Global Portfolio Rebalancing and Exchange Rates

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Abstract

We examine international equity allocations at the fund level and show how different returns on the foreign and domestic portion of the 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 an equilibrium model of incomplete FX risk trading in which exchange rate risk partially segments international equity markets.

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1 Introduction

Understanding the links between exchange rates and capital flows is a long standing issue in international economics. If anything this issue is becoming more pressing as gross capital flows have dwarfed trade flows and gross stocks of cross-border assets and liabilities have increased dramatically from around 60% of world GDP in the mid-1990s to approximately 200% in 2015 (Lane and Milesi-Ferretti, 2017).[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 impact the portfolio allocation decisions of investors and may trigger capital flows[3]. Most transactions on the foreign exchange market are due to asset trade rather than goods trade. Yet, there is surprisingly little systematic documentation about the interaction between exchange rates and trade in assets at the microeconomic level. How do international investors adjust their risk exposure in response to the fluctuations in realized returns they experience on their positions? Do they rebalance their portfolios towards their desired weights or do they increase their exposure to appreciating assets? What are the consequences of those portfolio decisions for capital flow and exchange rate dynamics?

This paper analyzes time series variation in international asset allocations of a large cross-section of institutional investors. A distinctive feature of our approach is its microeconomic focus: while international capital flows and returns are two key variables in international macroeconomics, a purely aggregate analysis is plagued by issues of endogeneity, heterogeneity and statistical power. For example, asset returns may be reasonably exogenous to the individual fund and its allocation decisions, but this is not true at the aggregate level, where capital flows are likely to influence asset and exchange rate returns. Fund heterogeneity can obscure the aggregate dynamics, but can also generate testable predictions on rebalancing behavior at the

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

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

[3] Portes and Rey (2001) provide an early study of the geography of capital flows.

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 a two country equilibrium model of optimal dynamic portfolio rebalancing and exchange rates. There are very few microfounded macroeconomic models of exchange rate determination based on capital flows and imperfect financial integration. A prominent exception is Gabaix and Maggiori (2015) where exchange rate changes follow from financial flows induced by trade in segmented *goods market* and limits to intertemporal FX arbitrage. Our model builds on Hau and Rey (2006) and focuses instead on international *trade in assets* and its interactions with the foreign exchange market. It features 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 and endogenous exchange rate risk across the two stock markets motivate the rebalancing behavior of the international investors in both countries and simultaneously drive the exchange rate and asset price dynamics in an incomplete market setting. Hence, our model allows for a joint determination of optimal equity portfolios of domestic and foreign investors and of the exchange rate. This is a crucial difference with Gabaix and Maggiori (2015), where demand for foreign exchange is driven solely by goods trade as their model features no endogenous asset trade nor optimal portfolio choice. Since asset trade is a key component of foreign exchange transactions in the data, whereas current account transactions account for a much smaller amount, we view these characteristics of our model as a major step forward. A key prediction of our model is that excess returns on the foreign equity market portion of the investor portfolio should be partially repatriated to maintain an optimal trade-off between international asset diversification and exchange rate exposure. The model also predicts that this trade-off is influenced by the level of exchange rate volatility.[4] From a macroeconomic point of view, our model generates home bias as an endogenous outcome and implies that the rebalancing behavior of international equity funds influence the (effective) exchange rate—a prediction we test in the data using an instrumental variable approach.

The main contribution of our paper is empirical. The disaggregate fund-level data track

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

quarterly fund holdings for 7,940 internationally invested equity funds for the period 1999–2015. The data comprise a total of 101,238 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-sectional panel with different investor locations and investment destinations. Our data show a high degree of heterogeneity in the portfolio composition of institutional investors, including significant differences in the degrees of home bias.[5]

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:

1. 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.

2. 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.

3. 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. The strength of the rebalancing increases disproportionally as the performance difference between the foreign and domestic portfolio share increases.

4. Stronger fund-level rebalancing is associated with more concentrated asset investment in fewer stocks, as measured by the Herfindahl-Hirschman Index (HHI). Also, smaller funds exhibit stronger rebalancing, which is consistent with transaction costs to dynamic portfolio adjustments increasing in fund size.

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

5. 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 (an increased investment by domestic funds in the foreign market) correlates with a domestic currency appreciation (depreciation).

These empirical results are consistent with the prediction of our two country model featuring equity market segmentation and limits to intertemporal FX arbitrage, optimal portfolio choice by mean-variance investors and an equilibrium determination of the exchange rate.

