

# Global Portfolio Rebalancing and Exchange Rates

Nelson Camanho

Queen Mary University of London<sup>1</sup>

Harald Hau

University of Geneva, CEPR and Swiss Finance Institute<sup>2</sup>

Hélène Rey

London Business School, CEPR and NBER<sup>3</sup>

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## Abstract

We examine international equity allocations at the fund level and show how excess foreign returns influence portfolio rebalancing and capital flows. Our equilibrium model of incomplete 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 funds depending on their characteristics. A granular instrumental variable (GIV) approach identifies a currency supply elasticity suggesting that an equity outflow shock of US\$3.9 billion depreciates the dollar by roughly 1 percent.

**JEL Classification:** G23, G15, G11

**Keywords:** International equity funds, portfolio rebalancing, valuation channel, granular instruments (GIV), exchange rates, capital flows

<sup>1</sup>School of Economics and Finance, Mile End Road, London E1 4NS, United Kingdom. Email: [n.camanho@qmul.ac.uk](mailto:n.camanho@qmul.ac.uk).

<sup>2</sup>Geneva Finance Research Institute, 42 Bd du Pont d'Arve, 1211 Genève 4, Switzerland. E-mail: [prof@haraldhau.com](mailto:prof@haraldhau.com).

<sup>3</sup>Department of Economics, Regent's Park, London NW1 4SA, United Kingdom. E-mail: [hrey@london.edu](mailto:hrey@london.edu).

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# 1 Introduction

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 cross-border assets and liabilities have increased dramatically from around 60% of world GDP in the mid-1990s to approximately 200% in 2015 (Lane and Milesi-Ferretti (2017)).<sup>1</sup> 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.<sup>2</sup> Valuation effects impact the portfolio allocation decisions of investors and may trigger capital flows.<sup>3</sup> Most transactions on the foreign exchange market are due to asset trade rather than goods trade. 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 the 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, 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 determination based on capital flows and imperfect financial integration. One prominent exception is Gabaix and Maggiori (2015) where exchange rate changes follow from financial flows induced by trade in 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

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<sup>1</sup>They peaked at slightly more than 200% in 2007, at the eve of the financial crisis. We use the Coordinated Portfolio Investment Survey (CPIIS) 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.

<sup>2</sup>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 (Forthcoming).

<sup>3</sup>Portes and Rey (2005) provide an early study of the geography of capital flows. Lilley et al. (2019) show a strong correlation between portfolio flows and exchange rates for the recent period.

on [Hau and Rey \(2006\)](#), does not model the goods market, but focuses instead on international *trade in assets* and its interactions with the foreign exchange market. In this respect, we follow the spirit of portfolio balance models in international finance pioneered by [Kouri \(1976\)](#), [Kouri \(1982\)](#) and [Kouri et al. \(1978\)](#) who model the joint behavior of asset prices (bonds and equity) and of the exchange rate.<sup>4</sup> 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 \(2015\)](#), where demand for foreign exchange is driven solely by goods trade as their model features no endogenous asset trade nor optimal portfolio choice.

Our model features 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 where net currency demand meets the supply of risk averse foreign exchange arbitrageurs. Our approach is closely related to the recent paper of [Kojien 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 policy. Like us they also assume that risky asset prices and exchange rates are jointly determined. Importantly, this allows for substitution effect across assets to affect the exchange rate. Building on [Kojien and Yogo \(2019\)](#), they estimate an entire demand system using cross-country aggregate holdings for 36 countries and can decompose asset prices in three sources of variation: policy variables, macroeconomic factors and latent demand. We focus instead on the interaction between equity portfolios at the fund level and differential in equity returns and use a granular instrumental variable approach to estimate the effect of equity flows on currencies.<sup>5</sup>

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.<sup>6</sup> 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 influence

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<sup>4</sup>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.

<sup>5</sup>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 focused on goods markets. It has had difficulty to match exchange rate dynamics. [Bacchetta and Van Wincoop \(2010\)](#) model agents who infrequently rebalance their portfolio in an overlapping generations (OLG) setting. [Sandulescu, Trojani, and Vedolin \(2018\)](#) 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 \(2016\)](#) and [Jeanne and Sandri \(2017\)](#) 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.

<sup>6</sup>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, have an impact on rebalancing behavior.

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.<sup>7</sup> 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.
3. Quantile regressions show that the strength of the rebalancing dynamics is non-linear in the return difference between a fund’s foreign and domestic equity investments. The strength of the rebalancing increases disproportionately as the performance difference between the foreign and domestic portfolio share increases. Transaction costs are a plausible explanation for this non-linearity.
4. Stronger fund-level rebalancing is associated with more concentrated asset 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. We estimate an elasticity of foreign exchange supply which implies that roughly US\$3.9bn in equity outflows are needed to depreciate the US dollar by 1 percent.

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.

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<sup>7</sup>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 [Coerdacier and Rey \(2013\)](#)). For a detailed study of home bias at the fund level, see [Hau and Rey \(2008\)](#).

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 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. [Froot and Ramadorai \(2005\)](#) explore links between asset prices and equity flows at a more granular level.<sup>8</sup> 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 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 (see e.g. [Adrian, Etula, and Shin \(2010\)](#), [Vayanos and Woolley \(2013\)](#), [Dziuda and Mondria \(2012\)](#), [Basak and Pavlova \(2013\)](#) and [Bruno and Shin \(2014\)](#)).

The remainder of the paper is organized as follows. In Section 2 we present a simple two-country model with partially segmented asset markets. Its parsimonious microeconomic structure allows us to derive testable propositions about the joint dynamics of equity returns, exchange rates, and asset rebalancing. In Section 3 we discuss the microdata on fund asset holdings. Section 4 presents our empirical results at the fund level. Section 4.1 reports the main microevidence on portfolio rebalancing. Section 4.2 documents that such rebalancing intensifies under higher exchange rate volatility. Section 4.3 explores non-linearities in rebalancing at different quantiles of the foreign excess return distribution; and Section 4.4 shows how fund characteristics influence portfolio rebalancing. Section 5.1 is dedicated to the links between exchange rate and aggregate equity fund flows. In Section 5.2 we propose a granular instrumental variable strategy to infer the supply elasticity of the exchange rate and estimate the causal effect of flows on the currency. Section 6 offers some alternative interpretations and Section 7 concludes.

## 2 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-

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<sup>8</sup>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.

averse global intermediary. The model builds on [Hau and Rey \(2002\)](#) and [Hau and Rey \(2006\)](#).

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 investor. 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 the home and foreign investor maximize a myopic 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 completely price elastic.

Both representative investors solve the optimization problem

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

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 the home and foreign investor, respectively, we can denote the stochastic profit flows as

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

respectively. The investor risk aversion is denoted by  $\rho$  and the domestic riskless rate is given by  $r$  in each country. The myopic investor objectives assure linear asset demand functions and 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 investor can be thought of as aggregating a unit interval of identical atomistic individual investors without any individual price impact.

Market clearing in the equity market requires

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

because we normalize the asset supply to one. Due to market clearing in equity markets, 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 risk-less 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. The supply of bonds is fully elastic in each country. In other words, both equity markets can experience independent changes in their investor composition so that net equity flows are generally non-zero.

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 price 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 and the U.S. as the foreign country, then  $dQ_t$  represents the net capital outflow out of the Eurozone into the U.S. 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

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

where  $\bar{E} = 1$  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  $\kappa$  reflects their risk aversion or their capital constraints. The reduced form assumption in Eq. (5) could be generalized to account for interest differentials by adding a foreign currency supply component that increases in the differences between the home and foreign (risk-less) interest rate [i.e. a term  $\kappa_2(r - r^*)$  with  $\kappa_2 > 0$ ]. We assume zero interest differential ( $r = r^*$ ) for simplicity. A higher exchange rate level  $E_t > 1$  generates a

risk arbitrage opportunity if the expected long-run exchange rate is  $\mathcal{E}_t(E_{t+h}) \approx 1$  (for large  $h$ ). In other words, risk-arbitrage by bond investors with respect to uncovered interest parity violations also provides a justification of the reduced form assumption in Eq. (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 (US) trade surplus. At a longer horizon, the parameter  $\kappa$  could also depend on the elasticity of substitution between domestic and foreign goods and the degree of nominal rigidity in the good markets.

Combining Eqs. (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

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

In Section 5 of the paper we explore this aggregate relationship empirically and measure the last two terms by the (percentage) net aggregate equity flow  $\Delta H_t^{Net}$  relative to the (average) steady state value  $\overline{PH}$  of foreign asset positions.<sup>9 10</sup>

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

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

Second, for a linear solution to the model, we also need to linearize Eq. (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 two linearizations and reasonable parameter values.<sup>11</sup>

## 2.1 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.

<sup>9</sup>For percentage aggregate holding changes  $\Delta H_t^f = dH_t^f/H_t^f$  and  $\Delta H_t^{h*} = dH_t^{h*}/H_t^{h*}$ , and asset positions  $A_t^f = P_t^{f*} H_t^f$  and  $A_t^{h*} = E_t P_t^h H_t^{h*}$ , respectively, we can write net aggregate equity flow as

$$P_t^{f*} dH_t^f - E_t P_t^h dH_t^{h*} = \frac{1}{2} [A_t^f - A_t^{h*}] \Delta H_t^{Net} \approx \overline{PH} \Delta H_t^{Net},$$

where we define percentage net flows as  $\Delta H_t^{Net} = 2\mu_t \Delta H_t^f - 2(1 - \mu_t) \Delta H_t^{h*}$  with  $\mu_t = A_t^f / (A_t^f + A_t^{h*})$ .

