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ABSTRACT

We examine international equity allocations at the fund level and show how different returns on the foreign and domestic proportion of portfolios determine rebalancing behavior and trigger capital flows. We document the heterogeneity of rebalancing across fund types, its greater intensity under higher exchange rate volatility, and the exchange rate effect of such rebalancing. The observed dynamics of equity returns, exchange rates, and fund-level capital flows are compatible with a model of incomplete FX risk trading in which exchange rate risk partially segments international equity markets.

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1 Introduction

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).[1] Capital gains and losses on those assets have significant effects on the dynamics of countries' external asset positions. The macroeconomic literature finds that valuation effects induced by asset price changes have become quantitatively large relative to the traditional determinants of the current account.[2] Valuation effects can also impact the portfolio allocation decisions of investors directly and trigger capital flows. Yet, there is surprisingly little systematic documentation about this 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 towards their desired weights or do they increase their exposure to appreciating assets? What are the consequences of those portfolio decisions for exchange rates and capital flow 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 fund level. Finally, any analysis at the individual fund level has enormous statistical power due to a large cross-section of individual funds.

To better frame our analysis, we start with an equilibrium model of optimal dynamic portfolio rebalancing (Hau and Rey, 2006). The model features an exogenous dividend pay-off process

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

[2] For data on the increase of gross assets and liabilities and valuation effects see Lane and Milesi-Ferretti (2007), Tille (2008), Gourinchas and Rey (2007) and Fratzscher, Juvenal, and Sarno (2007a). 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), Bénétrix, Lane, and Shambaugh (2015), Burger, Warnock, and Warnock (2017) and Maggiori, Neiman, and Schreger (2017).

in a two-country model with two distinct stock markets and a local riskless bond in fully price elastic supply. The exchange rate is determined by the flow dynamics of equity rebalancing between the two stock markets, assuming a risk averse FX liquidity supplier similar to Gabaix and Maggiori (2015). Differential returns 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. Unlike Gabaix and Maggiori (2015), where demand for foreign exchange is driven by goods trade, in our model demand is driven by asset trade and optimal porftolio choice. A key prediction of the model is that excess returns on the foreign equity market proportion of the investor portfolio should be partially repatriated to maintain an optimal trade-off between international asset diversification and exchange rate exposure. We also predict that this trade-off is influenced by the level of global exchange rate volatility as well as fund-level variables, such as the degree of fund diversification and its rebalancing costs, proxied by fund size and asset liquidity.

The main contribution of our paper is empirical. The disaggregate fund-level data track quarterly fund holdings for 8,585 internationally invested equity funds for the period 1999–2015. The data comprise a total of 109,487 fund-quarters and 25,856,215 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-section 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.[3]

Importantly, we find strong evidence for 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:

- At the fund-level, we study the dynamics of the *foreign value share* of the portfolio. Fund managers adjust their foreign portfolio share to mitigate the valuation effects of asset price changes. 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.

[3] For a detailed study of home bias at the fund level, see Hau and Rey (2008).

- A high level of global FX volatility reinforces the rebalancing behavior of international equity funds. Any excess return on the foreign equity component of the portfolio triggers a larger rebalancing toward domestic assets compared to a period of low FX volatility.

- Quantile regressions reveal that the strength of the rebalancing dynamics is non-linear in the return difference between a fund's foreign and domestic equity investments.

- 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 transaction costs to dynamic portfolio adjustments increasing in fund size.

- Aggregating the foreign equity investments of domestic funds and the domestic equity investments of foreign funds for each currency area, we show that a reduction in foreign equity investments by domestic funds (domestic investment by foreign funds) correlates with a subsequent domestic currency appreciation (depreciation).

The determinants of home bias and static portfolio allocations have been extensively studied in the literature (see e.g. the surveys of Lewis, 1999 and Coeurdacier and Rey, 2012). Much less attention has been given to the international portfolio dynamics and their determinants. While portfolio balance models were originally developed in the early 1980s (see Kouri, 1982 and Branson and Henderson, 1985), a lack of microfoundations limited their theoretical appeal. However, the financial globalization of the last two decades has resuscitated interest in portfolio balance models (see Blanchard, Giavazzi and Sa, 2005, Hau and Rey, 2006 and Gabaix and Maggiori, 2015) with their appealing focus on imperfect asset substitutability combined with plausible implications for exchange rate dynamics.[4] Empirical tests of the portfolio balance models relied on macroeconomic price data and aggregate cross-border flows. The corresponding results are generally inconclusive (see Frankel, 1982a,b and Rogoff, 1984). Bohn and Tesar (1996) analyze return chasing and portfolio rebalancing in an ICAPM framework, while Brennan and

[4]For linearized microfounded dynamic stochastic general equilibrium models of the open economy with optimal portfolio choice see, for example, Coeurdacier (2009), Devereux and Sutherland (2010a,b, 2011) and Tille and Van-Wincoop (2010). Dou and Verdelhan (2015) are able to account for the volatility of international capital flows and to generate a time-varying risk premium in an incomplete asset market model with disaster risk. Bacchetta and Van Wincoop (2010) model agents who infrequently rebalance their portfolio in an overlapping generations (OLG) setting.

Cao (1997) study the effect of information asymmetries between domestic and foreign investors on correlations between international portfolio flows and returns. Albuquerque, Bauer and Schneider (2007, 2009) provide models with information asymmetries and investor heterogeneity aimed at fitting stylized facts to aggregate correlations of flows and returns. Caballero and Simsek (2017) 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.

Common to most empirical papers is the use of aggregate data on U.S. international transactions (i.e., the U.S. TIC data) and the assumption that investors hold aggregate market indices.[5] Another well-known limitation of the aggregate TIC data concerns the recording of the transaction location, but not the asset location or currency denomination of the asset. Purchases by U.S. investors in the London markets are reported as U.K. asset transactions even if they concern a French stock. Furthermore, correlation evidence in aggregate data is difficult to interpret because of thorny endogeneity issues.[6] Our data allow us to get around some of these problems because we observe the exact portfolio of each individual fund manager and estimate the portfolio weight changes induced by past realized valuation changes in our sample of heterogeneous portfolios. Common shocks or aggregate demand effects and their price impact therefore pose less of an inference problem than they do in aggregate data. The approximately 25 million observations in our pooled sample also imply a tremendous increase in statistical power.

A related empirical study on portfolio rebalancing based on microeconomic data was undertaken by Calvet, Campbell and Sodini (2009). The authors investigate whether Swedish households adjust their risk exposure in response to the portfolio returns they experience during the period 1999–2002. In particular, they examine the rebalancing between the risky share of household portfolios and riskless assets and find evidence of portfolio rebalancing among the most educated and wealthiest households. Our study is different in that it focuses on institutional investors, who are arguably financially literate and understand exchange risk exposure.[7]

[5] Notable exceptions are Evans and Lyons (2012), who show a tight correlation between order flow and exchange rate, and Froot and Ramadorai (2005).

[6] There is an obvious endogeneity problem with contemporaneous correlations because of common shocks or price effects due to demand pressure. Correlations of aggregate flows with past and future returns may also be problematic to interpret as aggregate flows are persistent.

[7] It would also be interesting to study the global portfolios of the final owners of the securities but unfortunately our data do not provide the relevant information to do so.

Our empirical findings can also inform a burgeoning theoretical literature in macroeconomics and finance that aims at modeling financial intermediaries (see e.g. Vayanos and Wooley, 2013, Dziuda and Mondria, 2012, Basak and Pavlova, 2013, Gabaix and Maggiori, 2015 and Bruno and Shin, 2015).[8]

In Section 2 we present a simple two-country model with partially segmented asset markets.[9] Its parsimonious microeconomic structure allows us to derive two 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. The empirical part of our paper presents the rebalancing evidence (Section 4.1), the exchange rate volatility dependence of rebalancing (Section 4.2), and the evidence for non-linearities (Section 4.3). In Section 4.4 we discuss the role of fund characteristics for the rebalancing behavior, followed by evidence on the feedback effect of aggregate rebalancing on the exchange rate dynamics in Section 4.5. Section 5 concludes.

2 Model

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

A key feature of the model is that the exchange rate and investors' rebalancing dynamics are driven by the fundamental value of two dividend processes 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 holding 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

[8] Hau, Massa,and Peress (2010) and Adrian, Etula, and Shin (2014) also find that flows and financial conditions have an impact on exchange rates.

[9] The segmentation of the two equity markets is a consequence of non-tradeable exchange rate risk (market incompleteness) and endogenously determined by the level of exchange rate volatility.

demand of home and foreign equity investors, which can generate a high degree of exchange rate volatility driven by the (asymmetric) rebalancing desires of home and foreign investor.

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 $H_t^* = (H_t^{h*}, H_t^{f*})$, respectively. The superscripts h and f denote the home and foreign equity markets and the foreign investors are distinguished by a star ($*$). Both representative investors solve the optimization problem

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

where $\mathcal{E}_t$ denotes the expectation for the stochastic profit flow $d\Pi_t$ and its variance $d\Pi_t^2$. For 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

$$d\Pi_t = H_t dR_t$$
$$d\Pi_t^* = H_t^* dR_t^*,$$

respectively. The investor risk aversion is denoted by ρ and the domestic riskless rate is given by r in each country. The myopic investor objectives assure linear asset demand functions and abstracts from intertemporal hedging motives that arise in a more general utility formulation. We also note that 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

$$\begin{array}{rcl} H_t^h + H_t^{h*} & = & 1 \\ H_t^f + H_t^{f*} & = & 1, \end{array} \tag{2}$$

because we normalize the asset supply to one. An additional market clearing condition applies to the foreign exchange market with an exchange rate E_t. We can measure the equity-related capital outflows dQ_t of the home country (in foreign currency terms) as

$$dQ_t = E_t H_t^{h*} D_t^h dt - H_t^f D_t^f dt + P_t^f dH_t^f - E_t P_t^h dH_t^{h*}. \quad (3)$$

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*} 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 elasticity parameter κ. For an equilibrium exchange rate E_t, the excess supply of foreign exchange is given by

$$Q_t^S = -\kappa(E_t - \overline{E}), \quad (4)$$

where $\overline{E} = 1$ denotes the steady state exchange rate level.[10] Combining equations (3) and (4) 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 exchange rate dynamics dE_t is linearly related to the foreign holding changes dH_t^f by domestic funds and the domestic holding changes dH_t^{h*} of foreign funds as

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

Section 4.5 of the paper explores this aggregate relationship empirically.

Before we can solve this simple model, two more assumptions are needed. First, we have to specify the (exogenous) dividend dynamics. For tractability, we assume two independent Ornstein-Uhlenbeck processes with identical variance and mean reversion to a steady state

[10] For microfoundations of the linear currency supply assumption, see Gabaix and Maggiori (2015).

value $\overline{D}$, hence

$$\begin{aligned} dD_t^h &= \alpha_D(\overline{D} - D_t^h)dt + \sigma_D dw_t^h \\ dD_t^f &= \alpha_D(\overline{D} - D_t^f)dt + \sigma_D dw_t^f. \end{aligned} \tag{5}$$

Second, for a linear solution to the model, we also need to linearize equation (3) 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 linearization and reasonable parameter values.[11]

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. 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 dividends given by

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

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

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

where $dw_s = dw_t^h - dw_t^f$ and $\alpha_z > 0$. The variable $\Delta_t = D_t^h - D_t^f$ simply represents the difference in the dividend level between the home and foreign equity markets, whereas Λ_t aggregates past

[11] 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.

dividend innovations with a different decay factor α_z.