The determinants of home bias and static portfolio allocations have been extensively studied in the literature (see e.g. the surveys of Lewis, 1999 and Coeurdacier and Rey, 2013). 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; Branson and Henderson, 1985), a lack of microfoundations limited their theoretical appeal. However, the financial globalization of the last two decades has ressuscitated interest in portfolio balance models (see Blanchard, Giavazzi and Sa, 2005; Hau and Rey, 2006; Gabaix and Maggiori, 2015) with their appealing focus on imperfect asset substitutability combined with plausible implications for exchange rate dynamics.[6] Empirical tests of the portfolio balance models relied on macroeconomic price data and aggregate cross-border flows. The corresponding results were generally inconclusive (see Frankel, 1982a, 1982b; Rogoff, 1984). Bohn and Tesar (1996) analyze return chasing and portfolio rebalancing in an ICAPM framework, while Brennan and 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 for correlations of aggregate 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.

[6]For linearized microfounded dynamic stochastic general equilibrium models of the open economy with optimal portfolio choice see, for example, Coeurdacier (2009), Devereux and Sutherland (2010a,b, 2011) and Tille and Van-Wincoop (2010). Gourinchas, Rey and Govillot (2010) and Dou and Verdelhan (2015) are able to account for the pattern of international capital flows and to generate a time-varying risk premium in a model with disaster risk. Bacchetta and Van Wincoop (2010) model agents who infrequently rebalance their portfolio in an overlapping generations (OLG) setting. Sandulescu, Trojani and Vedolin (2018) show that market segmentation is behind the break down of the almost perfect correlation between the domestic and international SDFs.

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.Therre are notable exceptions such as Evans and Lyons (2012), who show a tight correlation between order flow and exchange rate and Froot and Ramadorai (2005) who explore links between asset prices and flows at a more granular level. 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.[7] 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. Those heterogeneous valuation changes are plausibly exogenous to each funds. Common shocks pose therefore 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 deals with equity holdings and exchange rates, has a much longer time span and focuses on institutional investors, who are arguably financially literate and understand exchange risk exposure. Closest to us is the recent work of Koijen and Yogo (2017) on institutional asset pricing and their application to international portfolios in Koijen and Yogo (2019). Our empirical findings can 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 and Bruno and Shin, 2015).[8]

[7]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.

[8]Hau, Massa,and Peress (2010) and Adrian, Etula, and Shin (2014) also find that flows and financial conditions

In Section 2 we present a simple two-country model with partially segmented asset markets.[9] Its parsimonious microeconomic structure allows us to derive testable propositions about the joint dynamics of equity returns, exchange rates, and asset rebalancing. In Section 3 we discuss the microdata on fund asset holdings. The empirical part of our paper presents the microevidence on portfolio rebalancing (Section 4.1), the effect of exchange rate volatility on the intensity 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 the estimation of the feedback effect of aggregate rebalancing on 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 builds on 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 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

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.

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

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

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

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

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

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

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

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

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

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

where $\overline{E} = 1$ denotes the steady state exchange rate level.[10] Combining Eqs. (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 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 Eq. (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

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

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

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

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 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:

[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.

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.

A straightforward empirical test of Corollary 1 consists in checking the negative covariance between the active foreign holding change $\Delta h_{j,t}^f$ of an individual fund j and its (fund-specific) foreign excess return $r_{j,t}^f - r_{j,t}^h$ in a linear regression framework. We pursue this analysis in Section 4.1.

But the model yields additional insights. 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

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

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 occasionally observed in the FX market.

So far we treated the parameters σ_D and κ as constant parameters. Yet these parameters are likely to change over time and it is interesting to explore the implications. 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 concerns variations in the intensity of fund rebalancing.

Corollary 2 (Rebalancing for different volatility levels and FX elasticities):

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 large parameter σ_D also implies a higher level of equity price volatility.

We test Corollary 2 by regressing foreign holding changes $\Delta h_{j,t}^f$ of fund j on the interaction terms $(r_{j,t}^f - r_{j,t}^h) \times Vol_{t-1}^{FX}$ and $(r_{j,t}^f - r_{j,t}^h) \times Vol_{t-1}^{EQ}$ between a funds foreign excess return $r_{j,t}^f - r_{j,t}^h$ and the the level of (lagged) FX volatility or equity market volatility, $Vol_{t-1}^{FX}$and Vol_{t-1}^{EQ}, respectively. We expect the linear regression

$$\Delta h_{j,t}^f = \beta(r_{j,t}^f - r_{j,t}^h) + \gamma Vol_{t-1}^{FX/EQ} + \delta(r_{j,t}^f - r_{j,t}^h) \times Vol_{t-1}^{FX/EQ} + \epsilon_{j,t}$$

to yield negative rebalancing coefficient $\delta < 0$. In other words, rebalancing toward home equity increases as FX volatility or global equity market volatility increases. We test the empirical validity of this proposition in Section 4.2.