<sup>10</sup>The active rebalancing of bond funds could induce additional confounding currency demands ignored in our model. However, bond investments are sometimes hedged in derivative markets, which should diminish their effect on exchange rates.

<sup>11</sup>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 portfolio internationally. Otherwise we revert to a corner solution of domestic investment only.

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

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

with constant terms defined as  $f_D = 1/(\alpha_D + r)$  and  $f_0 = (r^{-1} - f_D)\bar{D}$ . 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  $\Delta_t$  and  $\Lambda_t$  that embody the asset price dynamics around the fundamental value, that is

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

where  $dw_s = dw_s^h - dw_s^{f*}$  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  $\Lambda_t$  aggregates past dividend innovations with a different decay factor  $\alpha_\Lambda$ .<sup>12</sup>

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 ( $\rho < \bar{\rho}$ ). Under these conditions, the following unique equilibrium exists:

**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

$$P_t^h = p_0 + F_t^h + p_\Delta \Delta_t + p_\Lambda \Lambda_t \quad (10)$$

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

$$E_t = 1 + e_\Delta \Delta_t + e_\Lambda \Lambda_t \quad (12)$$

and dynamic portfolio holdings

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

where  $0 < \bar{H} \leq 0.5$  denotes the steady state holding of foreign assets and the coefficients  $p_0 < 0$ ,  $p_\Delta > 0$ ,  $p_\Lambda$ ,  $e_\Delta < 0$ ,  $e_\Lambda$ ,  $m_\Delta < 0$ , and  $m_\Lambda > 0$  are defined implicitly by the first-order and market

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<sup>12</sup>We note that the variance of the process  $\Lambda_t$  can be normalized to  $\sigma_\Lambda$  without loss of generality as parameters  $p_\Lambda$  and  $e_\Lambda$  in Proposition 1 (defined below) already scale the variance of the process.

clearing conditions stated in Appendix A. These parameters are functions of the six exogenous parameters  $\alpha_D$ ,  $\sigma_D$ ,  $\bar{D}$ ,  $r$ ,  $\kappa$  and  $\rho$ .

**Proof:** See Appendix A.

The home and foreign equity prices in Eqs. (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 price premium  $p_\Delta \Delta_t + p_\Lambda \Lambda_t$ , which moves the respective asset prices in opposite directions. A higher fundamental value for the home market (i.e.  $\Delta_t > 0$ ) inflates the home equity price further ( $p_\Delta > 0$ ), but decreases the exchange rate in Eq. (12) as  $e_\Delta < 0$ , which corresponds to a home (or Euro) depreciation. Intuitively, high home (Eurozone) equity valuations expose foreign (US) investors to more exchange rate risk so that they reduce their oversea equity position in Eurozone equity. The corresponding equity rebalancing from Euro denominated into Dollar denominated assets depreciates the Euro. The second  $2 \times 2$  matrix in Eq. (13) describes the steady state equity holdings with the endogenous home bias  $1 - \bar{H} > 0.5$ ; the third term in Eq. (13) characterizes the dynamic adjustment of the equity portfolios. As the diagonal elements add up to unity, market clearing is trivially assured. The stochastic term  $\frac{1}{2\rho} m_\Delta \Delta_t$  with  $m_\Delta < 0$  captures the reduced asset holding  $H_t^{h*}$  of the foreign investors in the home market whenever home equity valuations are relatively high (i.e.  $\Delta_t > 0$ ). 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 always 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  $\kappa \rightarrow \infty$ . In this special case all exchange rate volatility disappears ( $\bar{E}_t = 1$ ) 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  $\bar{H} \rightarrow 0.5$  and  $m_\Delta \rightarrow 0$ ,  $m_\Lambda \rightarrow 0$ . Both equity prices are then determined only by their domestic fundamentals.

## 2.2 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  $dr_t^f - dr_t^h = (dR_t^f - dR_t^h)/\bar{P}$  expressed in domestic currency feature a negative

covariance given by

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

and for the domestic stock investment of the foreign investor we have  $dH_t^{h*} = -dH_t^f$ .

**Proof:** See Appendix A.

Corollary 1 characterizes the rebalancing behavior  $dH_t^f$  in foreign equity by the representative home investor. It is derived 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 individual investment strategies deviate from the representative holdings due fund-specific beliefs about future stock returns. We pursue this analysis in Section 4.1. based on a linear regression model

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

where we predict for the rebalancing coefficient  $\beta < 0$ . Additional country-time and fund fixed effects can help to isolate the rebalancing component related to the fund-specific foreign excess return.

### 2.3 Comparative Statics in 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 FX supply elasticities  $\kappa \in [100, 1000]$ . The plot simulates a risk aversion  $\rho = 0.02$  and the parameters of the dividend process are set at  $\bar{D} = 1, r = 0.04, \alpha_D = 0.015$  and 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  $\sigma_D$  and risk aversion  $\rho$ , a lower FX supply elasticity  $\kappa$  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 can thus generate a higher level of FX volatility and increase the degree of equity market segmentation.

Our model does not feature any dynamic time variation in the parameter  $\kappa$ . 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 simple *comparative statics exercise* in the parameter  $\kappa$  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.<sup>13</sup>

**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  $\kappa$ . Formally, the rebalancing coefficient  $\beta$  decreases in FX volatility, that is,<sup>14</sup>

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

**Numerical simulation:** See Appendix A.

Figure 1, Panel B, plots the rebalancing coefficient  $\beta$  parametrically as a function of the instantaneous FX volatility for variations of the supply elasticity parameter  $\kappa \in [100, 1000]$ . 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, equivalent to a more intense rebalancing under higher FX volatility.

Corollary 2 suggest that episodes of higher FX volatility should coincide with a stronger and more negative rebalancing coefficient  $\beta$ . We can explore this prediction at the fund level by regressing foreign holding changes  $\Delta h_{j,t}^f$  over period  $t$  of fund  $j$  on the interaction terms  $(r_{j,t}^f - r_{j,t}^h) \times Vol_t^{FX}$  between a fund foreign excess return  $r_{j,t}^f - r_{j,t}^h$  and the the level of FX volatility  $Vol_t^{FX}$ . We expect the linear regression

$$\Delta h_{j,t}^f = \beta(r_{j,t}^f - r_{j,t}^h) + \gamma Vol_t^{FX} + \delta(r_{j,t}^f - r_{j,t}^h) \times Vol_t^{FX} + \mu_{j,t} \quad (18)$$

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.

### 3 Data

For data on global equity holdings we use FactSet/LionShares.<sup>15</sup> The data report individual mutual fund and other institutional holdings at the stock level. For investors in the U.S., the data are collected by the Securities and Exchange Commission (SEC) based on 13-F filings (fund family level) and N-SAR filings

<sup>13</sup>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.

<sup>14</sup>We compute  $\beta$  in Appendix A.

<sup>15</sup>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 slightly lower than those in the CPIS but still representative of foreign equity positions in the world economy.

(individual fund level). Outside the U.S., the sources are national regulatory agencies, fund associations, and fund management companies. The sample period covers the 16 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.<sup>16</sup>

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 CRPS (for U.S./Canadian stocks) and Datastream (for 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.<sup>17</sup> A more serious concern is that funds may carry out additional hedging operations that escape our inference. In spite of this data shortcoming, we believe that the analysis is still informative. 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.

To keep the data processing manageable, 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.<sup>18</sup> 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

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<sup>16</sup>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. [Froot, O'Connell, and Seasholes \(2001\)](#) high-frequency study 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.

<sup>17</sup>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.

<sup>18</sup>The Eurozone countries included in the sample are Austria, Belgium, Finland, France, Germany, Ireland, Italy, Luxembourg, the Netherlands, Portugal, and Spain.

feature in two consecutive quarters to be retained. Consecutive reporting dates are a pre-requisite 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 non-representative 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 renders funds with a narrow foreign or domestic investment mandate less interesting.<sup>19</sup>
- Non-diversified 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 return on combined equity holdings exceed 200% or if they lose more than 50% of their equity holdings value over a half-year. Individual stock observations are ignored if they feature extreme quarterly returns that exceed 500% or are below  $-80\%$ .<sup>20</sup>

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 are 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 U.S. 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 here are the (effective) exchange rate change of currency area  $c$  relative to the 10 other most important investment destinations, the aggregate rebalancing  $\Delta H_{c,t}^f$  from home to foreign investments for all funds domiciled within currency area  $c$ , and the reciprocal aggregate rebalancing  $\Delta H_{c,t}^{h*}$  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 casual effect of portfolio flows on the exchange rate.

<sup>19</sup>We are also unable to capture any "household rebalancing", which might consist of rebalancing out of foreign country funds into purely domestic equity funds.

<sup>20</sup>We discard very few observations this way. Extreme return values may be attributable to data errors.