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

Proposition 1 (Portfolio Rebalancing Equilibrium):

The unique equilibrium for the linearized model features asset prices and an exchange rate characterized by

$$
\begin{aligned}
P_t^h &= p_0 + F_t^h + p_\Delta \Delta_t + p_\Lambda \Lambda_t \\
P_t^f &= p_0 + F_t^f - p_\Delta \Delta_t - p_\Lambda \Lambda_t \\
E_t &= 1 + e_\Delta \Delta_t + e_\Lambda \Lambda_t
\end{aligned}
$$

and dynamic portfolio holdings

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

where $0 < \overline{H} \leq 0.5$ denotes the steady state holding of foreign assets and the coefficients $p_0 < 0$, $p_\Delta > 0$, p_Λ, $e_\Delta < 0$, e_Λ, $m_\Delta < 0$, and $m_\Lambda > 0$ are functions of the six exogenous parameters α_D, σ_D, $\overline{D}$, r, κ and ρ.

Proof: See Appendix A.

Limited currency supply elasticity plays a crucial role in the equilibrium. To appreciate this aspect, consider the limit case of an infinitely elastic currency supply with $\kappa \to \infty$. In this special case all exchange rate volatility disappears ($E_t = 1$) as $e_\Delta \to 0$, and $e_\Lambda \to 0$. 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 $p_\Delta \to 0$, and $p_\Lambda \to 0$. The limit case features perfect global risk sharing with both the home and the foreign investor holding half of the equity risk in each market, thus $\overline{H} \to 0.5$ and $k_\Delta \to 0$, $k_\Lambda \to 0$.

2.2 Model Implications

The model solution in Proposition 1 implies a unique covariance structure for the joint dynamics of international equity holdings and equity returns. 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 towards home country equity if the return on her foreign equity holdings exceeds the return on her home equity investments. Formally, the foreign equity holding change dH_t^f and the excess return of the foreign equity over home equity $dr_t^f - dr_t^h = (dR_t^f - dR_t^h)/\overline{P}$ feature a negative covariance given by

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

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

Proof: See Appendix A.

Figure 1, Panel A, plots the covariance $Cov(dH_t^f,\, dr_t^f - dr_t^h)/dt$ for varying FX supply elasticities $\log(\kappa) \in [10,\, 2000]$ and dividend volatility parameters $\sigma_D \in [0.1, 0.5]$, where we set $\overline{D} = 1$ and $\alpha_D = 0.01$. A lower supply elasticity or an increase in stock market volatility imply that the covariance becomes more negative as rebalancing and its impact on exchange rates intensifies. The instantaneous FX volatility given by

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

also increases in σ_D and decreases for larger κ as shown in Figure 1, Panel B. In particular, low values of κ can generate a high degree of exchange rate volatility generally observed in the FX market.

So far we have treated the σ_D and κ as constant exogenous parameters. Yet these two parameters are likely to change over time and it is interesting to explore the implications of this. For the validity of any comparative statistics, we need to assume that investors do not form forward-looking expectations of the parameters σ_D and κ but react to their changes in a myopic manner. While the parameter κ itself is not directly observable, its changes are monotonically related to corresponding changes in FX volatility. As volatility changes in financial markets tend to have a low degree of forecastability, the assumption of parameter myopia could be a reasonable approximation of investor behavior. Corollary 2 characterizes the rebalancing behavior under time-changing FX volatility.

Corollary 2 (Rebalancing under Parameter Change):

The home investor rebalances her foreign investment portfolio toward the home country more strongly under foreign excess returns $dr_t^f - dr_t^h$ if equity market volatility increases (larger σ_D) and the supply elasticity of FX balances decreases (smaller κ); hence

$$\frac{d}{d\sigma_D} Cov\left[dH_t^f\ ,\ dr_t^f - dr_t^h\right] < 0$$
$$\frac{d}{d\kappa} Cov\left[dH_t^f\ ,\ dr_t^f - dr_t^h\right] > 0.$$

Proof: See Appendix A.

According to Figure 1, Panel B, a larger σ_D and smaller κ both imply higher FX volatility. Unlike κ, FX volatility is directly observable. A simple empirical test of Corollaries 1 and 2 consists in regressing foreign holding changes of home investors on the contemporaneous relative performance of their respective foreign and domestic equity returns $r_t^f - r_t^h$ and their interaction with FX volatility given by $(r_t^f - r_t^h)Vol^{FX}$. This test can be implemented for a large cross-section of internationally invested equity funds. Let the foreign equity holding change for fund j in period t be denoted by $\Delta h_{j,t}^f$ and the corresponding excess return on the foreign equity share over the domestically invested share by $r_{j,t}^f - r_{j,t}^h$. We expect the linear regression

$$\Delta h_{j,t}^f = \beta(r_t^f - r_t^h) + \gamma Vol^{FX} + \delta(r_t^f - r_t^h)Vol^{FX} + \epsilon_{j,t}$$

to yield negative rebalancing coefficients $\beta < 0$, and $\delta < 0$. In other words, rebalancing toward home equity increases the return differential between foreign and home equity $r_t^f - r_t^h$ and this effect is reinforced by any increase in FX volatility Vol^{FX}. As higher levels of exchange rate volatility also increase investors' equity home bias (that is $\overline{H}$), we can also predict that $\gamma < 0$.

3 Data

For data on global equity holdings we use FactSet/LionShares.[12] 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 (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.[13]

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

[12] Ferreira and Matos (2008) examines 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.

[13] Other papers using disaggregated data on international institutional investors holdings, albeit with a different focus, are Chan, Covrig, and Ng (2005) who look at the determinants of static allocations at the country level and Covrig, Fontaine, Jimenez-Garcs, and Seasholes (2007) who study the effect of information asymmetries on home bias. Broner, Gelos, and Reinhart's (2006) interesting study focuses on country allocations of emerging market funds and looks at channels of crisis transmission. The authors present a model with time-varying risk aversion, which predicts in particular that overexposed investors tend to revert to the market portfolio in crisis times. In the absence of stock level data, they assume that funds hold a portfolio well proxied by the IFC US$ total return investable index. 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. 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. For a high-frequency study linking exchange rates to aggregated institutional investors flows using State Street Bank & Trust data, see Froot and Ramadorai (2005).

leverage are not a major concern for our analysis, since (postive 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.[14] 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, 1999), most mutual funds do not engage in any derivative trading because of high transaction costs 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 towards 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 (EZ) and Canada (CA).[15] These fund locations represent 91% of all quarterly fund reports in our data and constitute 94% of all reported positions by value. Funds in the Eurozone are pooled because of their common currency after 1999. To reduce data outliers and limit the role of reporting errors, a number of data filters are employed:

- We retain holding data only from the last reporting date of a fund in each quarter. A fund has to feature in two consecutive quarters to be retained. Consecutive reporting dates are a 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 funds 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

[14] 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.

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

a narrow foreign or domestic investment mandate less interesting.[16]

- Non-diversified funds with extreme investment biases in very few stocks are also ignored. We consider a fund diversified if fund 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%.[17]

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 \$955 million on total equity assets, out of which \$638 million are invested in home equity and \$317 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 53.2%. While the average quarterly rebalancing between foreign and domestic equity investments is small at 0.071%, its standard deviation is substantial at 4.5% of the total (equity) value of the portfolio.

The number of international funds in the sample increases steadily over time from only 167 funds reporting at the end of 1999 to 5,683 funds reporting at the end of 2015. 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 other investment destinations, the aggregate rebalancing from foreign to home investments for all funds domiciled within currency area c $(\Delta H^{f}_{c,t})$, and the **r**eciprocal aggregate rebalancing out of the home country for funds domiciled outside curency area c $(\Delta H^{h*}_{c,t})$.

[16] We are also unable to capture any "household rebalancing", which might consist of rebalancing out of foreign country funds into purely domestic equity funds.

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

4 Empirical Analysis

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 investments component is exposed to additional exchange rate risk and generates a rebalancing motive whenever its value grows relative to the domestic equity share in the investment 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. Such rebalancing behavior reflects the investor's desire to partly off-set exogenous changes in exchange rate risk exposure. These investment by fund flows in turn create a feedback effect on exchange rate volatility. The repatriated equity investments tend to lead to appreciation of the domestic currency. In this section we first explore the validity of the rebalancing hypothesis with respect to differential equity market performance. This analysis is undertaken at the fund level and represents the most important contribution of the paper. In the last part of this section, we also examine the link between aggregate fund flows and exchange rate dynamics. Here we aggregate fund flows to verify the portfolio flow effect on the exchange rate.

Our fund-level rebalancing statistic $\Delta h^f_{j.t}$ compares the *observed* foreign equity weights $w^f_{j,t}$ of fund j at the end of period (quarter) t to the *implied* weights $\widehat{w}^f_{j,t}$ from a simple holding strategy that does not engage in any buy or sell activity with respect to foreign equity investment. Formally, we define rebalancing as any deviation from the simple holding strategy given by

$$\Delta h^f_{j,t} = 100 \times \left(w^f_{j,t} - \widehat{w}^f_{j,t} \right) \qquad \text{with} \qquad \widehat{w}^f_{j,t} = w^f_{j,t-1} \left(\frac{1 + r^{f*}_{j,t}}{1 + r^P_{j,t}} \right),$$

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

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

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

Figure 2 illustrates the distribution of the rebalancing measure for each of the four fund domiciles. We graph the realized foreign portfolio share $w^f_{j,t}$ of each fund on the y-axis against the implied share $\widehat{w}^f_{j,t}$ under a passive holding strategy on the x-axis. The dispersion of points along the 45-degree line shows the difference in the foreign investment share across funds in the different domiciles. The vertical distance of any fund observation from the 45-degree line measures active portfolio management $\Delta h^f_{j,t}$ for the respective fund. Fund rebalancing at the quarterly frequency has a standard deviation of 4.5% for the full sample of 109,487 fund periods as stated in Table 1. It is highest for Eurozone funds at 5.0% and lowest for the U.K. and U.S. funds at 3.9% and 3.8%, respectively. We also highlight a larger average foreign investment share for U.K. funds and the stronger home bias for U.S. funds. By contrast, the Eurozone fund sample is more uniformly distributed in terms of its foreign investment share.

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

$$r^P_{j,t} = \sum_{i=1}^{N_j} w_{i,j,t-1} r^*_{i,t},$$

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

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

For stocks outside the currency area of the fund domicile, the return $r^*_{s,t}$ comprises an exchange rate component. Analogous to the model, we can define a foreign asset return strictly in local currency terms where $r_{s,t}$ denotes the local return in the currency of the stock domicile. The corresponding foreign return component of the portfolio (net of any exchange rate effect) then follows as

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

In Section 4.1 we explore how the return difference between this foreign equity return component (net of exchange rate effects) and the domestic return component, that is $r^f_{j,t-l} - r^h{}_{j,t-l}$ (at lag l), influences rebalancing. Expressing the return difference in terms of the respective local currency implies that exchange rate effects do not interfere with our inference on rebalancing.