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 (positive or negative) leverage simply implies a scaling of the absolute risk by a leverage factor. All our analysis is based on portfolio shares and therefore not affected by constant leverage or time variations in leverage, as long as these are independent of the excess return on foreign assets.[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, and Canada.[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 $1 billion on total equity assets, out of which $638 million are invested in home equity and $325 million in foreign equity. The data on internationally invested funds show a modest home bias, as the average domestic share of a fund portfolio is 53.2%. While the average quarterly rebalancing between foreign and domestic equity investments is small at 0.064%, its standard deviation is substantial at 4.6% of the total (equity) value of the portfolio.

The number of international funds in the raw sample increases steadily over time from only 167 funds reporting at the end of 1999 to 5,683 funds reporting at the end of 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 10 most important investment destinations, the aggregate rebalancing $\Delta H^{f}_{c,t}$ from foreign to home investments for all funds domiciled within currency area c, and the reciprocal aggregate rebalancing $\Delta H^{h*}_{c,t}$ out of the home country for funds domiciled outside currency area c.

[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 rebalancing 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 at the fund level. 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 all expressed in the currency of the fund domicile. Furthermore,

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

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 4.6% for the full sample of 101,238 fund periods as stated in Table 1. It is highest for Eurozone funds at 5.2% and lowest for the U.K. and U.S. funds at 3.9% and 3.8%, respectively. We also highlight a larger average foreign investment share for U.K. funds and the stronger home bias for U.S. funds. By contrast, the Eurozone fund sample is more uniformly distributed in terms of its foreign investment share.

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

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

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

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

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 101,238 fund-quarters yield the predicted negative coefficient at -2.256, 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, although the economic magnitude is much weaker at -0.719.

Adding the three coefficients in Column (4) implies a combined rebalancing effect of -4.792. A relative quarterly excess return of two standard deviations (or 0.138) therefore implies a reduction in the foreign equity weight by 0.661 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 flows of \$12.2 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

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

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

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 crisis and post-crisis period (Period II) thereafter. Columns (6) and (7) show the respective regression results and suggest that contemporaneous rebalancing is economically and statistically stronger in the more recent period.

4.2 Rebalancing and Market Volatility

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

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

where the weights $\omega_{c,i}$ are chosen to be the average foreign portfolio shares of all domestic funds in currency area c. For simplicity, we limit N to the ten most important equity investment destinations, which account for more than 95% of foreign equity investment of all funds in each of the four currency area c. The (realized) exchange rate volatility $VOL^{FX}_{c,t}$ for quarter t is defined as the standard deviation of the daily return $r^{FX}_{c,d} = \ln E_{c,d} - \ln E_{c,d-1}$ calculated for

66 trading days d of quarter t.[19] Figure 3, Panel A shows the realized effective exchange rate volatility of the four fund locations for the period January 1999–December 2015.

Analogously, we define a volatility measure for the global equity market. For simplicity, we use the Global MSCI index in local currency as the benchmark and define (realized) equity market volatility $VOL^{EQ}_{c,t}$ for quarter t in currency area c as the standard deviation of the daily return $r^{EQ}_{c,d} = \ln MSCI_{c,d} - \ln MSCI_{c,d-1}$ analogous to realized exchange rate volatility. Figure 3, Panel B plots the realized index volatility expressed in the four different local currencies for the period January 1999–December 2015. The average realized equity return volatility is higher than the average realized FX volatility by 80.2%. The cross-sectional correlation of realized volatility in the four currency denomination is very high at 0.75.

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

$$\Delta h^f_{j,t} = \sum_{l=0,1} \beta_l (r^f_{j,t-l} - r^h{}_{j,t-l}) + \gamma VOL^{FX}_{c,t-1} + \sum_{l=0,1} \delta_l (r^f_{j,t-l} - r^h{}_{j,t-l}) \times VOL^{FX}_{c,t-1} + \varepsilon_j + \mu_{j,t}, \quad (6)$$

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. We include fund fixed effects ε_j in the regression, but not the interacted time and investor fixed effects as we seek to identify the role of time variation in rebalancing channel.