## 4 Evidence on Portfolio Rebalancing

The model in Section 2 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 leads to appreciation of the domestic currency.

Using fund-level data tremendously increases the statistical power of any analysis of rebalancing behavior. We explore the role of FX volatility in Section 4.2, plausible non-linearities in rebalancing in Section 4.3, and the role of fund heterogeneity in Section 4.4. Our fund-level rebalancing variable  $\Delta h_{j,t}^f$  compares the *observed* foreign equity weights  $w_{j,t}^f$  of fund  $j$  at the end of period (quarter)  $t$  to the *implied* weights  $\widehat{w}_{j,t}^f$  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

$$\Delta h_{j,t}^f = w_{j,t}^f - \widehat{w}_{j,t}^f \quad \text{with} \quad \widehat{w}_{j,t}^f = w_{j,t-1}^f \left[ \frac{1 + r_{j,t}^f}{1 + r_{j,t}^P} \right], \quad (19)$$

where  $r_{j,t}^P$  represents the total portfolio return and  $r_{j,t}^f$  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,

$$w_{j,t}^f = \sum_{s=1}^{N_j} \mathbf{1}_{s=f} \times w_{s,j,t}, \quad (20)$$

where  $\mathbf{1}_{s=f}$  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  $w_{j,t}^f$  of each fund on the y-axis against the implied share  $\widehat{w}_{j,t}^f$  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  $\Delta h_{j,t}^f = w_{j,t}^f - \widehat{w}_{j,t}^f$  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  $r_{j,t}^P$  on fund  $j$  is defined as

$$r_{j,t}^P = \sum_{s=1}^{N_j} w_{s,j,t-1} r_{s,t} \quad , \quad (21)$$

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

$$r_{j,t}^f = \sum_{s=1}^{N_j} \frac{w_{s,j,t-1}}{w_{j,t-1}^f} r_{s,t} \times 1_{s=f} \quad r_{j,t}^h = \sum_{s=1}^{N_j} \frac{w_{s,j,t-1}}{w_{j,t-1}^h} r_{s,t} \times 1_{s=h} \quad (22)$$

## 4.1 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

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

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.<sup>21</sup> 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  $\varepsilon_j$  in most specifications. We note that a passive buy and hold strategy of an index produces  $\Delta h_{j,t}^f = 0$  and should imply a zero coefficient. Passive index investment will bias the coefficients  $\beta_l$  toward zero.

Table 2 reports the baseline results on the rebalancing behavior of international equity funds. Column (1) includes only the contemporaneous excess return  $r_{j,t}^f - r_{j,t}^h$  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  $r_{j,t}^f - r_{j,t}^h$  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 which should control for all macroeconomic effects such as common equity fund inflows in the investor domicile. The contemporaneous coefficient  $\beta_0$  and the lagged coefficient  $\beta_1$  are both negative at high levels of statistical

<sup>21</sup>The excess return of the foreign part of the portfolio over the home part of the portfolio  $r_{j,t-l}^f - r_{j,t-l}^h$  is measured in the currency of the fund domicile. Results are robust to an alternative specification where  $r_{j,t-l}^f - r_{j,t-l}^h$  is measured in local stock currency.

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  $r_{j,t-2}^f - r_{j,t-2}^h$  has some explanatory power for fund rebalancing, although the economic magnitude is weaker at  $-1.173$ .

Adding the three coefficients in Column (4) implies a combined rebalancing effect of  $-5.532$ . A relative quarterly excess return of two standard deviations (or  $0.140$ ) therefore implies a reduction in the foreign equity weight by  $0.774$  percentage points for the representative (foreign-invested) institutional investor.<sup>22</sup> In light of the large size of foreign equity positions valued at  $\$6.7$  trillion for U.S. investors in December 2015, this amounts to economically significant equity flows of  $\$52$  billion per quarter for U.S. equity investors alone.<sup>23</sup>

We also explore asymmetries in the rebalancing behavior of international investors by splitting the sample into negative and positive excess returns. Formally, we have

$$\Delta h_{j,t}^f = \sum_{l=0,1} \beta_l^+ (r_{j,t-l}^f - r_{j,t-l}^h) \times 1_{\Delta r \geq 0} + \sum_{l=0,1} \beta_l^- (r_{j,t-l}^f - r_{j,t-l}^h) \times 1_{\Delta r < 0} + \eta_{c,t} + \varepsilon_j + \mu_{j,t}, \quad (24)$$

where  $1_{\Delta r \geq 0}$  represents a dummy that is equal to 1 whenever the foreign excess return  $\Delta r = r_{j,t}^f - r_{j,t}^h \geq 0$  and 0 otherwise. The complementary dummy marking negative foreign excess returns is given by  $1_{\Delta r < 0}$ . The regression coefficients for the positive and negative components of the excess return 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 a separate foreign and home market return components, namely  $r_{j,t-l}^f$  and  $r_{j,t-l}^h$ . Again no evidence for an asymmetric rebalancing is found in these unreported regression results. Finally, we split the sample into a pre-crisis period up to June 2008 (Period I) and a crisis and post-crisis 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.

## 4.2 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

<sup>22</sup>We note that the dependent variable  $\Delta h_{j,t}^f$  is scaled by a factor of 100.

<sup>23</sup>Source: U.S. Portfolio Holdings of Foreign Securities as of December 3, 2015, U.S. Department of Treasury.

the  $N$  most important investment destinations indexed by  $i$ . Formally,

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

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 ten 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  $VOL_{c,t}^{FX}$  for quarter  $t$  is defined as the standard deviation of the daily return  $r_{c,d}^{FX} = \ln E_{c,d} - \ln E_{c,d-1}$  calculated for all trading days  $d$  of quarter  $t$ .<sup>24</sup> 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  $r_{j,t}^f - r_{j,t}^h$  with the contemporaneous measure of realized exchange rate volatility  $VOL_{c,t}^{FX}$ . The extended regression specification follows as

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

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

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  $VOL_{c,t}^{FX}$ , 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 towards home equity of 0.126% of funds under management ( $= -0.728 \times 0.1 \times 1.73$ ). The insignificant coefficient for the term  $r_{j,t}^f - r_{j,t}^h$  suggests that the intensity of rebalancing is approximately proportional to the realized volatility measure  $VOL_{c,t}^{FX}$ . Higher FX volatility increases the riskiness of the

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<sup>24</sup>For a total of  $D$  trading days in a given quarter  $t$ , realized volatility is calculated as follows

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

foreign equity share in the fund portfolio and thus strengthens the rebalancing motive. In Column (4) the interaction term  $(r_{j,t-1}^f - r_{j,t-1}^h) \times VOL_{c,t}^{FX}$  for lagged excess returns is also statistically significant and adds to the overall rebalancing flow. As noted before, fund rebalancing can occur with some time delay. We conclude that higher exchange rate volatility reinforces the rebalancing channel of international equity investment.

### 4.3 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 non-linear 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 differential 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  $\tau = 0.05, 0.15, 0.25, \dots, 0.85, 0.95$  of the distribution of holding changes.<sup>25</sup> Figure 4 plots the quantile coefficients  $\beta_0^\tau$  and  $\beta_1^\tau$  at lags 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  $\beta_1^\tau < 0$ , i.e., funds across all quantiles are willing to rebalance.

This means that the propensity to rebalance as a function of return 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 return differential  $r_{j,t-l}^f - r_{j,t-l}^h$ , 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 return differential on foreign and domestic equity positions. Hence, particularly large changes  $\Delta h_{j,t}^f$  at the edge of the rebalancing distribution contribute most to the average rebalancing effect captured by the 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.

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<sup>25</sup>We do not include time interacted with investor country fixed effects in the quantile regression specifications.

## 4.4 Fund Heterogeneity

The heterogeneous rebalancing responses of funds reported in Section 4.3 raise the question whether they are due to fund heterogeneity? Could the stronger rebalancing behavior shown in the tails of the  $\Delta h_{j,t}^f$  distribution be explained by differences in the 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  $w_{j,t}^f$ , 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  $\tau = 0.05, 0.15, 0.25, \dots, 0.85, 0.95$ . Vicinity means that observations associated with quantile  $\tau$  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  $(x_{j,t}, \Delta h_{j,t}^f)$  fulfill the conditions  $\Delta h_{j,t}^f - x_{j,t}\beta(\tau - .05) < 0$  and  $\Delta h_{j,t}^f - x_{j,t}\beta(\tau + .05) \geq 0$ . The regressors  $x_{j,t}$  are the same as in the quantile regression in Section 4.3 and include the excess return at lags  $l = 0, 1$ ; that is  $x_{j,t} = (r_{j,t}^f - r_{j,t}^h, r_{j,t-1}^f - r_{j,t-1}^h) \in \mathbb{R}^2$ . In other words, the vicinity space for each quantile  $\tau$  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 characterize the average and median fund size, foreign portfolio share and portfolio concentration along the various quantile regression lines, respectively. The average (median) fund size is less than one-third (one-half) at the edge of the distribution for the rebalancing statistics  $\Delta h_{j,t}^f$  than at its center. The strongest propensity to rebalance in reaction to return 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 return 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 Herfindahl-Hirschman Index (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.