4.1 Baseline Results on Rebalancing

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

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

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

Table 2 reports the baseline results on the rebalancing behavior of international equity funds. Column (1) includes only the contemporaneous excess return $r^f_{j,t} - r^h{}_{j,t}$ and does not include any fixed effects. The 109,487 fund-quarters yield the predicted negative coefficient at -2.357, 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 returns on foreign equity. The inclusion of lagged excess returns also presents a useful control of reverse causality. If a fund increases (decreases) its positions in illiquid foreign stocks, this may increase (decrease) their stock price, generate a positive (negative) foreign excess return $r^f_{j,t} - r^h{}_{j,t}$ and thus bias the contemporaneous coefficient towards 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 β_0 and the lagged coefficient β_1 are both negative at high levels of statistical significance. Adding fund fixed effects in Column (3) can absorb any positive or negative growth trend in a fund's foreign equity position, but their inclusion does not qualitatively affect the rebalancing evidence. Column (4) shows that even the second quarterly lag of foreign excess returns $r^f_{j,t-2} - r^h{}_{j,t-2}$ has some explanatory power for fund rebalancing, althought the economic magnitude is much weaker at -0.743.

Adding the three coefficients in Column (4) implies a combined rebalancing effect of -4.879. A relative quarterly excess return of two standard deviations (or 0.138) therefore implies a reduction in the foreign equity weight by 0.673 percentage points for the representative (foreign-invested) institutional investor.[18] In light of the large size of foreign equity positions valued at \$1.84 trillion globally in December 2014, this amounts to economically significant equity flow of \$12.4 billion per quarter.

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

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

where $1_{\Delta r \geq 0}$ represents a dummy that is equal to 1 whenever the foreign excess return $\Delta r = r^f_{j,t} - {r^h}_{j,t} \geq 0$ and 0 otherwise. The complementary dummy marking 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 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 $r^f_{j,t-l}$ and $r^h_{j,t-l}$. Again no evidence for an asymmetric rebalancing is found in these unreported regression results. Finally, we split the sample into a pre-crisis period up to June 2008 (Period I) and a post-crisis period (Period II) thereafter. Columns (6) and (7) show the respective regression results and indicate that the rebalancing behavior is relatively stable across the two subsamples. Excluding the financial crisis period (Period II) does not change the evidence on fund rebalancing behavior.

4.2 Rebalancing and FX Volatility

Higher FX volatility increases segmentation between the domestic and foreign equity markets. This reinforces portfolio rebalancing under incomplete FX risk trading in accordance with Corol-

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

lary 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 its N bilateral exchange rates $E_{c,i,d}$ with each investment destination i. Formally,

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

where the weights $\omega_{c,i}$ are chosen to be the average foreign portfolio shares of all domestic funds in currency area c. The (realized) exchange rate volatility $VOL_{c,t}^{FX}$ for quarter t is defined as the standard deviation of the return $r_{c,d}^{FX} = \ln E_{c,d} - \ln E_{c,d-1}$ measured for all trading days d of quarter t. Figure 3 shows the realized effective exchange rate volatility of the four fund locations for the period January 1999–December 2015. The exchange rate volatility across the four currency areas features a cross-sectional correlation of 0.71. Exchange rate volatility is also distinct from stock market uncertainty. For comparison, we plot here the average quarterly Cboe's Volatility Index VIX. The correlation between the VIX index of equity market uncertainty and the exchange rate volatility is 0.62.

To test for the FX volatility sensitivity of exchange rate rebalancing, we interact the excess return on foreign equity $r_{j,t}^{f} - r^{h}{}_{j,t}$ with a lagged measure of realized exchange rate volatility $VOL_{c,t-1}^{FX}$. The extended regression specification follows as

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

where β_l captures the volatility-independent component of fund rebalancing at lags $l = 0, 1$ and δ_l the sensitivity of rebalancing to changes in FX volatility. The coefficient γ measures any increase in the home bias of fund allocation related to changes in the level of FX volatility. As before, we include interacted investor country and time fixed effects $\eta_{c,t}$ and fund fixed effects ε_j in the regression.

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 $VOL_{c,t-1}^{FX}$, whereas Column (2) also includes lagged excess returns for a more complete description of the rebalancing behavior. We include fund fixed effects in the specifications, but no interacted time and investor country fixed effects as these would span the

FX volatility dynamics.

We find that the rebalancing behavior is stronger under higher levels of exchange rate volatility $\delta_0 < 0$ as predicted in Corollary 2. Higher FX volatility can increase the riskness of the foreign equity share in the fund portfolio and thus strengthen the rebalancing motive. The interaction term between lagged excess returns $r^f_{j,t-1} - r^h{}_{j,t-1}$ and the exchange rate volatility $VOL^{FX}_{c,t-1}$ in Column (2) is statistically insignificant. We also note that higher exchange rate volatility is *ceteris paribus* related to increases in the foreign fund position, as indicated by the positive coefficient γ, though the estimates are statistically insignificant or only weakly significant.

Columns (3)–(4) of Table 3 replace the measure of quarterly FX volatility with the average quarterly Cboe's Volatility Index VIX. Higher expected market volatility captured by the VIX does not appear to be related to stronger rebalancing behavior, unlike FX volatility. In particular, the interaction term of the excess returns $r^f_{j,t} - r^h{}_{j,t}$ and the VIX_{t-1} in the previous quarter $(t-1)$ does not bear any statistically significant relationship to the rebalancing of foreign equity holdings $\Delta h^f_{j,t}$. This suggests that exchange rate volatility is the more relevant driver of international equity market segmentation compared to investor uncertainty about stock market valuations.

4.3 Rebalancing by Quantiles

The linear regression model captures an average effect for the rebalancing channel. Yet the propensity to rebalance could be highly heterogeneous across funds 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 $\tau = 0.05,\ 0.15,\ 0.25, ...,\ 0.85,\ 0.95$ of the distribution of holding changes. Figure 4 plots the quantile coefficients β^τ_0 and β^τ_1 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.

We therefore find that the propensity to rebalance as a function of return differentials is weakest at moderate levels of portfolio rebalancing. A higher propensity to rebalance (a more negative coefficient) is associated first and foremost with the highest levels of rebalancing in absolute value (low quantiles $\tau = 0.05$, 0.15 of the rebalancing variable, which correspond to large capital repatriation, and highest quantiles $\tau = 0.85$, 0.95 of the rebalancing variable, which correspond to large capital expatriation). This means that particularly large changes $\Delta h^f_{j,t}$ at the edge of the rebalancing distribution are well explained by differential equity returns between the foreign and home share of the fund portfolio and that rebalancing intensity is particularly strong when associated with capital repatriation following an increase in foreign returns over domestic returns. With one lag the strong association of large rebalancing behavior with a large response to returns differential remains for the low quantiles ($\tau = 0.05$, 0.15) but the relationship for the higher quantiles becomes somewhat flatter. On the other hand, moderate rebalancing flows are not as responsive to changes in returns. For comparison, we add as blue horizontal lines the OLS estimate (dashed line) and its 95% confidence interval (dotted line). The OLS estimates capture the average rebalancing effect, which is much more intense at the edges of distribution of holding changes.

4.4 Fund Heterogeneity and Rebalancing

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 $\Delta h^f_{j,t}$ 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 $w^f_{j,t}$, and (iii) the fund investment concentration as measured by the Herfindahl-Hirschman Index (HHI) of all fund position weights $w_{s,j,t}$. Fund size may represent an obstacle to frequent rebalancing if average transaction costs increase with the size of the position change. Large funds are also likely to be more diversified so that large differences between foreign and domestic equity returns occur less frequently. Greater fund diversification is likely to attenuate the need for rebalancing. We therefore expect funds with more concentrated holdings to feature stronger rebalancing behavior.

We calculate the average and median values of these three fund characteristics for all observations in the direct vicinity of the regression line for 10 quantiles $\tau = 0.05$, 0.15, $0.25, ...,$ 0.85, 0.95. Formally, we associate with quantile τ all observations for which the regression residual switches signs from a negative value $\Delta h^f_{j,t} - x_{j,t}\beta(\tau - .05) < 0$ to a positive value $\Delta h^f_{j,t} - x_{j,t}\beta(\tau + .05) \geq 0$ by moving from a quantile regression at quantile $\tau - 0.05$ to the same regression undertaken at quantile $\tau + 0.05$. The regressors $x_{j,t}$ are the same as in the quantile regression in Section 4.3 and include the excess return at lags $l = 0, 1$ and interacted country and time fixed effects.

Figure 5, Panels A and B characterize the average and median fund size 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 $\Delta h^f_{j,t}$ than at its center. The strongest propensity to rebalance in reaction to return differentials is therefore observed for smaller funds. This is true for large rebalancing flows whether for the repatriation of capital (the lowest quantile of the rebalancing variable) or the expatriation of capital flows (largest quantile of the rebalancing variable). 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 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 suprising as these funds are also more likely to feature diverging performance on their domestic and foreign equity portfolios. Funds with concentrated equity positions feature stronger rebalancing behavior. The more diversified and largest funds tend in contrast to be associated with moderate rebalancing levels and low rebalancing propensities. They are more likely to follow more passive strategies.

4.5 Exchange Rate Effects of Fund Flows

A key element of the equilibrium model developed in Section 2 is that a country's exchange rate dynamics are in turn influenced by portfolio rebalancing. 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 is largely an empirical matter.

To explore the aggregate effect of equity fund flows on exchange rate dynamics, we define as D_c the set of all home funds domiciled in currency area c (= U.S., U.K., EZ, CA), and as I_c the set of all foreign funds invested in currency area c. Let the market value of all foreign equity positions of fund $j \in D_c$ at the end of quarter $t-1$ be denoted by $a^f_{j,t-1}$ and the value of all home equity positions in currency area c by a foreign fund $j' \in I_c$ be given by $a^{h*}_{j',t-1}$. We can then define the aggregate rebalancing of all domestic and foreign funds with respect to currency area c as

$$\Delta H^f_{c,t} = \frac{1}{A^f_{c,t-1}} \sum_{j \in D_c} \Delta h^f_{j,t} \times a^f_{j,t-1} \qquad \text{with} \qquad A^f_{c,t-1} = \sum_{j \in D_c} a^f_{j,t-1}$$

$$\Delta H^{h*}_{c,t} = \frac{1}{A^{h*}_{c,t-1}} \sum_{j \in I_c} \Delta h^{c*}_{j,t} \times a^{c*}_{j,t-1} \qquad \text{with} \qquad A^{h*}_{c,t-1} = \sum_{j \in I_c} a^{h*}_{j,t-1},$$

respectively, where $\Delta h^f_{j,t}$ denotes the fund-level rebalancing of home funds towards home equity and $\Delta h^{c*}_{j,t}$ the rebalancing of foreign funds from currency area c towards other currency areas. In the aggregation of the holding changes of individual funds, we ignore large rebalancing events with holding changes larger than 3% of fund assets. This filter should eliminate extremely large fund flows that might be less likely to originate in the rebalancing motive captured by our model. In total, we exclude from the aggregation approximately 10% of all fund-level rebalancing events.

