as an instrument for $\Delta H_{c,t}^{Net}$ is the intuitive approach. Alternatively, we could also instrument $-\Delta E_{c,t}$ first and then identify $\kappa/\overline{PH}$ directly (instead of its inverse) in the second-stage regression $H_{c,t}^{Net} = \frac{\kappa}{\overline{PH}}[-\Delta \widehat{E}_{c,t}] + \epsilon_{c,t}$. Both approaches yield the same elasticity estimate.

34 We compute principal components $\eta_t^{Outflows}$ and $\eta_t^{Inflows}$ from the raw flows $\Delta h_{j,t}^{f}$ and $\Delta h_{j,t}^{h*}$, respectively, and then define $\eta_t^{Net} = 2\mu_{c,t-1}\eta_t^{Outflows} - 2(1-\mu_{c,t-1})\eta_t^{Inflows}$.

35 We use the Matlab command pca.m and its built-in alternating least squares algorithm to compute the principal components. We retain the first 10 principal components as additional control variables. For GIV2, we follow the same procedure but use the residual portfolio flows.

at the fund level on a constant and collect the residuals. Adjusting with the relevant size variable, we pick the 10 largest shocks for each geographical region. We then look for news that can explain the shocks experienced by the funds selected earlier on the relevant quarter and check that these shocks are indeed idiosyncratic. We gather information on the shocks by analyzing the Factiva dataset. For example, in 2003q4, the largest shock related to U.S. outflows concerns Janus Capital Management LLC. This corresponds to the following legal event, described in the *Financial Times* in December 2003: "Janus Capital, one of the first fund groups to become embroiled in New York attorney-general Eliot Spitzer's crackdown on mutual fund trading scandals, has offered to return \$31.5m to its investors as compensation for the improper trading that took place in its funds." For Eurozone (EZ) outflows, one of the largest shocks occurred for Deutsche Asset Management Investment GmbH. Reuters reports that "The U.S. asset management arm of Deutsche Bank AG has agreed to pay \$19.3 million to settle a case involving directed brokerage and the Scudder Funds, U.S. regulators and the company said on Thursday." We provide the Factiva link, the date, and the news source for the shocks in Table A5 of the Internet Appendix.

4.3 FX Supply Elasticity Estimates

Table 5 reports our results for the four specifications—namely, GIV1 and GIV2—each with and without the principal components as control variables, respectively. Columns (1–4) provide the first-stage regression results for Equation (36), and columns (6–9) the second-stage estimates for Equation (37).[36] The Montiel-Pflueger F-statistics suggest very strong instruments in all four cases, although GIV1 features the strongest instruments, with values of 53.6 and 70.3, respectively. This is not surprising, as GIV2 applies more filters to the flow statistics entering the instrument construction.

The point estimate in column (6) for the GIV1 is 0.928, and statistically significant at the 5% level. It implies that an exogenous outflow shock given by one standard deviation of aggregate percentage flows (i.e., 0.813) depreciates the home currency by 0.754% (=0.928% $\times$ 0.813). This represents an economically significant effect. The implied currency supply elasticity follows, as $\widehat{\frac{\kappa}{\overline{PH}}}=1.078$. In other words, a 1% effective quarterly foreign exchange rate appreciation is associated with a net currency demand shock of 1.078% of the average aggregate foreign fund positions in a currency. For the United States, this amounts to approximately US\$7.1 billion (= 1.078% $\times$ US\$658 billion) at the end of 2014 (as $\overline{PH} \approx$ US\$658 billion). Allowing for the possibility of common factors has the effect of decreasing the elasticity to $\widehat{\frac{\kappa}{\overline{PH}}}=0.806$, implying that a 1% effective quarterly foreign exchange rate

36 For the specifications with principal components, we have $\Delta H_{c,t}^{Net} = \alpha\ z_{c,t} + \eta_t^{Net} + \epsilon_{c,t}$ as the first stage and $-\Delta \widehat{E}_{c,t} = \frac{\overline{PH}}{\kappa}\ \Delta \widehat{H}_{c,t}^{Net} + \eta_t^{Net} + \zeta_{c,t}$ as the second stage.

Table 5
Currency supply elasticity to equity flows

Dependent variables:	Net Equity Outflows $\Delta H^{Net}_{c,t}$				Effective Quarterly Foreign Currency Appreciation $-\Delta E_{c,t}$				
Stage:	GIV1 First	GIV1 First	GIV2 First	GIV2 First	OLS –	GIV1 Second	GIV1 Second	GIV2 Second	GIV2 Second
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
$\Delta H^{Net}_{c,t}$					1.046***				
					(0.357)				
$\Delta \widehat{H}^{Net}_{c,t}$						0.928**	1.009**	0.926**	1.240***
						(0.445)	(0.466)	(0.453)	(0.479)
$z^{Net}_{c,t}$	1.448***	1.393***	1.429***	1.403***					
	(0.092)	(0.088)	(0.095)	(0.092)					
First 10 PCs as controls	No	Yes	No	Yes	–	No	Yes	No	Yes
Implied estimate $\kappa/\overline{PH}$					–	1.078	0.991	1.080	0.806
Montiel-Pflueger F-stat.					–	53.594	70.343	48.627	101.921
Observations	143	143	143	143	143	143	143	143	143
Adjusted R^2	0.638	0.707	0.615	0.715	0.057	0.057	0.096	0.057	0.135

We estimate the exchange rate supply elasticity to net equity flows using different granular instrumental variable (GIV) estimators (Gabaix and Koijen 2020). Columns (1–4) report the first-stage regressions with the net equity outflows $\Delta H^{Net}_{c,t}$ as the dependent (instrumented) variable. Column (5) reports the OLS regression of the effective (log) foreign currency appreciation $-\Delta E_{c,t}$ ($\times 100$) of currency area c regressed on the observed net equity outflows $\Delta H^{Net}_{c,t}$. The second-stage regressions in columns (6–9) have the effective (log) foreign currency appreciation $-\Delta E_{c,t}$ ($\times 100$) of currency area c as the dependent variable and predicted net flows $\Delta \widehat{H}^{Net}_{c,t}$ from the first-stage regression as their regressor. For GIV1 in columns (1) and (6), we construct granular instruments $z^{Net}_{c,t}$ directly from the raw fund-level portfolio flows $\Delta h^{f}_{j,t}$ and $\Delta h^{h*}_{j,t}$ as described in Equations (34–35). In columns (2) and (7), we add as control variables the first 10 principal components of the net flows (not reported) extracted from the raw fund-level portfolio flows $\Delta h^{f}_{j,t}$ and $\Delta h^{h*}_{j,t}$, respectively. For GIV2 in columns (3) and (8), we construct granular instruments based on the residual portfolio flows $\Delta h^{f}_{j,t} - C_{j,t}\beta - \alpha_j$ or $\Delta h^{h*}_{j,t} - C_{j,t}\beta - \alpha_j$ where the predictable flow component $C_{j,t}\beta$ is subtracted along with fund fixed effects α_j. The control variables $C_{j,t}$ consist of the log fund size, the HHI of fund concentration, and the interaction terms of log fund size and HHI with a fund's foreign excess returns $r^{f}_{j,t} - r^{h}_{j,t}$. In columns (4) and (9), we report the corresponding regressions with the first 10 principal components added as controls. The latter are extracted from the residual portfolio flows $\Delta h^{f}_{j,t} - C_{j,t}\beta - \alpha_j$ or $\Delta h^{h*}_{j,t} - C_{j,t}\beta - \alpha_j$. The coefficient for the predicted net equity outflows $\Delta \widehat{H}^{Net}_{c,t}$ identifies the inverse of the supply elasticity parameter—namely, $\overline{PH}/\kappa$. *p <.1; **p <.05; ***p <.01.