## 5 Exchange Rate Effects of Portfolio Rebalancing

A key element of the equilibrium model developed in Section 2 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 5.1. We then proceed to estimate the causal effect of flows on the currency in Section 5.2 using a granular instrumental variable approach.

### 5.1 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  $c \in \{\text{U.S.}, \text{U.K.}, \text{Eurozone}, \text{Canada}\}$ , and  $F_c$  as the complementary set of all foreign funds domiciled in currency areas  $c' \in \{\text{U.S.}, \text{U.K.}, \text{Eurozone}, \text{Canada}\} \setminus \{c\}$ , 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  $a_{j,t-1}^f$  and the value of all equity positions in currency area  $c$  by a foreign fund  $j \in F_c$  be given by  $a_{j,t-1}^{h*}$ . 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

$$\begin{aligned} \Delta H_{c,t}^f &= \frac{1}{A_{c,t-1}^f} \sum_{j \in D_c} \Delta h_{j,t}^f \times a_{j,t-1}^f \quad \text{with} \quad A_{c,t-1}^f = \sum_{j \in D_c} a_{j,t-1}^f \\ \Delta H_{c,t}^{h*} &= \frac{1}{A_{c,t-1}^{h*}} \sum_{j \in F_c} \Delta h_{j,t}^{h*} \times a_{j,t-1}^{h*} \quad \text{with} \quad A_{c,t-1}^{h*} = \sum_{j \in F_c} a_{j,t-1}^{h*} \end{aligned} \quad (27)$$

respectively, where  $\Delta h_{j,t}^f$  denotes the fund-level rebalancing of home funds (domiciled in currency area  $c$ ) towards foreign equity (i.e., portfolio outflows from currency area  $c$ ) and  $\Delta h_{j,t}^{h*}$  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  $\Delta h$ , the aggregate rebalancing flows  $\Delta H$  represent percentage changes in the aggregate foreign equity position and therefore are not denominated in any currency. In the aggregation of the holding changes of individual funds, we ignore rebalancing events below the 2.5% and above the 97.5% percentile of the rebalancing statistics. This filter eliminates extremely large position changes that could originate in data errors rather than the rebalancing motive captured by our model. As extreme rebalancing events concerns mostly smaller funds, we effectively discard only 1.58% of the aggregate asset value under management.<sup>26</sup>

<sup>26</sup>We check robustness of the results with respect to 1%, 2% and 3% trimming thresholds. Our estimates are broadly unchanged.

Our model captures net aggregate flows as the last two terms in Eq.(6). For percentage aggregate holding changes  $\Delta H_{c,t+dt}^f = dH_{c,t}^f/H_{c,t}^f$  and  $\Delta H_{c,t+dt}^{h*} = dH_{c,t}^{h*}/H_{c,t}^{h*}$ , and asset positions  $A_{c,t}^f = P_{c,t}^{f*}H_t^f$  and  $A_{c,t}^{h*} = E_{c,t}P_{c,t}^hH_{c,t}^{h*}$ , respectively, we restate net aggregate equity flows as<sup>27</sup>

$$\begin{aligned} P_{c,t}^{f*}dH_{c,t}^f - E_{c,t}P_{c,t}^hdH_{c,t}^{h*} &= A_{c,t}^f\Delta H_{c,t+dt}^f - A_{c,t}^{h*}\Delta H_{c,t+dt}^{h*} \\ &= \frac{1}{2} \left[ A_{c,t}^f + A_{c,t}^{h*} \right] \left[ 2\mu_{c,t}\Delta H_{c,t+dt}^f - 2(1 - \mu_{c,t})\Delta H_{c,t+dt}^{h*} \right] \approx \overline{P\overline{H}}\Delta H_{c,t+dt}^{Net}, \end{aligned} \quad (28)$$

with percentage net flows defined as  $\Delta H_{c,t+dt}^{Net} \equiv 2\mu_{c,t}\Delta H_{c,t+dt}^f - 2(1 - \mu_{c,t})\Delta H_{c,t+dt}^{h*}$ . The parameter  $\mu_{c,t} \equiv A_{c,t}^f/(A_{c,t}^f + A_{c,t}^{h*})$  denotes the size of the 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 U.S., U.K., Eurozone, and Canada, respectively.

The correlation between aggregate equity rebalancing outflows and inflows and the quarterly effective (log) foreign currency appreciation  $-\Delta E_{c,t} = -[\ln E_{c,t} - \ln E_{c,t-1}]$  can be evaluated by the linear regressions

$$-\Delta E_{c,t} = \alpha\Delta H_{c,t}^{Net} + \epsilon_{c,t}, \quad (29)$$

where we pool observations across the four currency areas U.S., U.K., Eurozone, and Canada. We only include quarterly observations for a currency area if at least 20 fund observations are recorded.<sup>28</sup> Each currency area is in turn considered the home country with home funds accounting for aggregate rebalancing flows  $\Delta H_{c,t}^f$  and overseas funds contributing an aggregate rebalancing flow  $\Delta H_{c,t}^{h*}$ . The effective foreign currency appreciation  $-\Delta E_{c,t}$  (i.e., the relative depreciation of currency area  $c$  itself) is calculated based on fixed weights for the 10 most important outbound equity investment destinations as stated by Eq. (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  $\Delta H_{c,t}^f$  of funds incorporated in the home country and for the home country holding change  $\Delta H_{c,t}^{h*}$  of foreign funds. Column (2) reports corresponding results for the net flows  $\Delta H_{c,t}^{Net}$ , which account for values of  $\mu_{c,t}$  by currency area. The aggregate foreign holding decrease  $\Delta H_{c,t}^f > 0$  (or investment repatriation) indeed correlates with an appreciation of the foreign currency and a decrease in foreign fund investment at home  $\Delta H_{c,t}^{h*} < 0$  also correlates with an appreciation of the foreign currency. However, statistical significance at the conventional one percent 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%. The rebalancing model in Section 2 predicts a perfect negative correlation between  $\Delta H_{c,t}^f$  and  $\Delta H_{c,t}^{h*}$ , as well as between  $H_{c,t}^f$  and  $H_{c,t}^{h*}$ , but the empirical correlation is higher than -1 in both cases. Conceptually, any decrease in foreign equity ownership by home investors should be matched by an increase in home equity ownership by foreign investors

<sup>27</sup>In the discrete time framework, we give the percentage rebalancing  $\Delta h$  and  $\Delta H$  from (the end of) period  $t - 1$  to  $t$  the time index  $t$ , which corresponds to  $t + dt$  in continuous time.

<sup>28</sup>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.

— yet our data captures only institutional equity ownership for funds residing in our four currency areas. The imperfect negative correlation reflects our measurement problem with respect to the full universe of equity investors as well as measurement errors. The OLS coefficients in Table 4 therefore suffer from an attenuation bias.<sup>29</sup> We also explore time variation in the correlation between exchange rate movements and portfolio flows. First, a comparison between the recent period 2008-2015 in Column (6) with the pre-crisis period 1999-2007 in Column (4) suggests a higher correlation of flows and exchange rates after the crisis. Our regressions do not control for any of the common factors that may be driving equity flows and exchange rates. Hence we cannot assess the effect of capital flows on the currency based on these estimates. We take up this challenge in the next section.

## 5.2 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  $\kappa$ . To quantify this supply elasticity, we use disaggregate fund-level data and the granular instrumental variable (GIV) methodology proposed by [Gabaix and Koijen \(2020\)](#). While the theoretical model in Section 2 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. Here 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 Eq. (5) and assume

$$\Delta Q_{c,t}^S = -\kappa \Delta E_{c,t} + \varepsilon_t. \quad (30)$$

The error term  $\varepsilon_t$  allows for additional (liquidity) supply shocks that are not part of the theoretical model in Section 2. 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

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

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<sup>29</sup>If the measured aggregate rebalancing terms  $\Delta H_{c,t}^f$  and  $\Delta H_{c,t}^{f*}$  deviate from their true values by independent errors  $\varepsilon_1$  and  $\varepsilon_2$  of common variance  $\sigma_\varepsilon^2$  and zero mean, and the true rebalancing terms have a variance  $\sigma_H^2$  and also a zero mean, we find that the ratio of the error variance to the rebalancing variance follows as

$$\frac{\sigma_\varepsilon^2}{\sigma_H^2} = \frac{1}{\text{Corr}(\Delta H_{c,t}^f, \Delta H_{c,t}^{f*})} - 1.$$

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

$$\Delta Q_{c,t}^D = \overline{P\overline{H}} \Delta H_{c,t}^{Net} = \overline{P\overline{H}} \beta \overline{\theta} \Delta E_{c,t} + \overline{P\overline{H}} \tilde{\eta}_{c,t}^{Net} + \overline{P\overline{H}} \tilde{u}_{j,t}^{Net}, \quad (32)$$

where  $\tilde{\eta}_{c,t}^{Net}$  represents an aggregate error term,  $\tilde{u}_{j,t}^{Net}$  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  $\tilde{u}_{j,t}^{Net}$  capturing only idiosyncratic rebalancing with the aggregate error terms  $\tilde{\eta}_{c,t}^{Net}$  and with the FX supply shocks  $\varepsilon_t$ , that is

$$\mathcal{E}_t[\tilde{u}_{j,t}^{Net} \tilde{\eta}_{c,t}^{Net}] = \mathcal{E}_t[\tilde{u}_{j,t}^{Net} \varepsilon_t] = 0. \quad (33)$$