The effect of aggregate portfolio rebalancing on the quarterly effective exchange rate change $\Delta E_{c,t}$ can evaluated by the linear regression

$$-\Delta E_{c,t} = (1/\kappa)_1 \Delta H^f_{c,t-1} + (1/\kappa)_2 \Delta H^{h*}_{c,t-1} + \lambda \Delta E_{c,t-1} + \epsilon_{c,t},$$

where we pool observations across the four currency areas U.S, U.K, Eurozone and Canada.

Each currency area is in turn considered the home country with the three other currency areas representing the foreign country. The effective exchange rate is calculated based on fixed weights represented by the average size of their respective equity markets. In line with the model assumption in Eqs. (3) and (4), we predict $\kappa_1 > 0$ and $\kappa_2 < 0$, and for a symmetric flow impact we expect to find $(1/\kappa)_1 = -(1/\kappa)_2$. The aggregate holding changes are lagged by one quarter to eliminate the reverse causality whereby international stock market investment flows appreciate the local currency and simultaneously inflate equity prices.

Table 4 reports the regresssion results. Column (1) includes only the aggregate foreign holding change $\Delta H^f_{c,t-1}$ of funds incorporated in the home country and Column (2) only the home country holding change $\Delta H^{h*}_{c,t-1}$ of foreign funds. We find that an aggregate foreign holding decrease $\Delta H^f_{c,t-1} < 0$ (or investment repatriation) does indeed predict an appreciation of the domestic currency [Column (1)] and vice versa—a decrease in foreign fund investment at home $\Delta H^{h*}_{c,t-1} < 0$ predicts depreciation of the domestic currency [Column (2)]. The rebalancing model in Section 2 predicts a perfect negative correlation between $\Delta H^f_{c,t-1}$ and $\Delta H^{h*}_{c,t-1}$, but the empirical correlation is only -0.30. Yet, we cannot reject the null hypothesis that the coefficients κ_1 and κ_2 are equally large (in absolute terms) and of opposite sign. Concerns about collinearity suggest that we create the linear combination $\frac{1}{2}(\Delta H^f_{c,t-1} - \Delta H^{h*}_{c,t-1})$ as an alternative regressor; the corresponding regression results are reported in Column (4). The combined effect captured by the linear combination $\frac{1}{2}(\Delta H^f_{c,t-1} - \Delta H^{h*}_{c,t-1})$ produces a coefficient of 0.03. A decrease in net foreign holdings by two standard deviations (= 0.44) therefore appreciates the domestic currency by approximately 1.3% in the following quarter. The overall explantory power of the fund flow channel for exchange rate movements is very modest, as illustrated by the low regesssion R^2.

Notwithstanding our filtering procedure for aggregate flows and the lagged measurement of holding changes, it seems plausible that portfolio flows reflect many other macroeconomic factors uncorrelated with the rebalancing motive induced by differential return performance of home and foreign equity. As measurement errors for the relevant holding changes, they may attenuate the predicted positive correlation with the exchange rate change. Hence we apply an instrumental variable approach where we (i) predict in a first-stage regression the fund specific rebalancing according to the regression in Table 2, Column (2), and (ii) aggregate fund-level predicted rebalancing to the aggregate predicted rebalancing terms $\Delta \widehat{H}^f_{c,t-1}$ and $\Delta \widehat{H}^{h*}_{c,t-1}$. Columns (5)–(8) report the 2SLS regressions relating exchange rate changes to predicted aggregated holding changes of domestic and foreign funds. The 2SLS regressions for the exchange rate produce the correct positive sign for the instrumented foreign holding change of domestic funds $\Delta \widehat{H}^{f}_{c,t-1}$ at the 1% level of statistical significance and also the correct negative sign for the instrumented domestic holding change of foreign funds $\Delta \widehat{H}^{h*}_{c,t-1}$. The 2SLS coefficients are on average more than five times as large as the corresponding OLS coefficients, but also feature a similar increase in their standard error.

The statistically highly significant estimated coefficient of 0.297 for the $\frac{1}{2}(\Delta \widehat{H}^{f}_{c,t-1} - \Delta \widehat{H}^{h*}_{c,t-1})$ is economically extremely large. This may reflect an estimation bias observed when instruments (given by $r^{f}_{j,t} - r^{h}{}_{j,t}$ and $r^{f}_{j,t-1} - r^{h}{}_{j,t-1}$) are only semi-strong predictors of the second stage regressor and also feature some direct correlation with the dependent variable $-\Delta E_{c,t}$ beyond the flow effect of $\frac{1}{2}(\Delta \widehat{H}^{f}_{c,t-1} - \Delta \widehat{H}^{h*}_{c,t-1})$. In particular, measurement error with respect to the term $\frac{1}{2}(\Delta H^{f}_{c,t-1} - \Delta H^{h*}_{c,t-1})$ can induce a direct effect of $r^{f}_{j,t} - r^{h}{}_{j,t}$ on the exchange rate change $-\Delta E_{c,t}$ and bias the IV estimate toward a larger coefficient.[19] Hence, the economic magnitude of the 2SLS estimates needs to be interpreted with caution.

4.6 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

[19] See Jiang (2017) for an insightful discussion of the issue.

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: large heterogeneity of portfolios as measured by domestic and foreign weights—which implies large heterogeneity of portfolios in their exposure to exchange rate risk. Modeling financial intermediaries more realistically is an important agenda for future research.[20]

5 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. Some of this rebalancing occurs over the period of three quarters and is therefore unlikely to be driven by reverse causality. 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 accounting for such rebalancing behavior: limited international tradability of exchange rate risk implies that foreign equity investments are more risky 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

[20]Important progress has been made in that direction: see, for example, Bruno and Shin (2015), Gabaix and Maggiori (2015), and others.

exchange rate risk (measured by realized FX volatility) reinforces the rebalancing channel. By contrast, variations in stock market uncertainty do not account for intertemporal variations in the strength of the 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 particular, large rebalancing flows are associated with much stronger rebalancing elasticity to return differentials. 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. Last, we show that the aggregate fund flows induced by the documented rebalancing behavior move exchange rates in line with the model prediction, even though the explanatory power of this link is economically weak.

We speculate that our evidence potentially casts some light on two different types of international financial links. The first is an international financial adjustment mechanism (see Gourinchas and Rey, 2007). If persistent trade surpluses induce increasing foreign asset holdings, then the corresponding increase in the foreign portfolio share for domestic investors may ultimately depreciate the foreign currency and provide a mechanism for an adjustment of the trade balance. By contrast, the second is an international amplification mechanism. The valuation effects of a foreign asset market boom will tend to depreciate the foreign currency and reinforce the dynamics of a boom and bust cycle. Much remains to be done to better comprehend the complexity of international links across financial assets.

References

[1] Adrian, T., Etula E. and Shin, H.S., 2014. Risk appetite and exchange rates. Federal Reserve Bank of New York Staff Report, 361.

[2] Albuquerque, R., Bauer, G.H. and Schneider, M., 2007. International equity flows and returns: a quantitative equilibrium approach. The Review of Economic Studies, 74(1), pp. 1-30.

[3] Albuquerque, R., Bauer, G.H. and Schneider, M., 2009. Global private information in international equity markets. Journal of Financial Economics, 94(1), pp. 18-46.

[4] Bacchetta, P. and Van Wincoop, E., 2010. Infrequent portfolio decisions: A solution to the forward discount puzzle. American Economic Review, 100(3), pp. 870-904.

[5] Basak, S. and Pavlova, A., 2013. Asset prices and institutional investors. American Economic Review, 103(5), pp. 1728-58.

[6] Blanchard, O., Giavazzi F. and Sá F., 2005. International investors, the U.S. current account, and the dollar. Brookings Papers on Economic Activity, 36, pp. 1-66.

[7] Bénétrix, A.S., Lane, P.R. and Shambaugh, J.C., 2015. International currency exposures, valuation effects and the global financial crisis. Journal of International Economics, 96, pp. 98-109.

[8] Bohn, H. and Tesar, L.L., 1996. US equity investment in foreign markets: portfolio rebalancing or return chasing?. The American Economic Review, 86(2), pp. 77-81.

[9] Branson, W.H. and Henderson, D.W., 1985. The specification and influence of asset markets. Handbook of International Economics, 2, pp. 749-805.

[10] Brennan, M.J. and Cao, H.H., 1997. International portfolio investment flows. The Journal of Finance, 52(5), pp. 1851-1880.

[11] Broner, F.A., Gelos, R.G. and Reinhart, C.M., 2006. When in peril, retrench: Testing the portfolio channel of contagion. Journal of International Economics, 69(1), pp. 203-230.

[12] Bruno, V. and Shin, H.S., 2014. Cross-border banking and global liquidity. The Review of Economic Studies, 82(2), pp. 535-564.

[13] Burger, J.D., Warnock, F.E. and Warnock, V.C., 2017. The effects of US monetary policy on emerging market economies' sovereign and corporate bond markets. National Bureau of Economic Research, Working Paper, w23628.

[14] Caballero, R. and Simsek, A., 2016. A model of fickle capital flows and retrenchment. National Bureau of Economic Research, Working Paper, w22751.

[15] Calvet, L.E., Campbell, J.Y. and Sodini, P., 2009. Fight or flight? Portfolio rebalancing by individual investors. The Quarterly Journal of Economics, 124(1), pp. 301-348.

[16] Chan, K., Covrig, V. and Ng, L., 2005. What determines the domestic bias and foreign bias? Evidence from mutual fund equity allocations worldwide. The Journal of Finance, 60(3), pp. 1495-1534.

[17] Coeurdacier, N., 2009. Do trade costs in goods market lead to home bias in equities?. Journal of International Economics, 77(1), pp. 86-100.

[18] Coeurdacier, N. and Rey, H., 2012. Home bias in open economy financial macroeconomics. Journal of Economic Literature, 51(1), pp. 63-115.

[19] Covrig, V., Fontaine, P., Jimenez-Garces, S. and Seasholes, M.S., 2007. Information asymmetries, common factors, and international portfolio choice. Working Paper, SSRN eLibrary.

[20] Della Corte, P., Sarno, L. and Sestieri, G., 2012. The predictive information content of external imbalances for exchange rate returns: how much is it worth?. Review of Economics and Statistics, 94(1), pp. 100-115.

[21] Devereux, M.B. and Sutherland, A., 2010. Country portfolio dynamics. Journal of Economic Dynamics and Control, 34(7), pp. 1325-1342.

[22] Devereux, M.B. and Sutherland, A., 2010. Valuation effects and the dynamics of net external assets. Journal of International Economics, 80(1), pp. 129-143.

[23] Devereux, M.B. and Sutherland, A., 2011. Country portfolios in open economy macro-models. Journal of the European Economic Association, 9(2), pp. 337-369.