appreciation is associated with slightly lower inflows of US$5.3 billion (= 0.806%× US$658 billion). Some caution is required when translating the elasticity estimate into a currency inflow quantity required to produce a currency appreciation by one percentage point. The latter estimate depends on the correct measurement of the total capital $\overline{PH}$ involved in rebalancing. Since the FactSet data may not contain all institutional investors and excludes private portfolio investors, the total capital $\overline{PH}$ is underestimated. If these excluded equity positions participate to some extent in international equity rebalancing, we have to scale the quantity estimates accordingly. In other words: these quantities are best interpreted as a lower bound for the inflows needed to trigger an appreciation by one percentage point. Furthermore, it would not be correct to assume that net trade flows translate automatically into net currency demand. Trade imbalances need not generate any net currency demand from the real sector if the invoicing domestic entities convert foreign balances into net foreign asset holdings denominated and settled in foreign currency. Symmetrically, trade imbalances can be invoiced in domestic currency and bypass the foreign exchange market via an adjustment of the domestic currency assets of the foreign trading partner.

In Table 5, columns (8–9) report the second-stage results for the more robust (residual-based) granular instrument, without and with 10 principal components as controls, respectively. The point estimates for the supply elasticity $\widehat{\frac{\kappa}{\overline{PH}}}$ are 1.080 and 0.806 for GIV2 without principal components and GIV2 with principal components, respectively. The GIV2 estimate without principal components is very close to the baseline result for GIV1 without principal components, given by 1.078, but, just as before, the elasticity estimated with principal components is lower.

From a theoretical perspective, the stylized model in Section 1 can generate a realistic level of exchange rate volatility for a scaled supply elasticity parameter $\widehat{\frac{\kappa}{\overline{PH}}}$ below 20. Hence, our lower point estimate for the currency supply elasticity is consistent with high levels of exchange rate volatility. Our currency supply elasticity estimates can be compared to previous estimates in the literature. Hau, Massa, and Peress (2009) use a major exogenous change in MSCI's global index weights in 2001 to estimate the elasticity of currency supply to rebalancing flows. For a six-day window around the announcement of the index reweighting, the authors estimate for 33 mostly downweighted emerging market currencies an average supply elasticity of 0.4. This suggests that on average US$2.6 billion is needed for a 1% change of the bilateral dollar rate.[37] The elasticity estimates in Hau, Massa, and Peress (2009) are pooled over a large set of currency markets that includes many emerging market currencies and small open economies, all relative to the U.S. dollar. These estimates are therefore likely to provide a

[37] The point estimate of 2.49 on page 1699 corresponds to a supply elasticity of 0.4 [=1/2.49]. An average US$0.66 billion of equity outflows for every 10% country weight decrease in the MSCI index then implies the US$2.6 billion [=0.4 × 0.66 billion/0.1] in currency flows for a 1% exchange rate change.

lower bound for the supply elasticity of FX liquidity. Indeed, our estimates are somewhat higher and correspond to a more elastic currency supply.

5. Alternative Interpretations

Our empirical results provide strong support in favor of portfolio rebalancing. Can the observed rebalancing result from a simple behavioral hypothesis? One such behavioral hypothesis concerns "profit-taking" on appreciating stocks. Fund managers might sell stocks once a certain target price is reached. The evidence presented here reflects the decisions of investment professionals who should be less prone to behavioral biases compared to households. But we can identify two additional aspects of the data that cannot be easily reconciled with a "profit-taking motive" as an explanatory alternative. First, this behavioral hypothesis does not explain why funds buy foreign equity shares when these assets underperform domestic holdings, as documented in Section 3.1. Second, the "profit-taking motive" evaluates each stock in isolation from the other portfolio assets, unlike our risk-based paradigm, which looks at the portfolio of all foreign equity holdings. Third, we also show that higher exchange rate risk interacts with the rebalancing motive, although it is unclear why it should matter for a "profit-taking motive."

A second alternative interpretation concerns exogenous investment policies and mandates for the funds. Could the observed rebalancing behavior result from investment policies that commit a fund to a certain range of foreign stock ownership? French and Poterba (1991) note that fund mandates are an unlikely explanation for the home bias in equity. This does not preclude their greater importance for the rebalancing dynamics documented in this paper. To the extent that such mandates exist, we can interpret them as reflecting the risk management objectives of the ultimate fund investors. As such, they can be interpreted as direct evidence for limited asset substitutability and support, rather than contradict, the main message of our study. But rationalizing such mandates in the context of agency problems is beyond the scope of this paper. Distinguishing between mandated rebalancing and autonomous fund-based rebalancing presents an interesting issue for future research. To make progress on these issues, we doubtless need a better theoretical understanding of delegated investment strategies and one that is compatible with the stylized facts that we uncover in this paper. Modeling financial intermediaries more realistically is an important agenda for future research.[38]

6. Conclusion

This paper documents a pervasive feature of the international equity portfolios of institutional investors—namely, that they repatriate capital after making an

[38] Important progress has been made in that direction: see, for example, Gabaix and Maggiori (2015), Coimbra and Rey (2017), Koijen and Yogo (2019), and Koijen and Yogo (2020).

excess return on their foreign portfolio share relative to their domestic equity investment. We interpret such rebalancing behavior as a consequence of investor risk aversion in an equity market partially segmented by exchange rate risk and present a simple model characterizing the joint dynamics of stock prices, the exchange rate, and international portfolio holdings. Limited international tradability of exchange rate risk implies that foreign equity investments are riskier than home country equity investments. International investors reduce their foreign equity share if excess returns in the foreign market increase their FX exposure.