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  $z_{c,t}^{Outflows}$  denote the granular instrumental variable for the foreign investments of funds domiciled in currency area  $c$ ; and  $z_{c,t}^{Inflows}$  represent the granular instrumental variable for the domestic investments by funds domiciled outside currency area  $c$ :

$$\begin{aligned} z_{c,t}^{Outflows} &= \frac{1}{A_{c,t-1}^f} \sum_{j \in D_c} \Delta h_{j,t}^f \times a_{j,t-1}^f - \frac{1}{N_{D_c}} \sum_{j \in D_c} \Delta h_{j,t}^f \\ z_{c,t}^{Inflows} &= \frac{1}{A_{c,t-1}^{h*}} \sum_{j \in F_c} \Delta h_{j,t}^{h*} \times a_{j,t-1}^{h*} - \frac{1}{N_{F_c}} \sum_{j \in F_c} \Delta h_{j,t}^{h*}. \end{aligned} \quad (34)$$

In other words,  $z_{c,t}^{Outflows}$  is defined as the difference between the fund-size weighted and average weighted equity outflows by domestic funds in currency area  $c$  and  $z_{c,t}^{Inflows}$  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  $\Delta H_{c,t}^{Net}$  as

$$z_{c,t} \equiv GIV(\Delta H_{c,t}^{Net}) \equiv 2\mu_{c,t-1} z_{c,t}^{Outflows} - 2(1 - \mu_{c,t-1}) z_{c,t}^{Inflows}. \quad (35)$$

The parameters  $\mu_{c,t-1} \equiv A_{c,t-1}^f / (A_{c,t-1}^f + A_{c,t-1}^{h*})$  and  $1 - \mu_{c,t-1}$  denote again the relative size of outbound and inbound equity investments. The instrument  $z_{c,t}$  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  $\Delta H_{c,t}^{Net}$ . However, this idiosyncratic net flow component is still highly variable and represents a strong instrument for the aggregate net flows in a first stage regression.

$$\Delta H_{c,t}^{Net} = \alpha z_{c,t} + \epsilon_{c,t}. \quad (36)$$

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

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

the inverse of the supply elasticity parameter given by  $\frac{\overline{PH}}{\kappa} > 0$ .<sup>30</sup>

A successful identification of the supply elasticity hinges on the assumption that the instrument  $z_{c,t}$  filters all common or systematic fund rebalancing by forming the difference between value and equally weighted fund flows. However, in Section 4.4 we show that small and more concentrated equity funds rebalance more vigorously in response to excess returns on their foreign investment share. We can address this issue by constructing better instruments  $z_{c,t}$  from residual portfolio flows  $\Delta h_{j,t}^f - C_{j,t}\beta$  and  $\Delta h_{j,t}^{h*} - C_{j,t}\beta$ , where the predictable flow component  $C_{j,t}\beta$  is filtered. Natural candidates for such control variables  $C_{j,t}$  are the log fund size, the HHI of fund concentration, a fund's foreign excess return  $r_{j,t-l}^f - r_{j,t-l}^h$  (with lag  $l = 0, 1$ ), and the interaction terms of log fund size and HHI with a fund's foreign excess returns. In addition, we can add fund fixed effects to the control variables. In the results below we consider both the naive GIV specification (GIV1) where the common and systematic components are purged via differencing with the average net flows and the more comprehensive GIV specifications (GIV2 and GIV3) which also filter the known heterogeneity in the fund rebalancing. The specification GIV3 also takes out all trend growth in foreign investment shares by adding fund fixed effects.<sup>31</sup>

As pointed out in [Gabaix and Kojien \(2020\)](#) (in Proposition 3, page 13), the asymptotic variance of the GIV estimates can be reduced if we replace the equally weights  $\frac{1}{N}$  in Eqs. (34)-(35) by the so-called “precision-weighted quasi-equal weights” given by  $(1/\sigma_{u_i}^2) / \sum_i^N (1/\sigma_{u_i}^2)$ , where  $\sigma_{u_i}^2$  denotes the variance of the residual flows for fund  $i$ . The specifications GIV2 and GIV3 make this correction by subtracting from the aggregate (residual) flows the precision-weighted (residual) flows rather than the average (equal-weighted) flows.

### 5.3 FX Supply Elasticity Estimates

Table 5 report our results for the three specifications GIV1, GIV2, and GIV3. Columns (1)-(3) report the first-stage regression results for Eq. (36). The Montiel-Pflueger  $F$ -statistics shows that our granular instrument is strong in all three cases — although GIV1 features the strongest instruments. This is not surprising as more filters are applied to purge the flow statistics. Columns (5)-(7) provide coefficient estimates

<sup>30</sup>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  $\kappa/\overline{PH}$  regression 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.

<sup>31</sup>In light of the large cross-sectional sample size and the short time span of our data, filtering based on observable fund characteristics is preferable to a principle component analysis.

of the second-stage regression stated as Eq. (37). The point estimate 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  $\widehat{\frac{\kappa}{PH}} = 1.078$ . 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 U.S., this amounts to approximately US\$7.1bn ( $=1.078\% \times \text{US\$656bn}$ ) at the end of 2014.

For the GIV2 and GIV3 specifications, the point estimates for the supply elasticity  $\widehat{\frac{\kappa}{PH}}$  are substantially lower at 0.587 and 0.613, respectively. Prefer these estimates because the exogeneity argument for the instrument is more comprehensive. These lower supply elasticities estimates imply that by the end of 2014 only about US\$3.9bn ( $=0.587\% \times \text{US\$656bn}$ ) in net U.S. outflows are needed to trigger a 1% depreciation of the effective U.S. dollar rate. For the Euro, the British Pound and the Canadian Dollar, the corresponding net outflows triggering a 1% depreciation are lower at €1.7bn ( $=0.587\% \times \text{€288bn}$ ), £0.8bn ( $=0.587\% \times \text{£140bn}$ ), and CA\$0.5bn ( $=0.587\% \times \text{CA\$80bn}$ ), respectively.

We note that the estimated supply elasticities are considerably lower than what the stylized model in Section 2 suggest. The model yields already a reasonably high levels of exchange rate volatility for much higher values of the supply elasticity parameter  $\widehat{\frac{\kappa}{PH}}$  around 10. Unlike most macroeconomic models, our stylized model predicts too much rather than too little nominal exchange rate volatility.

Our currency supply elasticity estimates are reasonably close 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. They find that US\$1 billion of exogenous currency outflows depreciate a currency by roughly 0.38%, which implies that on average US\$2.6bn are needed for a 1% depreciation of bilateral dollar rates. Another strand of the literature, namely the research on the microstructure of FX market, seeks to estimate the effect of so-called market order shocks on the exchange rate. But the exchange rate impact of market order flow statistics extracted from FX limit order books is difficult to compare to our estimates. The time varying market shares for different trading venues, the often very short (intra-day) time horizon of the inference, the ability of investors to accomplish rebalancing by either market or limit orders, and the difficulty to attribute FX order flow to specific investor types all present challenges to this line of research.

## 6 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 4.1. 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, while 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.<sup>32</sup>

## 7 Conclusion

This paper documents a pervasive feature of the international equity portfolios of institutional investors, namely that they repatriate capital after making an 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 non-linear relationship. In other words, the rebalancing motive of equity funds increases as

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<sup>32</sup>Important progress has been made in that direction: see, for example, Gabaix and Maggiori (2015), Coimbra and Rey (2019), Kojen and Yogo (2019) and Kojen and Yogo (2020).

their 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 find that roughly US\$3.9bn in net U.S. rebalancing outflows are needed to trigger a 1% depreciation of the effective U.S. dollar rate.

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 the 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 remains to be done to better comprehend the complexity of international links across financial asset markets.