[24] Dou, W.W. and Verdelhan, A., 2015. The volatility of international capital flows and foreign assets. Working Paper, MIT.

[25] Dziuda, W. and Mondria, J., 2012. Asymmetric information, portfolio managers, and home bias. The Review of Financial Studies, 25(7), pp. 2109-2154.

[26] Evans, M. and Lyons, R., 2012. Order flow and exchange rate dynamics. Journal of Political Economy, 110(1), pp. 170-180.

[27] Ferreira, M.A. and Matos, P., 2008. The colors of investors' money: The role of institutional investors around the world. Journal of Financial Economics, 88(3), pp. 499-533.

[28] Frankel, J.A., 1982. In search of the exchange risk premium: A six-currency test assuming mean-variance optimization. Journal of International Money and Finance, 1, pp. 255-274.

[29] Frankel, J.A., 1982. A test of perfect substitutability in the foreign exchange market. Southern Economic Journal, pp. 406-416.

[30] Fratzscher, M., Juvenal, L. and Sarno, L., 2010. Asset prices, exchange rates and the current account. European Economic Review, 54(5), pp. 643-658.

[31] French, K., and Poterba, J., 1991. Investor diversification and international equity markets, American Economic Review, 81(2), p. 222-226.

[32] Froot, K.A., O'Connell, P.G. and Seasholes, M.S., 2001. The portfolio flows of international investors. Journal of Financial Economics, 59(2), pp. 151-193.

[33] Froot, K.A. and Ramadorai, T., 2005. Currency returns, intrinsic value, and institutional-investor flows. The Journal of Finance, 60(3), pp. 1535-1566.

[34] Gabaix, X. and Maggiori, M., 2015. International liquidity and exchange rate dynamics. The Quarterly Journal of Economics, 130(3), pp. 1369-1420.

[35] Gourinchas, P.O. and Rey, H., 2007. International financial adjustment. Journal of Political Economy, 115(4), pp. 665-703.

[36] Hau, H., Massa, M. and Peress, J. 2010. Do demand curves for currencies slope down? Evidence from the MSCI global index change. The Review of Financial Studies, 23(4), pp. 1681-1717.

[37] Hau, H. and Rey, H., 2002. Exchange rates, equity prices, and capital flows. National Bureau of Economic Research, Working Paper, w9398.

[38] Hau, H. and Rey, H., 2006. Exchange rates, equity prices, and capital flows. The Review of Financial Studies, 19(1), pp. 273-317.

[39] Hau, H. and Rey, H., 2008. Home bias at the fund level. American Economic Review, 98(2), pp. 333-38.

[40] Jeanne, O. and Sandri, D., 2017. Global financial cycle and liquidity management. Working Paper, John Hopkins.

[41] Jiang, W., 2017, Have instrumental variables brought us closer to the the truth?. Working Paper, Columbia University.

[42] Kouri, P.J., 1982. Balance of payment and the foreign exchange market: A dynamic partial equilibrium model. in Jagdeep Bhandari and Bluford Putnam, eds., Economic interdependance and flexible exchange rates, MIT Press, pp. 116-156.

[43] Lane, P.R. and Milesi-Ferretti, G.M., 2007. A global perspective on external positions, in Richard Clarida, ed., G-7 current account imbalances: Sustainability and adjustment, pp. 67-102.

[44] Lane, P.R. and Milesi-Ferretti, G.M., 2017. International financial integration in the aftermath of the global financial crisis. International Monetary Fund, Working Paper, 17/115.

[45] Lane, P.R. and Shambaugh, J.C., 2010. Financial exchange rates and international currency exposures. The American Economic Review, 100(1), pp. 518-540.

[46] Levich, R.M., Hayt G., and Ripston B., 1999. 1998 survey of derivative and risk management practices by U.S. institutional investors, Survey conducted by the NYU Salomon Center, CIBC World Markets, and KPMG.

[47] Lewis, K.K., 1999. Trying to explain home bias in equities and consumption. Journal of Economic Literature, 37(2), pp. 571-608.

[48] Maggiori, M., Neiman, B. and Schreger, J., 2017. International currencies and capital allocation. Working Paper, SSRN eLibrary.

[49] Miranda-Agrippino S. and Rey, H., 2015. World asset markets and the global financial cycle. National Bureau of Economic Research, Working Paper, w21722.

[50] Rogoff, K., 1984. On the effects of sterilized intervention: An analysis of weekly data. Journal of Monetary Economics, 14(2), pp. 133-150.

[51] Tille, C., 2008. Financial integration and the wealth effect of exchange rate fluctuations. Journal of International Economics, 75(2), pp. 283-294.

[52] Tille, C. and Van Wincoop, E., 2010. International capital flows. Journal of International Economics, 80(2), pp. 157-175.

[53] Vayanos, D. and Woolley, P., 2013. An institutional theory of momentum and reversal. The Review of Financial Studies, 26(5), pp. 1087-1145.

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 proved following the same steps as Hau and Rey (2002). Let $j = h, f$ denote the country index, $\mathbf{\Psi}_t^j = (1, D_t^j, \Delta_t, \Lambda_t)^T$ the state variable, $\mathbf{dw}_t^j = (dw_t^j, dw_t)^T = (dw_t^j, dw_t^h - dw_t^f)^T$ a (1×2) vector of innovations. For coefficients $\alpha_\Psi^j = (\alpha_0^j, \alpha_D^j, \alpha_\Delta^j, \alpha_\Lambda^j)$, $\alpha_\Psi^{j*} = (\alpha_0^{j*}, \alpha_D^{j*}, \alpha_\Delta^{j*}, \alpha_\Lambda^{j*})$, $\mathbf{b}_\Psi^j = (p_F f_D \sigma_D, b_\Psi^j)$, $\mathbf{b}_\Psi^{j*} = (p_F f_D \sigma_D, b_\Psi^{j*})$, and $f_D = 1/(\alpha_D + r)$, we express excess returns (in the investor currency) as

$$
\begin{aligned}
dR_t^j &= \alpha_\Psi^j \mathbf{\Psi}_t^j dt + \mathbf{b}_\Psi^j \mathbf{dw}_t^j \\
dR_t^{j*} &= \alpha_\Psi^{j*} \mathbf{\Psi}_t^j dt + \mathbf{b}_\Psi^{f*} \mathbf{dw}_t^j.
\end{aligned}
$$

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

$$
\begin{pmatrix} H_t^h & H_t^f \\ H_t^{f*} & H_t^{h*} \end{pmatrix} = \frac{1}{\rho dt} \mathcal{E}_t \begin{pmatrix} \alpha_\Psi^h \mathbf{\Psi}_t^h & \alpha_\Psi^f \mathbf{\Psi}_t^f \\ \alpha_\Psi^{f*} \mathbf{\Psi}_t^f & \alpha_\Psi^{h*} \mathbf{\Psi}_t^h \end{pmatrix} \mathbf{\Omega}^{-1},
$$

where $\mathbf{\Omega}$ denotes the (2×2) covariance matrix of instantaneous returns with matrix elements

$$
\begin{aligned}
\Omega_{11} &= (f_D \sigma_D)^2 + 2[p_\Delta \sigma_D + p_\Lambda]^2 + 2 f_D \sigma_D [p_\Delta \sigma_D + p_\Lambda] \\
\Omega_{12} &= -2(p_\Delta \sigma_D + p_\Lambda)^2 - [2(p_\Delta \sigma_D + p_\Lambda) + f_D \sigma_D] \overline{P} (e_\Delta \sigma_D + e_\Lambda) - 2(p_\Delta \sigma_D + p_\Lambda) f_D \sigma_D \\
\Omega_{22} &= (f_D \sigma_D)^2 + 2[\overline{P} (e_\Delta \sigma_D + e_\Lambda) + p_\Delta \sigma_D + p_\Lambda]^2 + 2 f_D \sigma_D [\overline{P} (e_\Delta \sigma_D + e_\Lambda) + p_\Delta \sigma_D + p_\Lambda].
\end{aligned}
$$

Market clearing implies $H_t^h + H_t^{h*} = 1$ and $H_t^{f*} + H_t^f = 1$. The seven endogenous parameters p_0, p_Δ, p_Δ, e_Δ, e_Λ, and z are determined by the following first-order and market clearing conditions:

$$
p_0 = \frac{-\rho \det \Omega - \mathcal{E}_t (dE_t dP_t^f)(-\Omega_{12} + \Omega_{11})}{r(\Omega_{11} - 2\Omega_{12} + \Omega_{22})} \tag{A1}
$$

$$
p_\Delta = -e_\Delta \frac{[(\alpha_D + r)\overline{P} - \overline{D}](\Omega_{21} + \Omega_{11})}{(\alpha_D + r)(\Omega_{11} + 2\Omega_{21} + \Omega_{22})} \tag{A2}
$$

$$
p_\Lambda = -e_\Lambda \frac{[(-z + r)\overline{P} - \overline{D}](\Omega_{21} + \Omega_{11})}{(-z + r)(\Omega_{11} + 2\Omega_{21} + \Omega_{22})} \tag{A3}
$$

$$0 = e_\Delta \left(\overline{KD} - \kappa\alpha_D\right) + m_\Delta \frac{1}{\rho} \left(\overline{D} + \alpha_D \overline{P}\right) + \overline{K} \tag{A4}$$

$$0 = e_\Lambda \left(\overline{KD} + \kappa z\right) + m_\Lambda \frac{1}{\rho} \left(\overline{D} - z\overline{P}\right) \tag{A5}$$

$$0 = \kappa \left[e_\Delta \sigma_D + e_\Lambda\right] - \frac{1}{\rho} \overline{P} \left[m_\Delta \sigma_D + m_\Lambda\right] \tag{A6}$$

$$0 = \left[(-z + r)\overline{P} - \overline{D}\right] \left(\overline{D} - z\overline{P}\right) - \frac{\rho}{2} \left(\overline{KD} + \kappa z\right) \left[\Omega_{11} + 2\Omega_{21} + \Omega_{22}\right] \tag{A7}$$

where we defined (with Ω^{-1}_{nm} denoting element (n, m) of the inverse matrix Ω^{-1})

$$m_\Delta = 2p_\Delta(\alpha_D + r)(\Omega^{-1}_{12} - \Omega^{-1}_{22}) - 2[(\alpha_D + r)\overline{P} - \overline{D}]e_\Delta \Omega^{-1}_{22} \tag{A8}$$

$$m_\Lambda = 2p_\Lambda(-z + r)(\Omega^{-1}_{12} - \Omega^{-1}_{22}) - 2[\overline{P}(-z + r) - \overline{D}]e_\Lambda \Omega^{-1}_{22} \tag{A9}$$

$$\det \Omega = \Omega_{11}\Omega_{22} - \Omega_{21}\Omega_{21}. \tag{A10}$$

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

$$\overline{P} = p_0 + \frac{\overline{D}}{r} + p_\Lambda \overline{\Lambda} = p_0 + \frac{\overline{D}}{r} \tag{A11}$$

$$\overline{H} = \frac{\rho \left[\Omega_{11} - \Omega_{21}\right] - \mathcal{E}_t(dE_t dP^f_t)}{\rho \left(\Omega_{11} - 2\Omega_{21} + \Omega_{22}\right)}. \tag{A12}$$

and

$$\mathcal{E}_t(dE_t dP^h_t)/dt = -\mathcal{E}_t(dE_t dP^f_t)/dt = (e_\Delta \sigma_D + e_\Lambda) \left[f_D \sigma_D + 2 \left(p_\Delta \sigma_D + p_\Lambda\right)\right] < 0.$$

Corollary 1:

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

$$dH^f_t = -\frac{1}{2\rho} m_\Delta d\Delta_t - \frac{1}{2\rho} m_\Lambda d\Lambda_t = -\frac{1}{2\rho} m_\Delta \left[-\alpha_D \Delta_t dt + \sigma_D dw_t\right] - \frac{1}{2\rho} m_\Lambda \left[-\alpha_z \Delta_t dt + dw_t\right], \tag{A13}$$

where we define $dw_t = dw^h_t - dw^f_t$ and $\mathcal{E}_t(dw_t dw'_t) = 2$.