We document a rich set of new empirical facts that support this interpretation. First, higher exchange rate risk (measured by realized FX volatility) reinforces the risk-rebalancing channel. Second, the largest correlation between rebalancing and foreign excess returns is found at the tails of the rebalancing distribution—suggesting a nonlinear relationship. In other words, the rebalancing motive of equity funds increases as the return differential between foreign and domestic fund positions becomes more extreme. Third, we find that smaller funds and funds with a higher concentration of their investments in fewer stocks have the largest rebalancing propensity in reaction to return differentials. By contrast, rebalancing is observed equally across funds with very heterogeneous foreign investment shares. To estimate aggregate effects of rebalancing flows on the exchange rate, we use the disaggregated structure of fund flows to construct a granular instrumental variable as in Gabaix and Koijen (2020). This allows us to estimate the elasticity of supply of foreign exchange and the causal effect from rebalancing flows to exchange rate movements. We speculate that our evidence casts some light on international financial linkages. Gourinchas and Rey (2007) show that current account adjustments go through a trade channel and a financial adjustment channel, the latter becoming more important over recent years. In the presence of a foreign asset market boom, which is usually associated with a real foreign currency appreciation and a current account deficit, domestic investors will at some point repatriate their funds, thereby depreciating the foreign currency with a stabilizing effect. Much research remains to be done to better comprehend the complexity of international links across financial asset markets.

Appendix A: Model Solution

To solve the model, we conjecture a linear solution for asset returns. The existence and uniqueness of equilibrium in the class of linear equilibria can be shown following the same steps as Hau and Rey (2002). Asset price for the home and foreign equity processes are indexed by h and f as P_t^h as P_t^f, respectively, if expressed in the currency of the home investor, and indexed by $h*$ and $f*$ as P_t^{h*} and P_t^{f*}, respectively, if expressed in the currency of the foreign investor. We define the corresponding (instantaneous) excess returns (on one unit of asset) as $dR_t = (dR_t^h, dR_t^f)^T$ and $dR_t^* = (dR_t^{h*}, dR_t^{f*})^T$ in terms of the currency of the home and foreign investors, respectively. Indices $h, f*$ then refer to home and foreign country variables expressed in local stock currency and $h*, f$ to the same variables expressed in the currency of the overseas investor.

Next, we conjecture for excess returns a solution in two state variables $\boldsymbol{\Psi}_t^h = (1, D^h, \Delta_t, \Lambda_t)^T$ and $\boldsymbol{\Psi}_t^{f*} = (1, D_t^{f*}, \Delta_t, \Lambda_t)^T$ with $\Delta_t \equiv D_t^h - D_t^{f*}$ and the stochastic process Λ_t. Let $\mathbf{dw}_t^h = (dw_t^h, dw_t)^T = (dw_t^h, dw_t^h - dw_t^{f*})^T$ and $\mathbf{dw}_t^{f*} = (dw_t^{f*}, dw_t)^T = (dw_t^{f*}, dw_t^h - dw_t^{f*})^T$ denote two (1×2) vectors of innovations. Vectors $\alpha_\Psi^i = (\alpha_0^i, \alpha_D^i, \alpha_\Delta^i, \alpha_\Lambda^i)$ and $\mathbf{b}_\Psi^i = (f_D\sigma_D, b_\Delta^i)$, $(i \in \{h, f*, h*, f\})$ with $f_D = 1/(\alpha_D + r)$ allow us to express excess returns as

$$\begin{bmatrix} dR_t^h & dR_t^{f*} \\ dR_t^{h*} & dR_t^f \end{bmatrix} = \begin{bmatrix} \alpha_\Psi^h & \alpha_\Psi^{f*} \\ \alpha_\Psi^{h*} & \alpha_\Psi^f \end{bmatrix} \begin{bmatrix} \boldsymbol{\Psi}_t^h dt \\ \boldsymbol{\Psi}_t^{f*} dt \end{bmatrix} + \begin{bmatrix} \mathbf{b}_\Psi^h & \mathbf{b}_\Psi^{f*} \\ \mathbf{b}_\Psi^{h*} & \mathbf{b}_\Psi^f \end{bmatrix} \begin{bmatrix} \mathbf{dw}_t^h \\ \mathbf{dw}_t^{f*} \end{bmatrix}. \tag{A1}$$

All coefficients are functions of six exogenous model parameters α_D, σ_D, $\overline{D}$, r, κ, and ρ. The first-order conditions for the optimal asset demand functions follow as

$$\begin{bmatrix} H_t^h \\ H_t^f \end{bmatrix} = \frac{1}{\rho}\boldsymbol{\Omega}^{-1}\mathcal{E}_t \begin{bmatrix} \alpha_\Psi^h \boldsymbol{\Psi}_t^h \\ \alpha_\Psi^f \boldsymbol{\Psi}_t^{f*} \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} H_t^{f*} \\ H_t^{h*} \end{bmatrix} = \frac{1}{\rho}\boldsymbol{\Omega}^{-1}\mathcal{E}_t \begin{bmatrix} \alpha_\Psi^{f*} \boldsymbol{\Psi}_t^{f*} \\ \alpha_\Psi^{h*} \boldsymbol{\Psi}_t^h \end{bmatrix} \tag{A2}$$

for the home and foreign investors, respectively. The matrix $\boldsymbol{\Omega}$ denotes the (2×2) covariance matrix of instantaneous returns and $\boldsymbol{\Omega}^{-1}$ its inverse matrix. We approximate excess returns (around steady-state values $\overline{P}^h = \overline{P}^{f*} = \overline{P}$ and $\overline{E} = 1$) as

$$dR_t^h = dP_t^h - rP_t^h dt + D_t^h dt \tag{A3}$$

$$dR_t^f \approx -dE_t\overline{P} + dP_t^{f*} - dE_t dP_t^{f*} - r[P_t^{f*} - \overline{P}(E_t - 1)]dt + [D_t^{f*} - \overline{D}(E_t - 1)]dt \tag{A4}$$

$$dR_t^{f*} = dP_t^{f*} - rP_t^{f*}dt + D_t^{f*}dt \tag{A5}$$

$$dR_t^{h*} \approx dE_t\overline{P} + dP_t^h + dE_t dP_t^h - r\left[P_t^h + \overline{P}(E_t - 1)\right]dt + \left[D_t^h + \overline{D}(E_t - 1)\right]dt. \tag{A6}$$