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## 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 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  $\Psi_t^h = (1, D^h, \Delta_t, \Lambda_t)^T$  and  $\Psi_t^{f^*} = (1, D^{f^*}, \Delta_t, \Lambda_t)^T$  with  $\Delta_t \equiv D_t^h - D_t^{f^*}$  and the stochastic process  $\Lambda_t$ . 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  $(1 \times 2)$  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

$$\begin{bmatrix} dR_t^h & dR_t^{f^*} \\ dR_t^{h^*} & dR_t^f \end{bmatrix} = \begin{bmatrix} \alpha_\Psi^h & \alpha_\Psi^{f^*} \\ \alpha_\Psi^{h^*} & \alpha_\Psi^f \end{bmatrix} \begin{bmatrix} \Psi_t^h dt \\ \Psi_t^{f^*} dt \end{bmatrix} + \begin{bmatrix} \mathbf{b}_\Psi^h & \mathbf{b}_\Psi^{f^*} \\ \mathbf{b}_\Psi^{h^*} & \mathbf{b}_\Psi^f \end{bmatrix} \begin{bmatrix} \mathbf{dw}_t^h \\ \mathbf{dw}_t^{f^*} \end{bmatrix}. \quad (\text{A1})$$

All coefficients are functions of six exogenous model parameters  $\alpha_D, \sigma_D, \bar{D}, r, \kappa$  and  $\rho$ . The first-order conditions for the optimal asset demand functions follow as

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

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

$$dR_t^h = dP_t^h - rP_t^h dt + D_t^h dt \quad (\text{A3})$$

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

$$dR_t^{f^*} = dP_t^{f^*} - rP_t^{f^*} dt + D_t^{f^*} dt \quad (\text{A5})$$

$$dR_t^{h^*} \approx dE_t \bar{P} + dP_t^h + dE_t dP_t^h - r[P_t^h + \bar{P}(E_t - 1)]dt + [D_t^h + \bar{D}(E_t - 1)]dt. \quad (\text{A6})$$

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

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

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

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

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  $\bar{H}$ )

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

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

The six endogenous parameters  $p_0$ ,  $p_\Delta$ ,  $p_\Lambda$ ,  $e_\Delta$ ,  $e_\Lambda$ , and  $\alpha_\Lambda$  are determined by the equity market clearing condition (implying A11-A13) and by compliance with the flow constrain in A10 (implying A14-A16):

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

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

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

$$0 = e_\Delta (\bar{H}\bar{D} - \kappa\alpha_D) + m_\Delta \frac{1}{\rho} (\bar{D} + \alpha_D\bar{P}) + \bar{H} \quad (\text{A14})$$

$$0 = e_\Lambda (\bar{H}\bar{D} + \kappa\alpha_\Lambda) + m_\Lambda \frac{1}{\rho} (\bar{D} - \alpha_\Lambda\bar{P}) \quad (\text{A15})$$

$$0 = \kappa [e_\Delta\sigma_D + e_\Lambda] - \frac{1}{\rho}\bar{P} [m_\Delta\sigma_D + m_\Lambda] \quad (\text{A16})$$

$$0 = [(\alpha_\Lambda + r)\bar{P} - \bar{D}] (\bar{D} - \alpha_\Lambda\bar{P}) - \frac{\rho}{2} (\bar{H}\bar{D} + \kappa\alpha_\Lambda) [\Omega_{11} + 2\Omega_{21} + \Omega_{22}]. \quad (\text{A17})$$

The expressions  $m_\Delta$ ,  $m_\Lambda$ , and  $\det \Omega$  are defined as

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

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

$$\det \Omega = \Omega_{11}\Omega_{22} - \Omega_{21}\Omega_{11}, \quad (\text{A20})$$

where  $\Omega_{ij}^{-1}$  denotes element  $(i, j)$  of the inverse matrix  $\Omega^{-1}$ .

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

$$\bar{P} = p_0 + \frac{\bar{D}}{r} + p_\Lambda\bar{\Lambda} = p_0 + \frac{\bar{D}}{r} \quad (\text{A21})$$

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

and

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

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

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

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  $\bar{P}$ ) follow as  $dr_t^h = dR_t^h/\bar{P}$ ,  $dr_t^{f*} = dR_t^{f*}/\bar{P}$ ,  $dr_t^f = dR_t^f/\bar{P}$ , and  $dr_t^{h*} = dR_t^{h*}/\bar{P}$ .

**Corollary 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

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

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

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

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

**Corollary 2 (Rebalancing for different FX Supply Elasticities):**

The instantaneous variance of the excess return process can be derived as

$$\begin{aligned} Var(dr_t^f - dr_t^h) &= \frac{1}{\bar{P}^2} \mathcal{E}_t (dR_t^f - dR_t^h) (dR_t^f - dR_t^h) = \\ &= \frac{2}{\bar{P}^2} [\bar{P}(e_\Delta \sigma_D + e_\Lambda) + f_D \sigma_D + 2p_\Delta \sigma_D + 2p_\Lambda]^2 dt. \end{aligned} \quad (\text{A27})$$

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

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

We note that the endogenous terms  $\bar{P}$ ,  $p_\Delta$ ,  $p_\Lambda$ ,  $e_\Delta$ , and  $e_\Lambda$  in Eq. (A28) generally depend on the exogenous parameter  $\kappa$ . 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  $\kappa \in [100, 1000]$ .

## Appendix B: Data Issues

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 only use 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 U.S., the U.K., the Eurozone, and Canada.<sup>33</sup> All small funds with a capitalization of less than \$10 million are deleted. These small funds might represent incubator funds or other non-representative 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 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.

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<sup>33</sup>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.

## Appendix C: Granular Instruments

This section outlines the conditions under which the granular instrumental variable (GIV) estimator discussed in Section 5.2 provides consistent estimates for the FX supply elasticity parameter. Our exposition follows closely 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

$$\Delta Q_{c,t}^S = -\kappa \Delta E_{c,t} + \varepsilon_t \quad (\text{C1})$$

in analogy to Eq. (24) in [Gabaix and Koijen \(2020\)](#) with  $\kappa > 0$ . The term  $\varepsilon_t$  allows for additional supply shocks which were ignored in the theoretical model in Section 2.

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

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

where  $r_{j,t}^f - r_{j,t}^h$  and  $r_{j,t}^{h*} - r_{j,t}^{f*}$  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 component 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

$$\begin{aligned} r_{j,t}^f - r_{j,t}^h &= r_t^f - r_t^h + v_{j,t} & \text{for } j \in D \\ r_{j,t}^{h*} - r_{j,t}^{f*} &= r_t^{h*} - r_t^{f*} + v_{j,t}^* & \text{for } j \in F_c \end{aligned} \quad (\text{C3})$$

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

$$r_t^f - r_t^h = -\left(r_t^{h*} - r_t^{f*}\right) = \theta \Delta E_{c,t} + \vartheta_{c,t}, \quad (\text{C4})$$

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

Substitution of Eqs. (C3)-(C4) into Eqs. (C2) yields

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

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

$$y_{c,t}^{Net} = \frac{2\mu_c}{A_{c,t-1}^f} \sum_{j \in D_c} y_{j,t} \times a_{j,t-1}^f - \frac{2(1-\mu_c)}{A_{c,t-1}^{h*}} \sum_{j \in F_c} y_{j,t}^* \times a_{j,t-1}^{h*} \quad , \quad (C6)$$

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

$$\Delta Q_{c,t}^D = \overline{PH} \Delta H_{c,t}^{Net} = \overline{PH} \beta \theta \Delta E_{c,t} + \overline{PH} \tilde{\eta}_{c,t}^{Net} + \overline{PH} \tilde{u}_{j,t}^{Net} \quad , \quad (C7)$$

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

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

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

Eq. (C8) has the same structure as Eq. (25) in [Gabaix and Koijen \(2020\)](#).  $\frac{\bar{\kappa}}{\overline{PH}}$  is the elasticity of supply while  $\beta \theta$  is the demand elasticity for rebalancing flows.

Eqs. (32)-(33) define the granular instrumental variable  $z_{c,t} \equiv GIV(\Delta H_{c,t}^{Net})$ . By construction,  $z_{c,t}$  is a linear (size-weighted) linear combination of idiosyncratic fund-level errors only, which are by assumption orthogonal to  $\tilde{\eta}_{c,t}^{Net}$  and  $\varepsilon_t$ , hence

$$\mathcal{E}_t[\tilde{\eta}_{c,t}^{Net} z_{c,t}] = \mathcal{E}_t[\varepsilon_t z_{c,t}] = 0. \quad (C9)$$

The relevance of the instrument follows from

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

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

$$\frac{1}{\kappa} = \frac{\mathcal{E}_t[-\Delta E_{c,t} z_{c,t}]}{\mathcal{E}_t[(\Delta Q_{c,t}^S + \kappa \Delta E_{c,t}) z_{c,t}]} = \frac{\mathcal{E}_t[-\Delta E_{c,t} z_{c,t}]}{\overline{PH} \mathcal{E}_t[\Delta H_{c,t}^{Net} z_{c,t}]} \quad , \quad (C11)$$

and the corresponding IV estimator follows as

$$\frac{\widehat{\overline{PH}}}{\kappa} = \frac{\frac{1}{T} \sum_{c,t} -\Delta E_{c,t} z_{c,t}}{\frac{1}{T} \sum_{c,t} \Delta H_{c,t}^{Net} z_{c,t}} \quad (C12)$$

is consistent. Eq. (C11) corresponds to Eq. (30) in [Gabaix and Koijen \(2020\)](#). In Section 5.2, we describe the equivalent two-step estimator in Eqs. (36)-(37) which projects first the net equity flows  $\Delta H_{c,t}^{Net}$  onto  $z_{c,t}$  and then the exchange rate change  $-\Delta E_{c,t}$  onto the predicted values  $\Delta \hat{H}_{c,t}^{Net}$ .