The excess return dynamics (in local currency returns) are approximated by

$$dr^h_t \overline{P} = dP^h_t - rP^h_t dt + D^h_t dt = dF^h_t + p_\Delta d\Delta_t + p_\Lambda d\Lambda_t - rP^h_t dt + D^h_t dt \tag{A14}$$

$$dr^f_t \overline{P} = dP^f_t - rP^f_t dt + D^f_t dt = dF^f_t - p_\Delta d\Delta_t - p_\Lambda d\Lambda_t - rP^f_t dt + D^f_t dt \tag{A15}$$

Ignoring terms of order dt^2 and using Eq. (A13) we can characterize

$$Cov(dH_t^f,\ dr_t^f - dr_t^h) = \frac{1}{2\rho}\left[m_\Delta \sigma_D + m_\Lambda\right]\left[\frac{1}{\overline{P}} f_D \sigma_D + 2\left[p_\Delta \sigma_D + p_\Lambda\right]\right]\mathcal{E}_t(dw_t dw_t')$$
$$= \kappa \frac{1}{\overline{P}}\left[\frac{1}{\overline{P}} f_D \sigma_D + 2\left[p_\Delta \sigma_D + p_\Lambda\right]\right]\left[e_\Delta \sigma_D + e_\Lambda\right] < 0 \qquad \text{(A16)}$$

as $[e_\Delta \sigma_D + e_\Lambda] < 0$ and $\frac{1}{\overline{P}} f_D \sigma_D + 2\left[p_\Delta \sigma_D + p_\Lambda\right] > 0$.

Corollary 2:

Because of the endogeneity of the terms $\overline{P}$, p_Δ, p_Λ, e_Δ,and e_Λ in Eq. (A16) it is difficult to show in closed form that the derivative of $Cov(dH_t^f,\ dr_t^f - dr_t^h)$ is negative with respect to $d\sigma_D$ and positive with respect to $d\kappa$. But the numerical solution plotted in Figure 1B provides a simple illustration that this is generally the case.

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 *et al.* (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.[21] 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

[21] 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.

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.

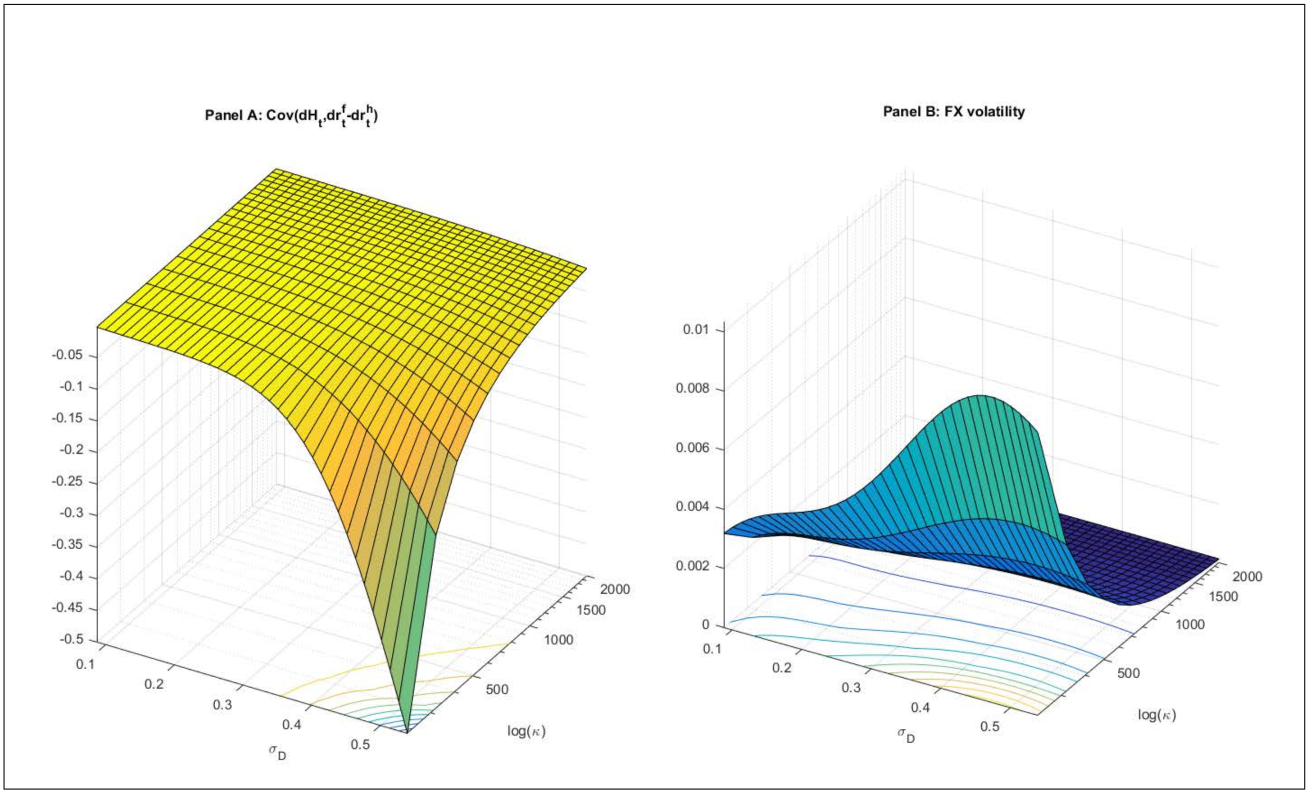

Figure 1: Panel A depicts the covariance between the rebalancing statistics $\Delta H^f_{j,t}$ and the excess return $dr^f_t - dr^h_t$ on the foreign, relative to the domestic, component of the portfolio share as a function of the standard deviation of the dividend process σ_D and the (log) elasticity $log(\kappa)$ of the currency supply. Panel B plots the exchange rate volatility Vol^{FX} associated with the same parameter variations.

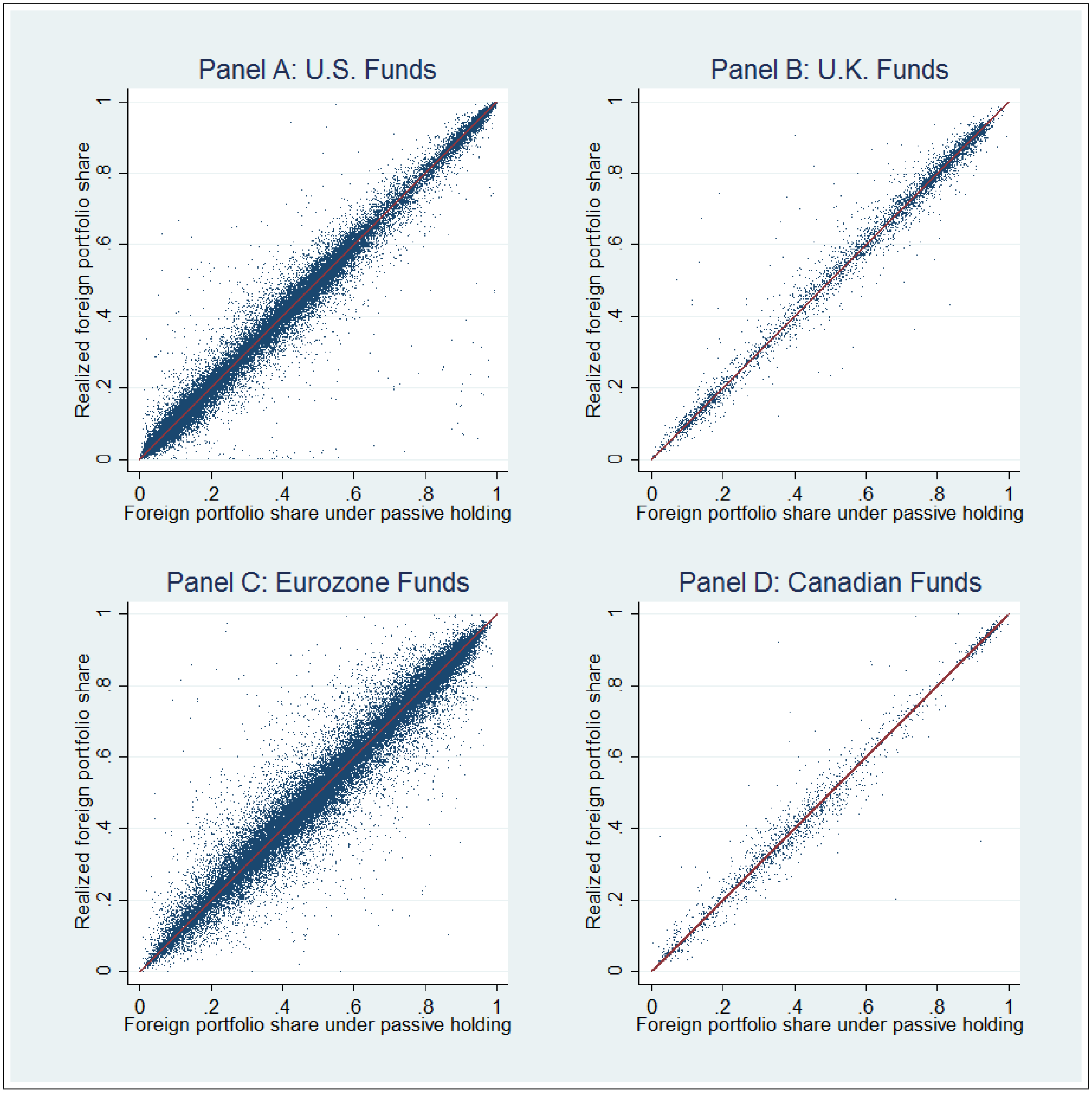

Figure 2: We plot the realized foreign portfolio share $w^f_{j,t}$ (y-axis) relative to the portfolio share implied by a passive holding strategy $\widehat{w}^f_{j,t}$ (x-axis) or funds domiciled in the U.S. (Panel A), the U.K. (Panel B), the Eurozone (Panel C), and Canada (Panel D). The vertical distance to the 45-degree line is proportional to the active rebalancing measure $\Delta h^f_{j,t} = 100 \times (w^f_{j,t} - \widehat{w}^f_{j,t})$.