Substitution of the linear equations in Proposition 1 into Equations (A3–A6) yields the representation in Equation (A1) and determines the vectors α_Ψ^j, α_Ψ^i, $\mathbf{b}_\Psi^j$, $\mathbf{b}_\Psi^i$. For the covariance elements we obtain

$$\Omega_{11} = (f_D\sigma_D)^2 + 2[p_\Delta\sigma_D + p_\Lambda]^2 + 2f_D\sigma_D[p_\Delta\sigma_D + p_\Lambda] \tag{A7}$$

$$\Omega_{12} = -2(p_\Delta\sigma_D + p_\Lambda)^2 - [2(p_\Delta\sigma_D + p_\Lambda) + f_D\sigma_D]\overline{P}(e_\Delta\sigma_D + e_\Lambda) - 2(p_\Delta\sigma_D + p_\Lambda)f_D\sigma_D \tag{A8}$$

$$\Omega_{22} = (f_D\sigma_D)^2 + 2[\overline{P}(e_\Delta\sigma_D + e_\Lambda) + p_\Delta\sigma_D + p_\Lambda]^2 + 2f_D\sigma_D[\overline{P}(e_\Delta\sigma_D + e_\Lambda) + p_\Delta\sigma_D + p_\Lambda]. \tag{A9}$$

Market clearing in the two stock markets implies $H_t^h + H_t^{h*} = 1$ and $H_t^{f*} + H_t^f = 1$. Market clearing in the FX market requires $Q_t^D = Q_t^S = -\kappa(E_t - 1)$ or in the linearized version (around foreign asset holding $\overline{H}$)

$$-\kappa dE_t = (E_t - 1)\overline{H}\,\overline{D}dt + (H_t^{h*} - H_t^f)\overline{D}dt + (D_t^h - D_t^{f*})\overline{H}dt + (dH_t^f - dH_t^{h*})\overline{P}, \tag{A10}$$

where the last term $dH^{Net}\overline{P} = (dH_t^f - dH_t^{h*})\overline{P}$ denotes the net portfolio rebalancing (or net equity outflow), $-dE_t$ the associated foreign currency appreciation, and κ the currency supply elasticity. The first three terms account for asymmetric dividend incomes between the home and foreign investors.

The six endogenous parameters p_0, p_Δ, p_Λ, e_Δ, e_Λ, and α_Λ are determined by the equity market clearing condition (implying A11–A13) and by compliance with the flow constraint in A10 (implying A14–A16):

$$p_0 = \frac{-\rho\det\Omega - \mathcal{E}_t(dE_t dP_t^{f*})(-\Omega_{12} + \Omega_{11})}{r(\Omega_{11} - 2\Omega_{12} + \Omega_{22})} \tag{A11}$$

$$p_\Delta = -e_\Delta \frac{[(\alpha_D + r)\overline{P} - \overline{D}](\Omega_{21} + \Omega_{11})}{(\alpha_D + r)(\Omega_{11} + 2\Omega_{21} + \Omega_{22})} \tag{A12}$$

$$p_\Lambda = -e_\Lambda \frac{[(\alpha_\Lambda + r)\overline{P} - \overline{D}](\Omega_{21} + \Omega_{11})}{(\alpha_\Lambda + r)(\Omega_{11} + 2\Omega_{21} + \Omega_{22})} \tag{A13}$$

$$0 = e_{\Delta}\left(\overline{HD} - \kappa\alpha_D\right) + m_{\Delta}\frac{1}{\rho}\left(\overline{D} + \alpha_D\overline{P}\right) + \overline{H} \tag{A14}$$

$$0 = e_{\Lambda}\left(\overline{HD} + \kappa\alpha_{\Lambda}\right) + m_{\Lambda}\frac{1}{\rho}\left(\overline{D} - \alpha_{\Lambda}\overline{P}\right) \tag{A15}$$

$$0 = \kappa\left[e_{\Delta}\sigma_D + e_{\Lambda}\right] - \frac{1}{\rho}\overline{P}\left[m_{\Delta}\sigma_D + m_{\Lambda}\right] \tag{A16}$$

$$0 = [(\alpha_{\Lambda} + r)\overline{P} - \overline{D}]\left(\overline{D} - \alpha_{\Lambda}\overline{P}\right) - \frac{\rho}{2}\left(\overline{HD} + \kappa\alpha_{\Lambda}\right)[\Omega_{11} + 2\Omega_{21} + \Omega_{22}]. \tag{A17}$$

The expressions m_{Δ}, m_{Λ}, and $\det\Omega$ are defined as

$$m_{\Delta} = 2p_{\Delta}(\alpha_D + r)(\Omega_{12}^{-1} - \Omega_{22}^{-1}) - 2[(\alpha_D + r)\overline{P} - \overline{D}]e_{\Delta}\Omega_{22}^{-1} \tag{A18}$$

$$m_{\Lambda} = 2p_{\Lambda}(\alpha_{\Lambda} + r)(\Omega_{12}^{-1} - \Omega_{22}^{-1}) - 2[\overline{P}(\alpha_{\Lambda} + r) - \overline{D}]e_{\Lambda}\Omega_{22}^{-1} \tag{A19}$$

$$\det\Omega = \Omega_{11}\Omega_{22} - \Omega_{21}\Omega_{21}, \tag{A20}$$

where Ω_{ij}^{-1} denotes element (i, j) of the inverse matrix Ω^{-1}.

For the steady-state values $\overline{P} > 0$, $\overline{D} > 0$, $\overline{\Lambda} = 0$, and $0 < \overline{H} < 1$, we require

$$\overline{P} = p_0 + \frac{\overline{D}}{r} + p_{\Lambda}\overline{\Lambda} = p_0 + \frac{\overline{D}}{r} \tag{A21}$$

$$\overline{H} = \frac{\rho[\Omega_{11} - \Omega_{21}] - \mathcal{E}_t(dE_t dP_t^{f*})}{\rho(\Omega_{11} - 2\Omega_{21} + \Omega_{22})}. \tag{A22}$$

and

$$\mathcal{E}_t(dE_t dP_t^h)/dt = -\mathcal{E}_t(dE_t dP_t^{f*})/dt = (e_{\Delta}\sigma_D + e_{\Lambda})[f_D\sigma_D + 2(p_{\Delta}\sigma_D + p_{\Lambda})] < 0. \tag{A23}$$

For the rebalancing dynamics of home investors in foreign assets, we obtain

$$dH_t^f = -\frac{1}{2\rho}m_{\Delta}d\Delta_t - \frac{1}{2\rho}m_{\Lambda}d\Lambda_t = -\frac{1}{2\rho}m_{\Delta}[-\alpha_D\Delta_t dt + \sigma_D dw_t] - \frac{1}{2\rho}m_{\Lambda}[-\alpha_{\Lambda}\Delta_t dt + dw_t], \tag{A24}$$

where we define $dw_t = dw_t^h - dw_t^{f*}$ and $\mathcal{E}_t(dw_t dw_t')/dt = 2$. The excess returns (relative to the steady-state price $\overline{P}$) follow, as $dr_t^h = dR_t^h/\overline{P}$, $dr_t^{f*} = dR_t^{f*}/\overline{P}$, $dr_t^f = dR_t^f/\overline{P}$, and $dr_t^{h*} = dR_t^{h*}/\overline{P}$.