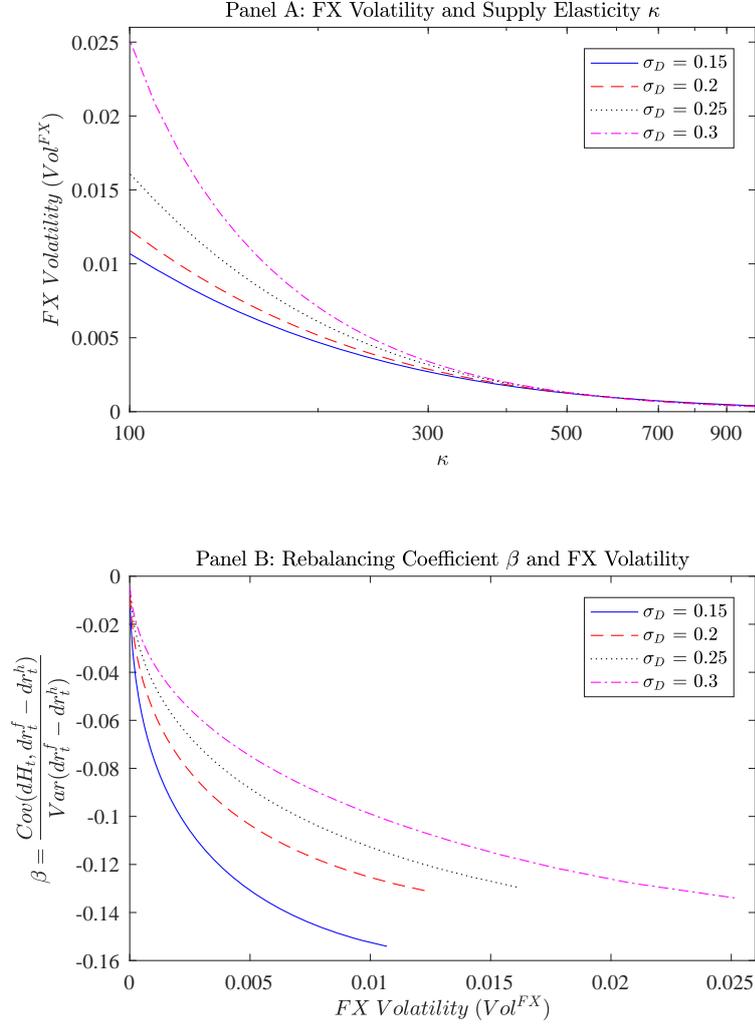


Figure 1: In Panel A, we plot FX volatility as a function of the supply elasticity parameter  $\kappa$  for different stock volatility values  $\sigma_D \in \{0.15, 0.20, 0.25, 0.30\}$ . In Panel B, we plot the rebalancing coefficient  $\beta = \frac{Cov(H_t^f, dr_t^f - dr_t^h)}{Var(dr_t^f - dr_t^h)}$  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  $\bar{D} = 1$ .

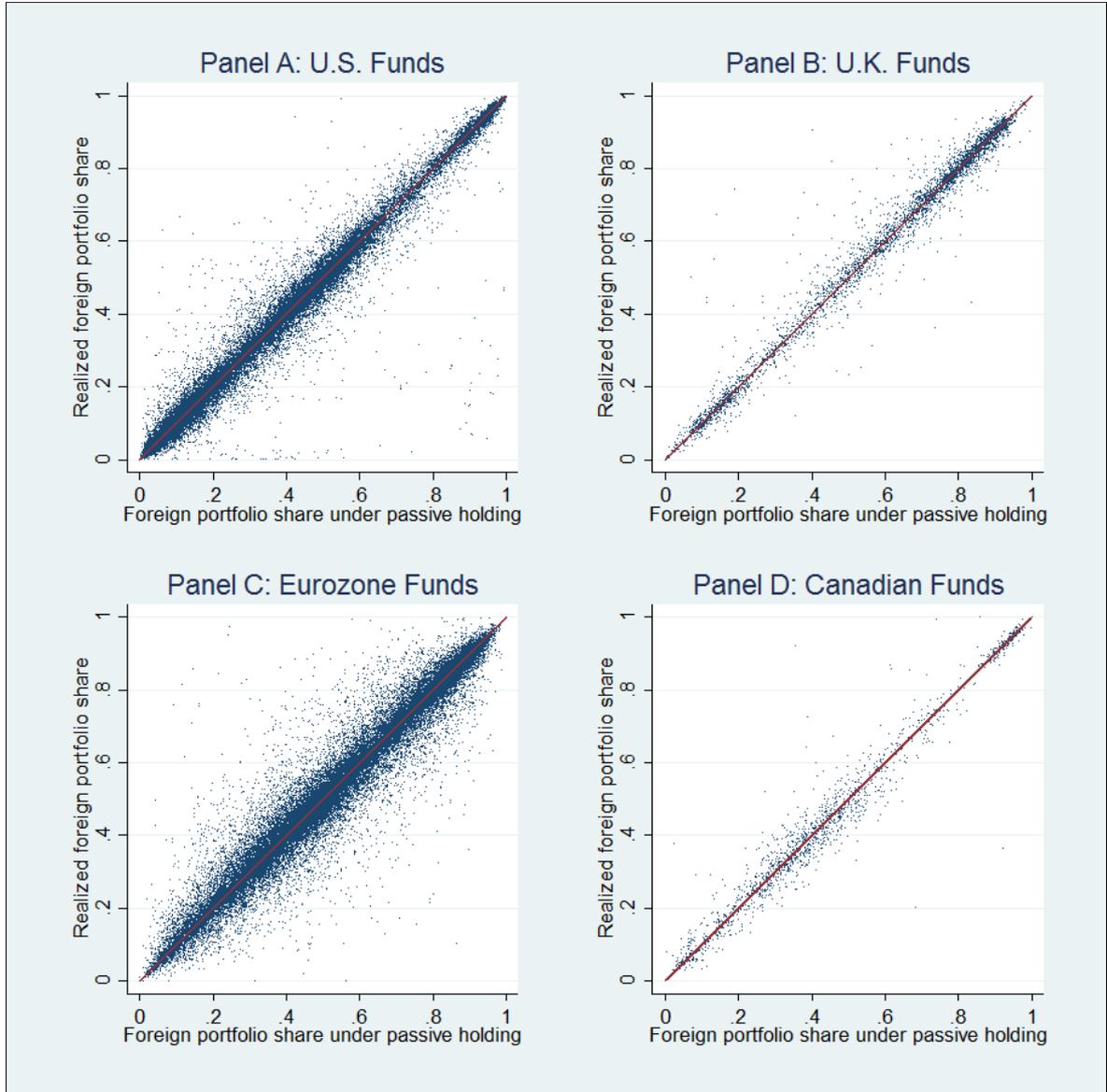


Figure 2: We plot the realized foreign portfolio share  $w_{j,t}^f$  (y-axis) relative to the portfolio share implied by a passive holding strategy  $\hat{w}_{j,t}^f$  (x-axis) of funds domiciled in the U.S. (Panel A), the U.K. (Panel B), the Eurozone (Panel C), and Canada (Panel D). The vertical distance to the 45-degree line is proportional to the active rebalancing measure  $\Delta h_{j,t}^f = w_{j,t}^f - \hat{w}_{j,t}^f$ .

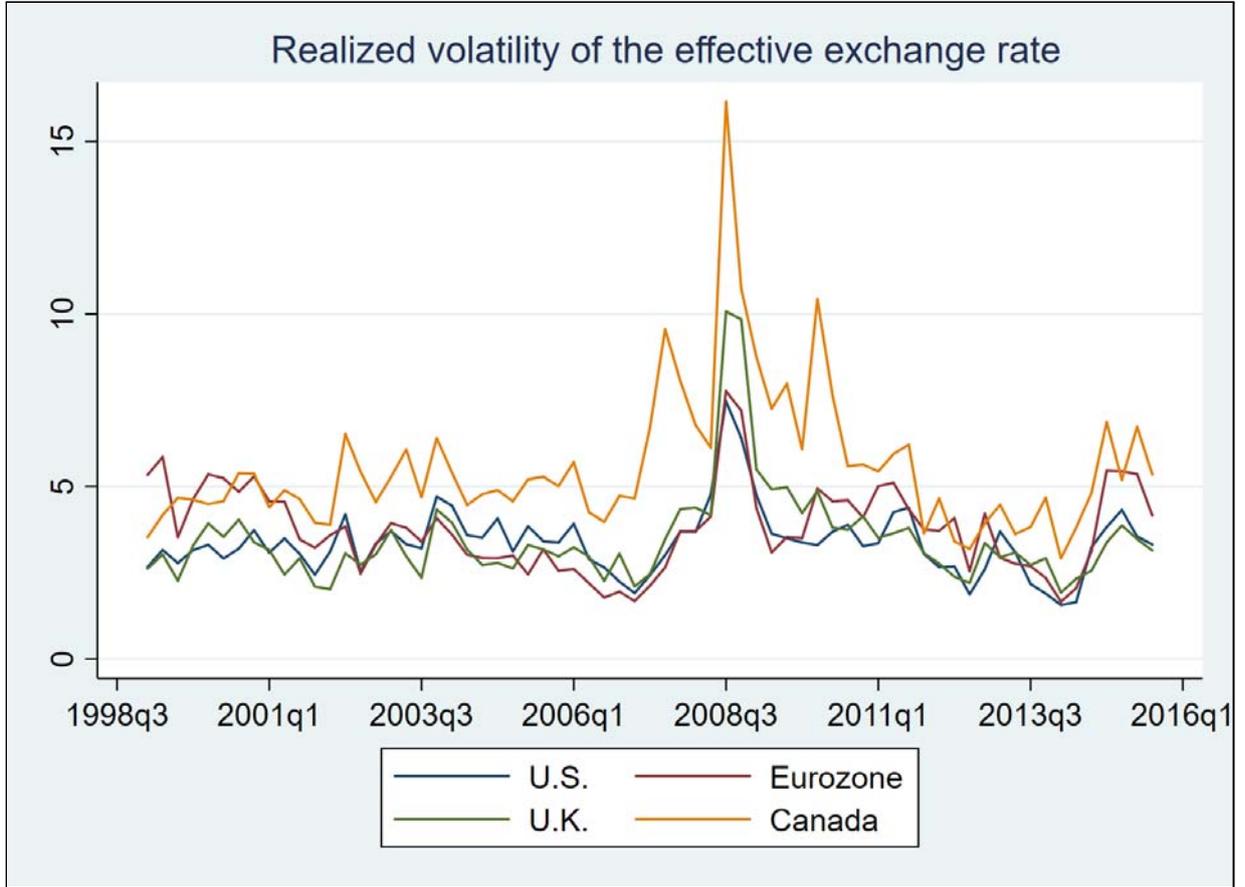


Figure 3: We plot the quarterly realized volatility  $VOL_{c,t}^{FX}$  of the effective exchange rate for the U.S., U.K., Eurozone, and Canada, respectively for the period January 1999–December 2015. For a total of  $D$  trading days in a given quarter  $t$ , realized volatility is calculated as