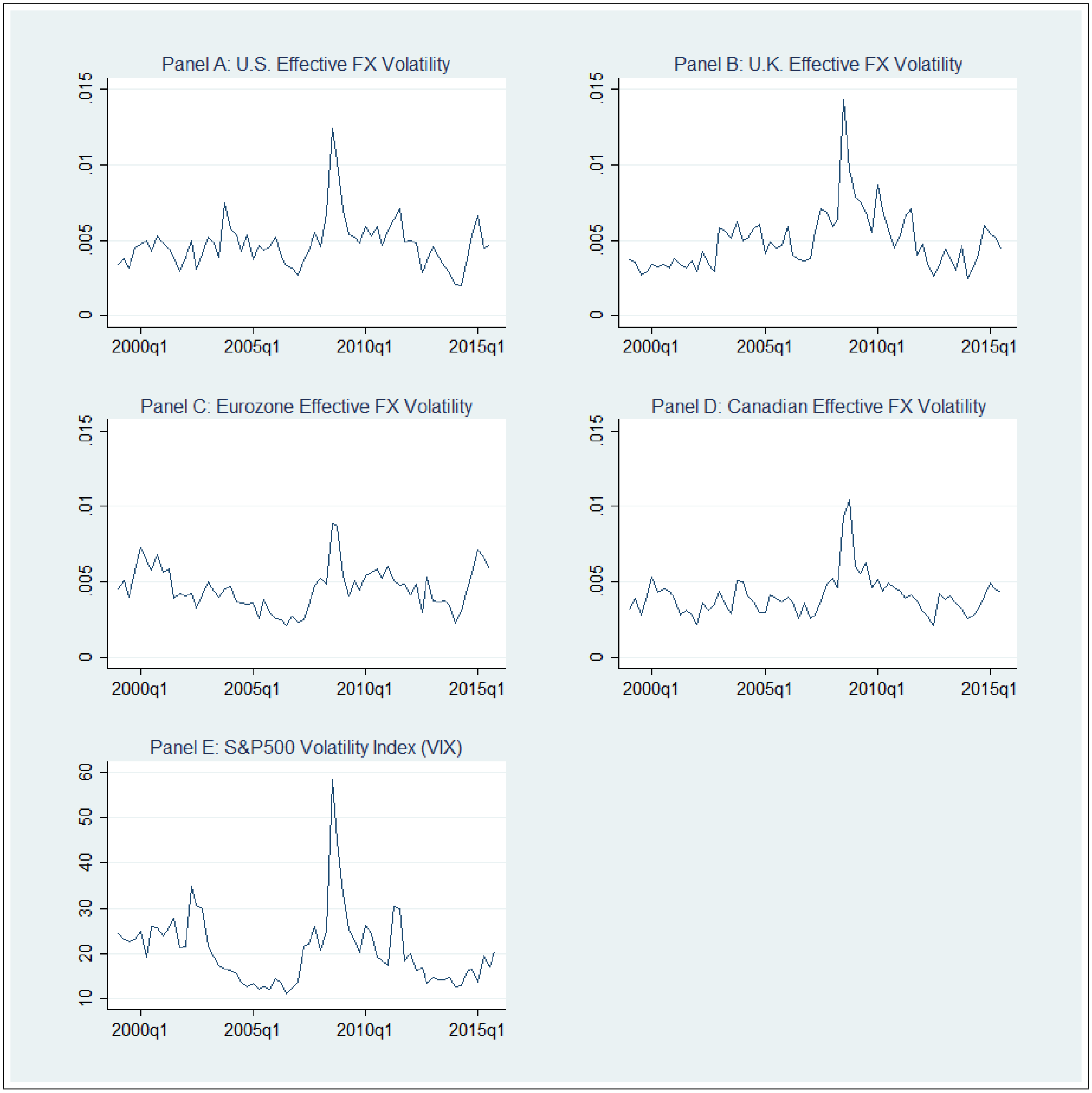

Figure 3: We plot the quarterly realized volatility $VOL_{c,t}^{FX}$ of the effective exchange rate for the U.S. (Panel A), the U.K. (Panel B), the Eurozone (Panel C), and Canada (Panel D). For comparison, we show the quarterly average S&P volatility index (VIX) in Panel E.

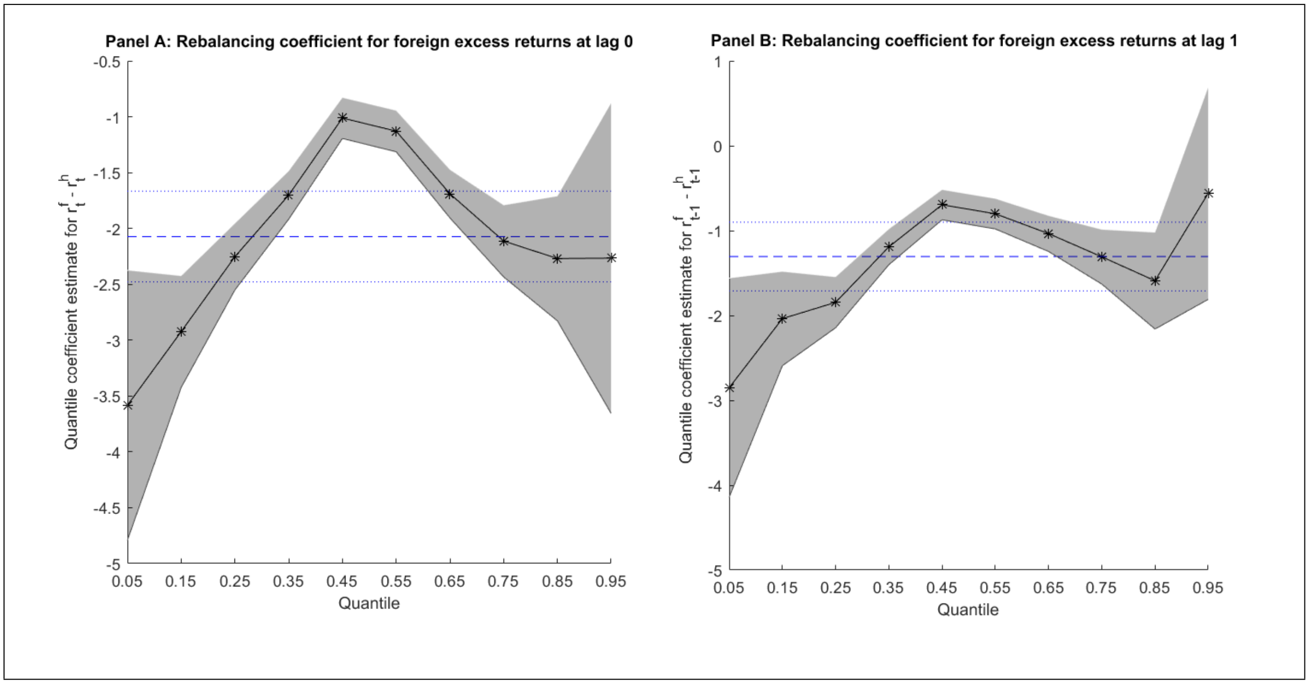

Figure 4: Panels A and B shows the rebalancing coefficients β_0 and β_1 for the foreign excess return and the lagged foreign excess return, respectively, for the 10 quantile regressions at quantiles $\tau = 0.05, 0.15, 0.25, ..., 0.95$ together with a confidence interval of two standard deviations. The horizontal dashed blue line represents the point estimate of the OLS coefficient surrounded by its 95% confidence interval (dotted blue lines).

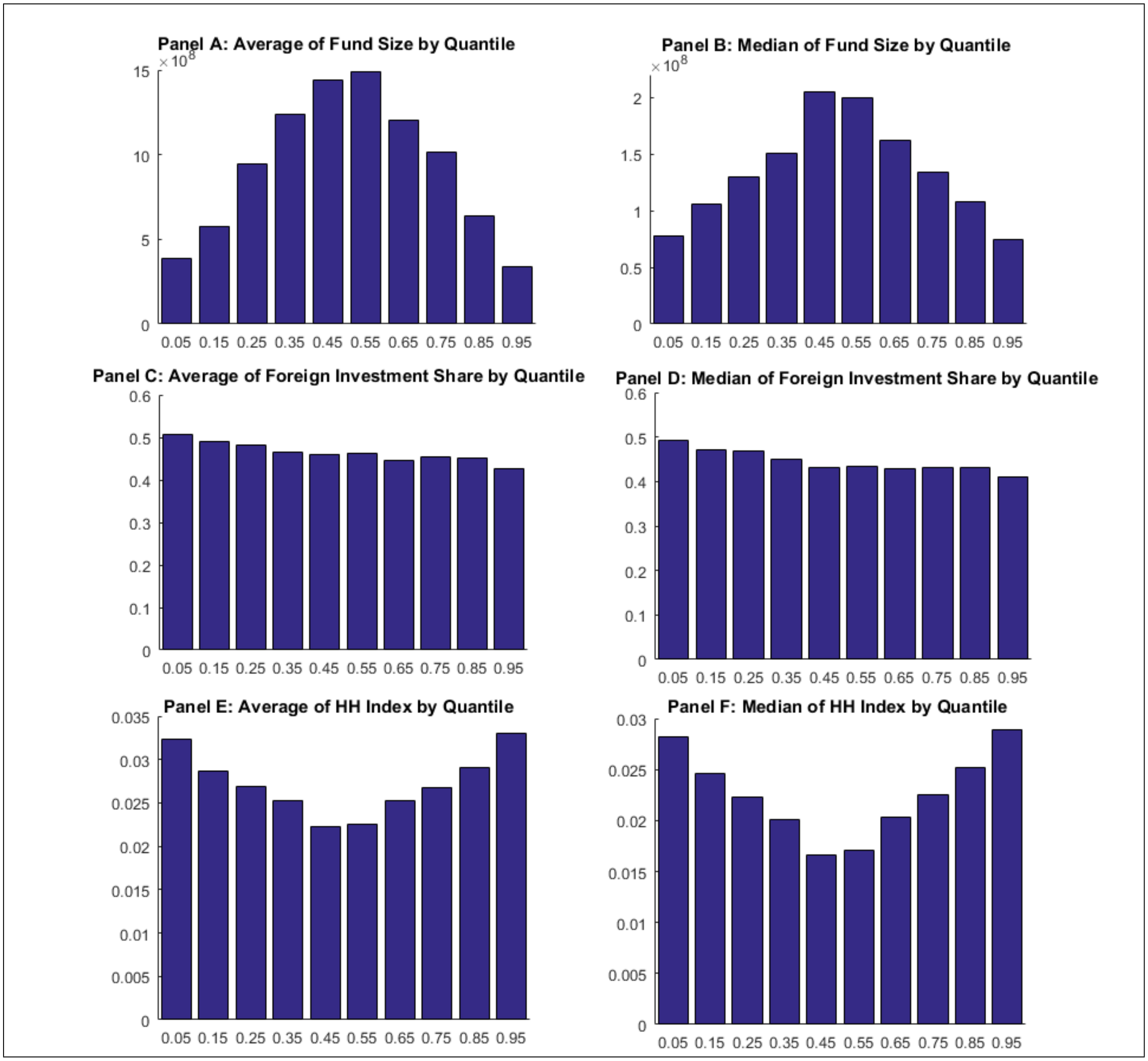

Figure 5: Panels A and B characterize the mean and median fund size around a quantile regression at the quantiles $\tau = 0.05,\ 0.15,\ 0.25, ..., 0.95$, where the interquantile range of mean and median calculation is from $\tau - 0.05$ to $\tau + 0.05$. Panels C and D show the mean and median estimates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