Corollary A.1 (Rebalancing and Foreign Excess Returns). Ignoring terms of order dt^2, we find:
(i) a negative correlation between foreign equity holdings and excess returns expressed in investor currency; hence,

$$Cov(dH_t^f,\, dr_t^f - dr_t^h)/dt = \kappa\frac{1}{\overline{P}}\left[\frac{1}{\overline{P}}f_D\sigma_D + 2p_{\Delta}\sigma_D + 2p_{\Lambda} + e_{\Delta}\sigma_D + e_{\Lambda}\right][e_{\Delta}\sigma_D + e_{\Lambda}] < 0, \tag{A25}$$

(ii) a negative correlation between foreign equity holdings and excess returns expressed in stock currency; hence,

$$Cov(dH_t^f,\, dr_t^{f*} - dr_t^h)/dt = \kappa\frac{1}{\overline{P}}\left[\frac{1}{\overline{P}}f_D\sigma_D + 2p_{\Delta}\sigma_D + 2p_{\Lambda}\right][e_{\Delta}\sigma_D + e_{\Lambda}] < 0. \tag{A26}$$

This follows from $[e_{\Delta}\sigma_D + e_{\Lambda}] < 0$ and $\frac{1}{\overline{P}}f_D\sigma_D + 2p_{\Delta}\sigma_D + 2p_{\Lambda} + e_{\Delta}\sigma_D + e_{\Lambda} > 0$.

Corollary A.2 (Rebalancing for Different FX Supply Elasticities). The instantaneous variance of the excess return process can be derived as

$$Var\left(dr_t^f - dr_t^h\right) = \frac{1}{\overline{P}^2}\mathcal{E}_t\left(dR_t^f - dR_t^h\right)\left(dR_t^f - dR_t^h\right) =$$

$$= \frac{2}{\overline{P}^2}\left[\overline{P}(e_\Delta \sigma_D + e_\Lambda) + f_D\sigma_D + 2p_\Delta\sigma_D + 2p_\Lambda\right]^2 dt. \qquad \text{(A27)}$$

Using the covariance term in Equation (A25), we obtain for the OLS regression coefficient

$$\beta = \frac{Cov\left(dH_t^f, dr_t^f - dr_t^h\right)}{Var\left(dr_t^f - dr_t^h\right)} = \frac{\kappa(e_\Delta\sigma_D + e_\Lambda)}{2\left[\overline{P}(e_\Delta\sigma_D + e_\Lambda) + f_D\sigma_D + 2p_\Delta\sigma_D + 2p_\Lambda\right]} < 0. \qquad \text{(A28)}$$

We note that the endogenous terms $\overline{P}$, p_Δ, p_Λ, e_Δ, and e_Λ in Equation (A28) generally depend on the exogenous parameter κ. We verify

$$\frac{d\beta}{dVol^{FX}} < 0$$

numerically for a large variety of exogenous parameters. Figure 1, panel B, provides a parametric plot of $\beta(\kappa)$ and $dVol^{FX}(\kappa)$ for $\kappa \in [100, 5000]$.

Appendix B: Data

FactSet/LionShares provides three different data files: (i) the "holding master file," (ii) the "fund file," and (iii) the "entity (institution) file." The first file provides the fund positions on a quarterly frequency, while the other two give information on fund and institutional investor characteristics. For our analysis, we use only the "holding master file," which reports the FactSet fund identifier, the CUSIP stock identifier, the number of stock positions, the reporting date, the country domicile of the fund, the stock price on the reporting date, and the number of shares outstanding at the reporting date. We complement the FactSet/LionShares data with data from Datastream, which provides the total stock return index (assuming dividends are reinvested and correcting for stock splits) for each stock, the country of stock domicile/listing, the currency of the stock listing, and the exchange rate. In a first step, we match holding data for each fund with holding data in the same fund in the two previous quarters. Holding data for which no holding date is reported in the previous quarter are discarded. Additional holding data from quarter $t-2$ are matched whenever available. For each fund, we retain only the latest reporting date within a quarter. The stock price, total return index, and exchange rate data are matched for the same reporting date as stated in the holding data. Similar to Calvet, Campbell, and Sodini (2009), we use a sequence of data filters to eliminate the role of reporting errors in the data. We focus on the four largest fund domiciles—namely, the United States, the United Kingdom, the Eurozone, and Canada.[39] All small funds with a capitalization of less than \$10 million are deleted. These small funds might represent incubator funds or other nonrepresentative entities. Funds with a growth in total assets over the quarter of more than 200% or less than −50% are also discarded. Finally, we treat as missing those stock observations for which the return exceeds 500% or is below −80% over the quarter. Missing observations do not enter into the calculation of the stock weights or the foreign excess returns. We use filters discarding potential reporting errors and typos such as (i) positions with negative holdings, (ii) positions with missing or negative prices, (iii) positions larger than \$30 billion, and (iv) positions for which

39 As previously stated, we define the Eurozone as the original 11 members in 1999: Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain.

the combined stock capitalization (in this dataset) exceeds \$300 billion. Two additional selection criteria guarantee a minimal degree of fund diversification. First, we ignore funds with fewer than five foreign and five domestic stocks in their portfolio. Pure country funds or pure domestic funds are therefore excluded from the sample. Second, all funds with a Herfindahl-Hirschman index over all stock weights above 20% are discarded. This fund concentration threshold is surpassed if a fund holds more than $\sqrt{0.2} \approx 0.447\%$ in a single stock. Funds with such extreme stock weights are unlikely to exhibit much consideration for risk diversification. The latter criterion eliminates approximately 0.1% of fund quarters from the sample.