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

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

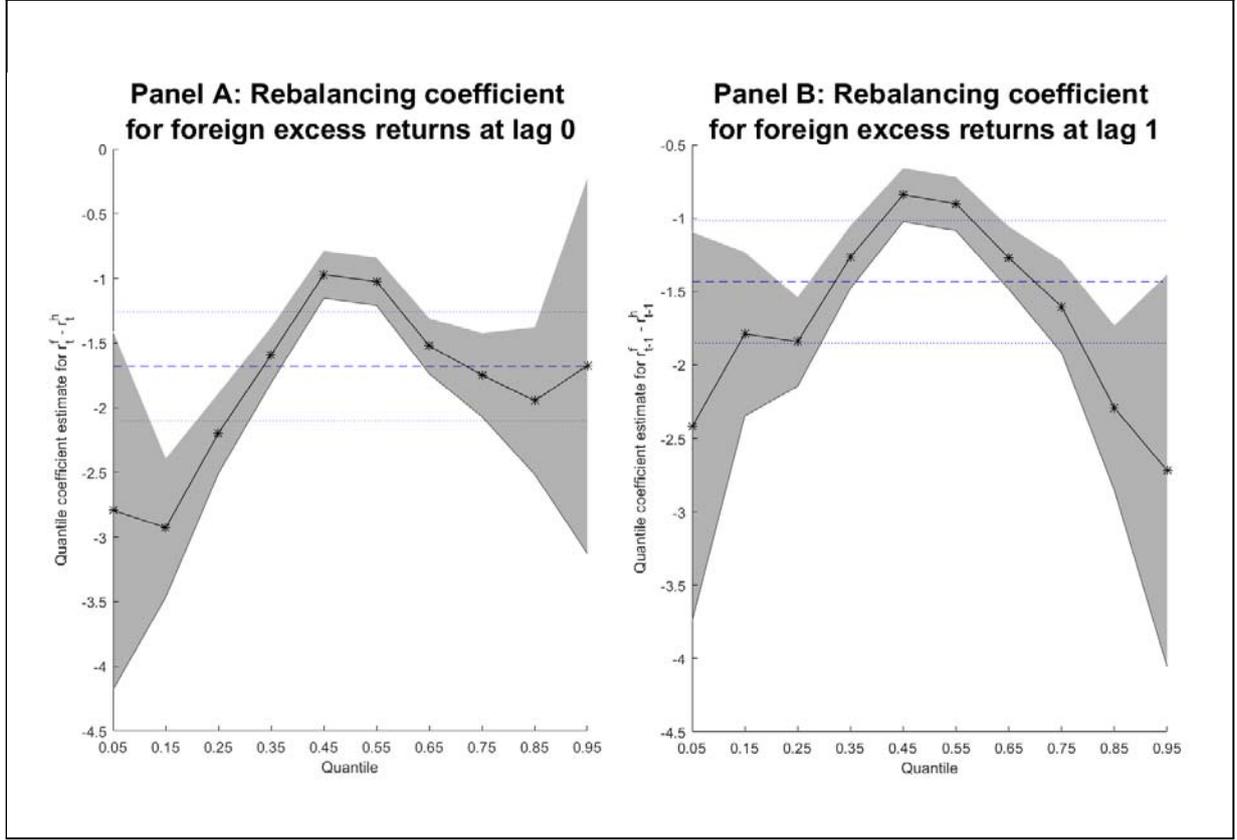


Figure 4: Panels A and B show the rebalancing coefficients  $\beta_0$  and  $\beta_1$  in the regression

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

for the foreign excess return and the lagged foreign excess return, respectively, for the 10 quantile regressions at quantiles  $\tau = 0.05, 0.15, 0.25, \dots, 0.95$  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.

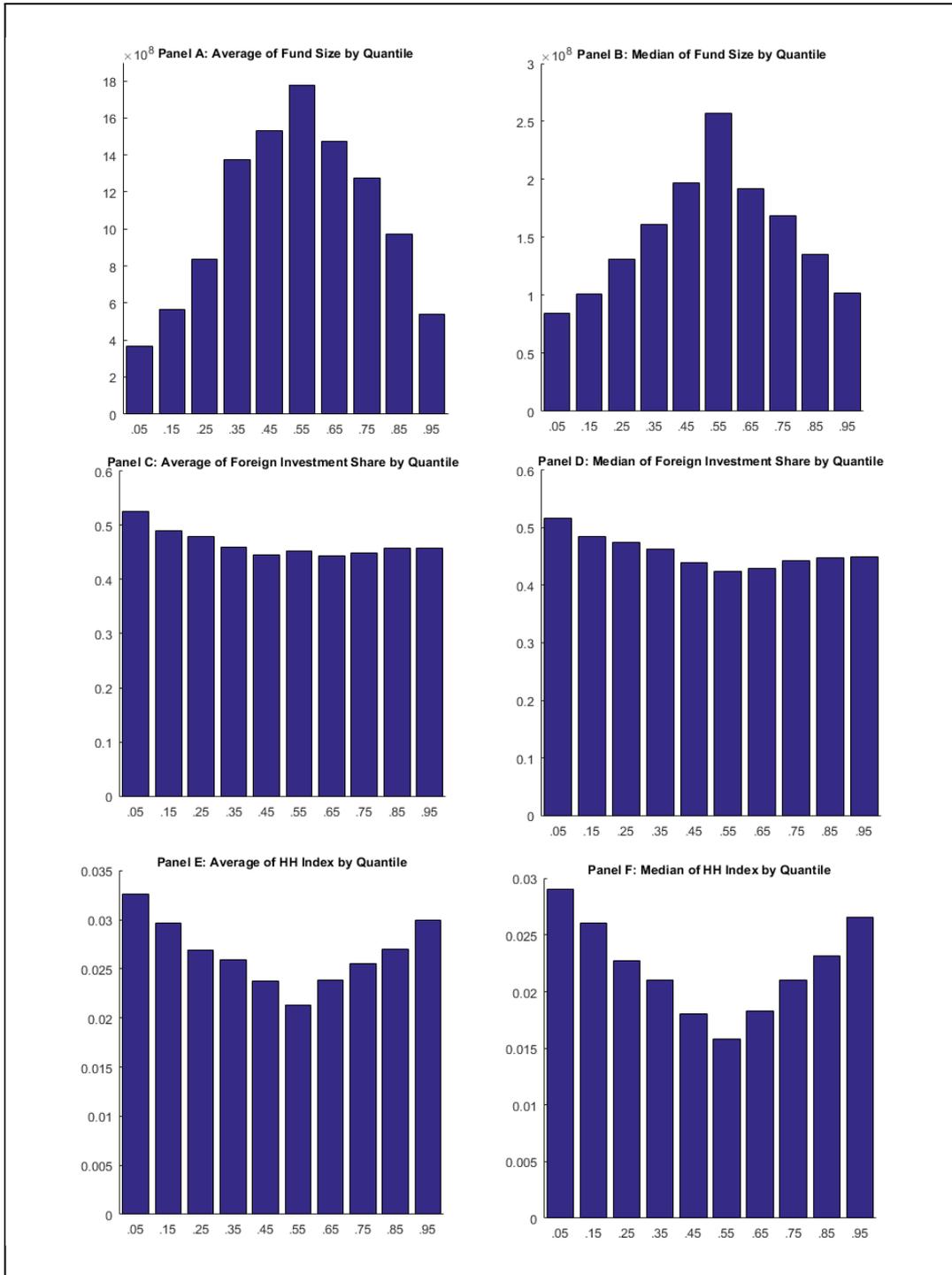


Figure 5: Panels A and B characterize the mean and median fund size around a quantile regression at the quantiles  $\tau = 0.05, 0.15, 0.25, \dots, 0.95$ , where the interquantile range of mean and median calculation is from  $\tau - 0.05$  to  $\tau + 0.05$ . Panels C and D show the mean and median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