Table 1: Summary Statistics

We use the FactSet dataset (available at WRDS) to calculate in Panel A fund-level statistics for 109,487 fund-quarter observations for the period 1999–2015. Considered are all funds domiciled in the United States (U.S.), the United Kingdom (U.K.), the Eurozone (EZ), and Canada (CA). Reported are total fund assets, the fund assets held in the home and foreign country, respectively; the portfolio shares held in the home (w_h) and foreign country (w_f), respectively; the active rebalancing ($\Delta h^f_{j,t}$) of the foreign investment share (toward the home country scaled by the factor of 100) by fund j in quarter t ; and its relationship to the fund-level excess returns on foreign minus home-country investment positions within the same quarter ($r^f_{j,t} - r^h_{j,t}$) or in the previous quarter ($r^f_{j,t-1} - r^h_{j,t-1}$). Panel B reports aggregate statistics on the quarterly effective exchange rate volatility ($VOL^{FX}_{c,t}$) for each fund domicile c and quarterly market volatility (VIX_t); the effective exchange rate change ($\Delta E_{c,t}$) based on a weighted exchange rate with respect to the the three other fund domiciles with the aggregate foreign investment position of domestic funds as weights; and the aggregate rebalancing $\Delta H^f_{c,t}$ ($\Delta H^{h*}_{c,t}$) of all foreign investment positions held by domestic funds (all domestic positions held by all foreign funds).

		Obs.	Mean	STD	Min	10th	50th	90th	Max
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Fund-level statistics									
Fund assets	Mio USD	109, 487	955	4, 622	10	19	128	1, 423	145, 289
Fund assets at home	Mio USD	109, 487	638	3, 541	0	6	51	854	109, 235
Fund assets abroad	Mio USD	109, 487	317	1, 907	0	6	46	482	122, 816
Home asset share	w_h	109, 487	0.532	0.289	0.000	0.121	0.537	0.928	1.000
Foreign asset share	w_f	109, 487	0.468	0.289	0.000	0.072	0.463	0.879	1.000
Fund rebalancing (×100)	$\Delta h^f_{j,t}$	109, 487	0.071	4.499	−89.015	−3.461	0.019	3.650	72.833
Excess returns									
$r^f_{j,t} - r^h_{j,t}$	(quarterly)	109, 487	−0.002	0.069	−0.602	−0.081	−0.002	0.078	0.676
$r^f_{j,t} - r^h_{j,t}$ (≥ 0 only)	(quarterly)	109, 487	−0.026	0.042	−0.602	−0.081	−0.002	0.000	0.000
$r^f_{j,t} - r^h_{j,t}$ (< 0 only)	(quarterly)	109, 487	0.025	0.041	0.000	0.000	0.000	0.078	0.676
Panel B: Aggregate statistics									
Exchange rate change	$\Delta E_{c,t}$	255	−0.000	0.040	−0.121	−0.048	−0.001	0.044	0.203
Foreign rebalancing	$\Delta H^f_{c,t}$	208	0.017	0.320	−1.297	−0.323	0.003	0.334	2.034
Domestic rebalancing	$\Delta H^{h*}_{c,t}$	247	−0.036	0.202	−0.958	−0.243	−0.012	0.187	0.593
Average rebalancing	$\frac{1}{2}(\Delta H^f_{c,t} - \Delta H^{h*}_{c,t})$	202	0.028	0.221	−0.676	−0.214	0.018	0.239	1.297
FX volatility	$VOL^{FX}_{c,t}$	255	0.005	0.002	0.002	0.003	0.004	0.007	0.014
Market volatility	VIX_t	259	20.633	8.112	11.026	12.766	19.279	29.974	58.322

Table 2: Rebalancing Dynamics

Fund rebalancing of the foreign investment share $\Delta h^f_{j,t}$ of fund f in quarter t is regressed on the excess return of the foreign over the domestic investment share, $r^f_{j,t} - r^h_{j,t}$, and its lagged values $r^f_{j,t-l} - r^h_{j,t-l}$ for lags $l = 1, 2$. In Column (1) we report OLS regression results without fixed effects, Columns (2)–(7) add interacted time and country fixed effects and Column (3) adds additional fund fixed effects. Column (5) splits the execess return on the foreign portfolio share into a positive and negative realizations to test for symmetry of the rebalancing behavior. In Columns (6)–(7) we report the baseline regression of Column (3) for the subsample until June 2008 (Period I) and thereafter (Period II). We report robust standard errors clusterd at the fund level and use ***, **, and * to denote statistical significance at the 1%, 5%, and 10% level respectively.

Dependent variable:	Fund Level Rebalancing $\Delta h^f_{j,t}$						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$r_{f,t} - r_{h,t}$	-2.357^{***}	-2.929^{***}	-2.744^{***}	-2.787^{***}		-2.200^{***}	-2.869^{***}
	(0.235)	(0.285)	(0.309)	(0.320)		(0.639)	(0.362)
$r_{f,t-1} - r_{h,t-1}$		-1.394^{***}	-1.220^{***}	-1.349^{***}		-1.879^{***}	-1.054^{***}
		(0.267)	(0.294)	(0.305)		(0.590)	(0.354)
$r_{f,t-2} - r_{h,t-2}$				-0.743^{**}			
				(0.292)			
$r_{f,t} - r_{h,t}$ ($\geq$ 0 only)					-3.128^{***}		
					(0.555)		
$r_{f,t} - r_{h,t}$ (<0 only)					-2.339^{***}		
					(0.510)		
$r_{f,t-1} - r_{h,t-1}$ (≥ 0 only)					-0.101		
					(0.531)		
$r_{f,t-1} - r_{h,t-1}$ (<0 only)					-2.383^{***}		
					(0.496)		
Time × Investor Country FEs	No	Yes	Yes	Yes	Yes	Yes	Yes
Fund FEs	No	No	Yes	Yes	Yes	Yes	Yes
Sample	Full	Full	Full	Full	Full	Until June 2008	After June 2008
Observations	109,487	96,267	96,267	85,620	92,267	17,458	78,809
Adjusted R^2	0.001	0.070	0.137	0.146	0.137	0.180	0.143

Table 3: Rebalancing and Exchange Rate Volatility

Fund rebalancing of the foreign investment share $\Delta h^f_{j,t}$ of fund f in quarter t is regressed on the excess return of the foreign over the domestic investment share, $r^f_{j,t} - r^h_{j,t}$, a market volatility measure Vol_{t-1} in the previous quarter $t-1$, and the interaction between foreign excess return and volatility, $(r^f_{j,t} - r^h_{j,t}) \times Vol_{t-1}$. Columns (1)–(2) use the standard deviation of the realized (daily) volatility Vol^{FX}_{t-1} in quarter $t-1$ of the effective exchange rate of the fund domicile country as the relevant volatility measure, whereas Columns (3)–(4) use market volatility captures by the VIX_{t-1}. In Columns (2) and (4) we also add lagged excess returns, $r^f_{j,t-1} - r^h_{j,t-1}$, and their interaction with the volatility measure as additional regressors. We report robust standard errors clusterd at the fund level and use ***, **, and * to denote statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable:	Fund Level Rebalancing $\Delta h^f_{j,t}$			
	(1)	(2)	(3)	(4)
Vol_{t-1}	0.146	0.161*	0.004**	0.005***
	(0.093)	(0.094)	(0.002)	(0.002)
$r_{f,t} - r_{h,t}$	−0.268	−0.322	−1.514**	−1.634***
	(0.645)	(0.644)	(0.593)	(0.594)
$(r_{f,t} - r_{h,t}) \times Vol_{t-1}$	−2.4717**	−2.751**	−0.011	−0.009
	(1.169)	(1.167)	(0.025)	(0.025)
$r_{f,t-1} - r_{h,t-1}$		−1.314*		−0.561
		(0.751)		(0.669)
$(r_{f,t-1} - r_{h,t-1}) \times Vol_{t-1}$		−0.650		−0.026
		(1.408)		(0.029)
Time × Investor Country FEs	No	No	No	No
Fund FEs	Yes	Yes	Yes	Yes
Volatility Measure Vol_{t-1}	FxVol	FxVol	VIX	VIX
Observations	89,174	89,174	96,267	96,267
Adjusted R^2	0.074	0.074	0.074	0.074
F-statistics	13.717	11.911	16.502	14.865

Table 4: Rebalancing and Exchange Rate Change

The effective (log) exchange rate change in quarter t of the four currency areas (U.S., U.K., EZ, CA) (defined in domestic curreny terms relative to weighted average of the other three major destinations of outbound portfolio investment) is regressed in Column (1) on the aggregate rebalancing $\Delta H^{f}_{c,t-1}$ of the foreign portfolio share of domestically registered funds and in Column (2) on the aggregate rebalancing $\Delta H^{h*}_{c,t-1}$ of the portfolio share of foreign registered funds invested in domestic stocks. Column (3) includes both terms and in Column (4) we use the linear combination $\frac{1}{2}(\Delta H^{f}_{c,t-1} - \Delta H^{h*}_{c,t-1})$ as regressor. Columns (5)–(8) provide analagous regressions in which the actual aggregate rebalancing terms are replaced by the aggregate *predicted* rebalancing terms estimated by the fund-specific excess return $r_{f,t-1} - r_{h,t-1}$ as in Table 2, Column (2). We report robust standard errors and use ***, **, and * to denote statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable:	Effective Exchange Rate Change $\Delta E_{c,t}$							
	OLS				2SLS (Second Stage)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$\Delta H^{f}_{c,t-1}$	0.014		0.009		0.172^{***}		0.165^{***}	
	(0.009)		(0.010)		(0.040)		(0.042)	
$\Delta H^{h*}_{c,t-1}$		-0.030^{**}	-0.030^{**}			-0.179^{*}	-0.087	
		(0.013)	(0.014)			(0.096)	(0.096)	
$\frac{1}{2}(\Delta H^{f}_{c,t-1} - \Delta H^{h*}_{c,t-1})$				0.032^{**}				0.297^{***}
				(0.014)				(0.069)
$\Delta E_{c,t-1}$	0.082	0.070	0.106	0.105	0.003	0.034	0.005	0.007
	(0.072)	(0.065)	(0.074)	(0.074)	(0.062)	(0.063)	(0.062)	(0.062)
Observations	208	244	202	202	251	249	249	249
R^2	0.014	0.023	0.035	0.029	0.070	0.016	0.074	0.072
F-test: $\kappa_1 = -\kappa_2$			1.24				0.47	