Appendix C: Granular Instruments

This section outlines the conditions under which the granular instrumental variable (GIV) estimator discussed in Section 4.2 provides consistent estimates for the FX supply elasticity parameter. Our exposition closely follows Section 2.3 in Gabaix and Koijen (2020). For the aggregate currency supply change for country c (relative to the rest of the world), we assume a linear function

$$\Delta Q^S_{c,t} = -\kappa \Delta E_{c,t} + \varepsilon_t \tag{C1}$$

analogous to Equation (24) in Gabaix and Koijen (2020) with $\kappa > 0$. The term ϵ_t allows for additional supply shocks that were ignored in the theoretical model in Section 1.

The demand side in the FX market is composed of a set of home funds ($j \in D_c$) with foreign equity positions ($\Delta h^f_{j,t} > 0$ implies home outflows and a positive foreign currency demand) and a set of overseas funds ($j \in F_c$) invested in the home country ($\Delta h^{h*}_{j,t} > 0$ implies home inflows and a negative foreign currency demand). The respective rebalancing is characterized by

$$\begin{aligned} \Delta h^f_{j,t} &= \beta(r^f_{j,t} - r^h_{j,t}) + \eta_{c,t} + u_{j,t} \quad \text{for } j \in D_c \\ \Delta h^{h*}_{j,t} &= \beta(r^{h*}_{j,t} - r^{f*}_{j,t}) + \eta^*_{c,t} + u^*_{j,t} \quad \text{for } j \in F_c \end{aligned}, \tag{C2}$$

where $r^f_{j,t} - r^h_{j,t}$ and $r^{h*}_{j,t} - r^{f*}_{j,t}$ denote the foreign excess returns in the fund domicile currency, respectively, and $\beta < 0$ characterizes rebalancing away from the location of excess returns. Here $\eta_{c,t}$ and $u_{j,t}$ denote the common and idiosyncratic components of rebalancing not captured by the excess return, respectively. We assume that the idiosyncratic fund-level errors are orthogonal to the common error and the supply shock; that is, $\mathcal{E}_t[u_{j,t}\eta_{c,t}] = \mathcal{E}_t[u^*_{j,t}\eta^*_{c,t}] = \mathcal{E}_t[u_{j,t}\varepsilon_t] = \mathcal{E}_t[u^*_{j,t}\varepsilon_t] = 0$.

Next, we express the fund excess returns on foreign equity as deviations from the aggregate excess returns—that is,

$$\begin{aligned} r^f_{j,t} - r^h_{j,t} &= r^f_t - r^h_t + \upsilon_{j,t} \quad \text{for } j \in D \\ r^{h*}_{j,t} - r^{f*}_{j,t} &= r^{h*}_t - r^{f*}_t + \upsilon^*_{j,t} \quad \text{for } j \in F_c \end{aligned}. \tag{C3}$$

Again, we assume that idiosyncratic fund-level error terms $\upsilon_{j,t}$ and $\upsilon^*_{j,t}$ are orthogonal to the aggregate error terms $\eta_{c,t}$, $\eta^*_{c,t}$, and ε_t. From Hau and Rey (2006), the aggregate excess returns in turn relate to the exchange rate change as follows:

$$r^f_t - r^h_t = -\left(r^{h*}_t - r^{f*}_t\right) = \theta \Delta E_{c,t} + \vartheta_{c,t} , \tag{C4}$$

where $\vartheta_{c,t}$ denotes an aggregate error term orthogonal to the fund-level shocks; that is, $\mathcal{E}_t[u_{j,t}\vartheta_{c,t}] = \mathcal{E}_t[u^*_{j,t}\vartheta_{c,t}] = \mathcal{E}_t[\upsilon_{j,t}\vartheta_{c,t}] = \mathcal{E}_t[\upsilon^*_{j,t}\vartheta_{c,t}] = 0$. A foreign stock excess return ($r^f_t - r^h_t > 0$) often coincides with a home currency appreciation ($\Delta E_{c,t} > 0$), and hence $\theta > 0$. For empirical evidence on this uncovered equity parity condition, see Hau and Rey (2006).

Substitution of Equations (C3–C4) into Equation (C2) yields

$$\begin{aligned}\Delta h^{f}_{j,t} &= \beta\theta\Delta E_{c,t}+\widetilde{\eta}_{c,t}+\widetilde{u}_{j,t} \quad \text{for } j\in D_c \\ \Delta h^{h*}_{j,t} &= -\beta\theta\Delta E_{c,t}+\widetilde{\eta}^{*}_{c,t}+\widetilde{u}^{*}_{j,t} \quad \text{for } j\in F_c\end{aligned}, \tag{C5}$$

where we define linear combinations of errors as $\widetilde{\eta}_{c,t}=\beta\vartheta_{c,t}+\eta_{c,t}$, $\widetilde{\eta}^{*}_{c,t}=-\beta\vartheta_{c,t}+\eta^{*}_{c,t}$ and $\widetilde{u}_{j,t}=\beta\upsilon_{j,t}+u_{j,t}$, $\widetilde{u}^{*}_{j,t}=\beta\upsilon^{*}_{j,t}+u^{*}_{j,t}$. The new idiosyncratic (fund-level) errors $\widetilde{u}_{j,t}$ and $\widetilde{u}^{*}_{j,t}$ are orthogonal to the aggregate errors $\widetilde{\eta}_{c,t}$, $\widetilde{\eta}^{*}_{c,t}$, and ε_t because their components are orthogonal.

It is useful to define a value-weighted aggregation operator (with superscript Net) for any fund-level variable $y_{j,t}$ as

$$y^{Net}_{c,t}=\frac{2\mu_c}{A^{f}_{c,t-1}}\sum_{j\in D_c} y_{j,t}\times a^{f}_{j,t-1}-\frac{2(1-\mu_c)}{A^{c*}_{c,t-1}}\sum_{j\in F_c} y^{*}_{j,t}\times a^{h*}_{j,t-1}, \tag{C6}$$

where we denote fund capitalizations as $a^{f}_{j,t-1}$ and $a^{h*}_{j,t-1}$, and their respective country aggregates as $A^{f}_{c,t-1}$, $A^{h*}_{c,t-1}$, respectively. The aggregate currency demand from investor rebalancing in currency c follows as

$$\Delta Q^{D}_{c,t}=\overline{PH}\ \Delta H^{Net}_{c,t}=\overline{PH}\ \beta\theta\Delta E_{c,t}+\overline{PH}\ \widetilde{\eta}^{Net}_{c,t}+\overline{PH}\ \widetilde{u}^{Net}_{j,t}, \tag{C7}$$

where we find for the (aggregate) common error $\widetilde{\eta}^{Net}_{c,t}=2\mu_c\widetilde{\eta}_{c,t}-2(1-\mu_c)\widetilde{\eta}^{*}_{c,t}$. The previous orthogonality conditions imply $\mathcal{E}_t[\widetilde{u}^{Net}_{j,t}\widetilde{\eta}^{Net}_{c,t}]=\mathcal{E}_t[\widetilde{u}^{Net}_{j,t}\varepsilon_t]=0$. We note that the currency demand $\Delta Q^{D}_{c,t}$ is (like the supply) an increasing function in $-\Delta E_{c,t}$ because $-\overline{PH}\beta\theta>0$. As a stability condition, we impose $\kappa>\overline{\kappa}=-\overline{PH}\beta\theta$.

Equating changes in currency demand and supply ($\Delta Q^{D}_{c,t}=\Delta Q^{S}_{c,t}$) implies for the equilibrium exchange rate change

$$-\Delta E_{c,t}=\frac{\overline{PH}\ \widetilde{\eta}^{Net}_{c,t}+\overline{PH}\ \widetilde{u}^{Net}_{j,t}-\varepsilon_t}{\kappa+\overline{PH}\ \beta\theta}\quad. \tag{C8}$$

Equation (C8) has the same structure as Equation (25) in Gabaix and Koijen (2020). The elasticity of supply is $\frac{\kappa}{\overline{PH}}$, and the elasticity of demand is $\beta\theta$.

Equations (34–35) define the granular instrumental variable $z_{c,t}\equiv GIV(\Delta H^{Net}_{c,t})$. By construction, $z_{c,t}$ is a linear (size-weighted) combination of idiosyncratic fund-level errors only, which are by assumption orthogonal to $\widetilde{\eta}^{Net}_{c,t}$ and ε_t, and hence

$$\mathcal{E}_t[\widetilde{\eta}^{Net}_{c,t}z_{c,t}]=\mathcal{E}_t[\varepsilon_t z_{c,t}]=0. \tag{C9}$$

The relevance of the instrument follows from

$$\mathcal{E}_t[-\Delta E_{c,t}z_{c,t}]=\frac{1}{\frac{\kappa}{\overline{PH}}+\beta\theta}\mathcal{E}_t[\widetilde{u}^{Net}_{j,t}z_{c,t}]\neq 0. \tag{C10}$$

The moment condition $\mathcal{E}_t[(\Delta Q^{S}_{c,t}+\kappa\Delta E_{c,t})z_{c,t}]=0$ implies that the inverse of the supply elasticity parameter is characterized by

$$\frac{1}{\kappa}=\frac{\mathcal{E}_t[-\Delta E_{c,t}z_{c,t}]}{\mathcal{E}_t[(\Delta Q^{S}_{c,t}z_{c,t}]}=\frac{\mathcal{E}_t[-\Delta E_{c,t}z_{c,t}]}{\overline{PH}\mathcal{E}_t[\Delta H^{Net}_{c,t}z_{c,t}]}, \tag{C11}$$

and the corresponding intrumental variable (IV) estimator follows, as

$$\widehat{\frac{\overline{PH}}{\kappa}}=\frac{\frac{1}{T}\sum_{c,t}-\Delta E_{c,t}z_{c,t}}{\frac{1}{T}\sum_{c,t}\Delta H^{Net}_{c,t}z_{c,t}} \tag{C12}$$

is consistent. Equation (C11) corresponds to Equation (30) in Gabaix and Koijen (2020). In Section 4.2, we describe the equivalent two-step estimator in Equations (36–37), which projects first the net equity flows $\Delta H^{Net}_{c,t}$ onto $z_{c,t}$ and then the exchange rate change $-\Delta E_{c,t}$ onto the predicted values $\Delta\widehat{H}^{Net}_{c,t}$.

References

Adrian, T., E. Etula, and H. S. Shin. 2015. Risk appetite and exchange rates. Working Paper, Federal Reserve Bank of New York.

Albuquerque, R., G. H. Bauer, and M. Schneider. 2007. International equity flows and returns: A quantitative equilibrium approach. *Review of Economic Studies* 74:1–30.

Bacchetta, P., M. Davenport, and E. Van Wincoop. Forthcoming. Can sticky portfolios explain international capital flows and asset prices? *Journal of International Economics*.

Bacchetta, P., and E. Van Wincoop. 2010. Infrequent portfolio decisions: A solution to the forward discount puzzle. *American Economic Review* 100:870–904.

Basak, S., and A. Pavlova. 2013. Asset prices and institutional investors. *American Economic Review* 103:1728–58.

Benetrix, A. S., P. R. Lane, and J. C. Shambaugh. 2015. International currency exposures, valuation effects and the global financial crisis. *Journal of International Economics* 96:S98–S109.

Blanchard, O., F. Giavazzi, and F. Sá. 2005. International investors, the U.S. current account, and the dollar. *Brookings Papers on Economic Activity* 1:1–65.

Bohn, H., and L. L. Tesar. 1996. U.S. equity investment in foreign markets: Portfolio rebalancing or return chasing? *American Economic Review* 86:77–81.

Branson, W. H., and D. W. Henderson. 1985. The specification and influence of asset markets. *Handbook of International Economics* 2:749–805.

Brennan, M. J., and H. H. Cao. 1997. International portfolio investment flows. *Journal of Finance* 52:1851–80.

Broner, F. A., R. G. Gelos, and C. M. Reinhart. 2006. When in peril, retrench: Testing the portfolio channel of contagion. *Journal of International Economics* 69:203–30.

Bruno, V., and H. S. Shin. 2014. Cross-border banking and global liquidity. *Review of Economic Studies* 82:535–64.

Caballero, R. J., and A. Simsek. 2020. A model of fickle capital flows and retrenchment. *Journal of Political Economy* 128:2288–2328.

Calvet, L. E., J. Y. Campbell, and P. Sodini. 2009. Fight or flight? Portfolio rebalancing by individual investors. *Quarterly Journal of Economics* 124:301–48.

Chan, K., V. Covrig, and L. Ng. 2005. What determines the domestic bias and foreign bias? Evidence from mutual fund equity allocations worldwide. *Journal of Finance* 60:1495–1534.

Coeurdacier, N. 2009. Do trade costs in goods market lead to home bias in equities? *Journal of International Economics* 77:86–100.

Coeurdacier, N., and H. Rey. 2013. Home bias in open economy financial macroeconomics. *Journal of Economic Literature* 51:63–115.

Coimbra, N., and H. Rey. 2017. Financial cycles with heterogeneous intermediaries. Working Paper No. w23245, National Bureau of Economic Research.

Della Corte, P., L. Sarno, and G. Sestieri. 2012. The predictive information content of external imbalances for exchange rate returns: How much is it worth? *Review of Economics and Statistics* 94:100–115.

Devereux, M. B., and A. Sutherland. 2010. Valuation effects and the dynamics of net external assets. *Journal of International Economics* 80:129–43.

———. 2011. Country portfolios in open economy macro-models. *Journal of the European Economic Association* 9:337–69.

Dou, W. W., and A. Verdelhan. 2015. The volatility of international capital flows and foreign assets. Working Paper, Massachusetts Institute of Technology.

Driskill, R., and S. McCafferty. 1980. Exchange-rate variability, real and monetary shocks, and the degree of capital mobility under rational expectations. *Quarterly Journal of Economics* 95:577–86.

Dziuda, W., and J. Mondria. 2012. Asymmetric information, portfolio managers, and home bias. *Review of Financial Studies* 25:2109–54.

Evans, M. D., and R. K. Lyons. 2002. Order flow and exchange rate dynamics. *Journal of Political Economy* 110:170–80.

Ferreira, M. A., and P. Matos. 2008. The colors of investors' money: The role of institutional investors around the world. *Journal of Financial Economics* 88:499–533.

Frankel, J. A. 1982a. In search of the exchange risk premium: A six-currency test assuming mean-variance optimization. *Journal of International Money and Finance* 1:255–74.

———. 1982b. A test of perfect substitutability in the foreign exchange market. *Southern Economic Journal* 49:406–16.

Fratzscher, M., L. Juvenal, and L. Sarno. 2010. Asset prices, exchange rates and the current account. *European Economic Review* 54:643–58.

French, K. R., and J. M. Poterba. 1991. Investor diversification and international equity markets. *American Economic Review* 81:222–26.

Froot, K. A., P. G. O'Connell, and M. S. Seasholes. 2001. The portfolio flows of international investors. *Journal of Financial Economics* 59:151–93.

Froot, K. A., and T. Ramadorai. 2005. Currency returns, intrinsic value, and institutional-investor flows. *Journal of Finance* 60:1535–66.

Gabaix, X., and R. S. Koijen. 2020. Granular instrumental variables. Working Paper No. w28204, National Bureau of Economic Research.

Gabaix, X., and M. Maggiori. 2015. International liquidity and exchange rate dynamics. *Quarterly Journal of Economics* 130:1369–420.

Gourinchas, P.-O., and H. Rey. 2007. International financial adjustment. *Journal of Political Economy* 115:665–703.

Hau, H., M. Massa, and J. Peress. 2009. Do demand curves for currencies slope down? Evidence from the MSCI Global Index change. *Review of Financial Studies* 23:1681–717.

Hau, H., and H. Rey. 2002. Exchange rate, equity prices and capital flows. Working Paper No. w9398, National Bureau of Economic Research.

———. 2006. Exchange rates, equity prices, and capital flows. *Review of Financial Studies* 19:273–17.

———. 2008. Home bias at the fund level. *American Economic Review* 98:333–38.

Jeanne, O., and D. Sandri. 2020. Global financial cycle and liquidity management. Working Paper No. w27901, National Bureau of Economic Research.

Koijen, R. S., and M. Yogo. 2019. A demand system approach to asset pricing. *Journal of Political Economy* 127:1475–515.

———. 2020. Exchange rates and asset prices in a global demand system. Working Paper No. w27342, National Bureau of Economic Research.

Kouri, P. J. 1976. The exchange rate and the balance of payments in the short run and in the long run: A monetary approach. *Scandinavian Journal of Economics* 78:280–304.

———. 1983. Balance of payment and the foreign exchange market: A dynamic partial equilibrium model. In J. S. Bhandari and B. H. Putnam (Eds.), *Economic Interndependence and Flexible Exchange Rates*, 116–56. Cambridge, MA: MIT Press.

Kouri, P. J., J. B. De Macedo, W. S. Salant, and M. v. N. Whitman. 1978. Exchange rates and the international adjustment process. *Brookings Papers on Economic Activity* 1:111–57.

Lane, P. R., and G. M. Milesi-Ferretti. 2007. A global perspective on external positions. In R. H. Clarida (Ed.), *G7 current account imbalances: Sustainability and adjustment*, 67–102. Chicago: University of Chicago Press.

———. 2017. International financial integration in the aftermath of the global financial crisis. Working Paper No. 17/115, International Monetary Fund.

Lane, P. R., and J. C. Shambaugh. 2010. Financial exchange rates and international currency exposures. *American Economic Review* 100:518–40.

Lee, A. S. 2021. Implications of infrequent portfolio adjustment for international portfolio choices. Working Paper, University of Wisconsin–Madison.

Levich, R. M., G. S. Hayt, and B. A. Ripston. 1998. Survey of derivatives and risk management practices by U.S. institutional investors. Working Paper, Leonard N. Stern School of Business.

Lewis, K. K. 1999. Trying to explain home bias in equities and consumption. *Journal of Economic Literature* 37:571–608.

Liao, G., and T. Zhang. 2020. The hedging channel of exchange rate determination. Working Paper, Federal Reserve Board.

Lilley, A., M. Maggiori, B. Neiman, and J. Schreger. 2020. Exchange rate reconnect. *Review of Economics and Statistics,* 1–28.

Maggiori, M., B. Neiman, and J. Schreger. 2020. International currencies and capital allocation. *Journal of Political Economy* 128:2019–66.

Portes, R., and H. Rey. 2005. The determinants of cross-border equity flows. *Journal of International Economics* 65:269–96.

Raddatz, C., S. Schmukler, and T. Williams. 2017. International asset allocations and capital flows: The benchmark effect. *Journal of International Economics* 108:413–30.

Rogoff, K. 1984. On the effects of sterilized intervention: An analysis of weekly data. *Journal of Monetary Economics* 14:133–50.

Sandulescu, M., F. Trojani, and A. Vedolin. 2021. Model-free international stochastic discount factors. *Journal of Finance* 76:935–76.

Stavrakeva, V., and J. Tang. 2018. The dollar during the Great Recession: US monetary policy signaling and the flight to safety. Working Paper, Federal Reserve Bank of Boston.

———. 2020. Deviations from fire and exchange rates: A GE theory of supply and demand. Working Paper, Federal Reserve Bank of Boston.

Tille, C. 2008. Financial integration and the wealth effect of exchange rate fluctuations. *Journal of International Economics* 75:283–94.

Tille, C., and E. Van Wincoop. 2010. International capital flows. *Journal of International Economics* 80:157–75.

Vayanos, D., and P. Woolley. 2013. An institutional theory of momentum and reversal. *Review of Financial Studies* 26:1087–145.