Table 3 presents the regression results for the extended specification. Column (1) includes only the contemporaneous component of excess returns (lag $l = 0$) and its interaction with exchange rate volatility $VOL^{FX}_{c,t-1}$, whereas Column (2) also includes lagged excess returns for a more complete description of the rebalancing behavior. We find that the rebalancing behavior in response to differential equity returns is stronger under higher levels of exchange rate volatility ($\delta_0 < 0$) as predicted in Corollary 2. An increase of the interaction term by one standard

[19] For a total of D trading days in a given quarter t, realized volatility is calcuated as follows

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

deviation (= 0.274) generates an additional rebalancing flow towards home equity of 0.15% of funds under management (= -0.547×0.274). The insignificant coefficient for the term $r^f_{j,t-l} - r^h{}_{j,t-l}$ suggests that the intensity of rebalancing is approximately proportional to the realized volatility measure $VOL^{FX}_{c,t}$. Higher FX volatility can increase the riskiness 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.

Columns (3)–(4) of Table 3 replace the measure of quarterly realized FX volatility with the realized volatility of the global MSCI equity index. As stated in Corollary and illustrated in Figure 1, Panel A, a higher equity volatility represented by a higher model parameter σ_D implies a more negative covariance between a fund's rebalancing $\Delta h^f_{j,t}$ and its foreign excess return. In line with this prediction, the coefficient for the interaction term $(r^f_{j,t-l} - r^h{}_{j,t-l}) \times VOL^{EQ}_{c,t-1}$ in Column (4) is negative and statistically significant at lag zero ($l = 0$). The point estimate of $\delta_0 = -0.17$ implies that a one standard deviation increase in the interaction term (= 0.619) triggers additional contemporaneous rebalancing flows of 0.11% of fund assets. We conclude that both higher exchange rate volatility and higher global equity volatility reinforce the rebalancing channel of international equity investment.

4.3 Rebalancing by Quantiles

The linear regression model captures an average effect for the rebalancing channel. Yet the propensity to rebalance could be 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. 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 surprising as these funds are also more likely to feature diverging performance on their domestic and foreign equity portfolios. Funds with concentrated equity positions feature stronger rebalancing behavior. The more diversified and largest funds tend in contrast to be associated with moderate rebalancing levels and low rebalancing propensities. They are more likely to follow more passive strategies.

4.5 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 at a given horizon 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 one of four currency areas $c \in \{$U.S., U.K., Eurozone, Canada$\}$, and F_c as the complementary set of all foreign funds domiciled in currency areas $c' \in \{$U.S., U.K., Eurozone, Canada$\}\backslash\{c\}$, but with equity investment in currency area c. Let the market value of all foreign equity positions of fund $j \in D_c$ at the end of quarter $t-1$ be denoted by $a^f_{j,t-1}$ and the value of all equity positions in currency area c by a foreign fund $j \in F_c$ be given by $a^{h*}_{j,t-1}$. We can then define the aggregate rebalancing of all home and and foreign domiciled funds with respect to currency area c as

$$\begin{aligned} \Delta H^f_{c,t} &= \tfrac{1}{A^f_{c,t-1}} \sum_{j \in D_c} \Delta h^f_{j,t} \times a^f_{j,t-1} \quad \text{with} \quad A^f_{c,t-1} = \sum_{j \in D_c} a^f_{j,t-1} \\ \Delta H^{h*}_{c,t} &= \tfrac{1}{A^{c*}_{c,t-1}} \sum_{j \in I_c} \Delta h^{h*}_{j,t} \times a^{h*}_{j,t-1} \quad \text{with} \quad A^{h*}_{c,t-1} = \sum_{j \in I_c} a^{h*}_{j,t-1}, \end{aligned} \tag{7}$$

respectively, where $\Delta h^f_{j,t}$ denotes the fund-level rebalancing of home funds (domiciled in currency area c) towards foreign equity and $\Delta h^{h*}_{j,t}$ the rebalancing of foreign domiciled funds from foreign equity positions into equity in currency area c. 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. Like their fund level counterparts $\Delta h^f_{j,t}$ and $\Delta h^{h*}_{j,t}$, the aggregate rebalance terms $\Delta H^f_{c,t}$ and $\Delta H^{h*}_{c,t}$ represent average active portfolio weight changes and therefore are not denominated in any currency. We also define the net aggregate rebalancing flows as

$$\Delta H^{Net}_{c,t} = \mu \Delta H^f_{c,t} - (1-\mu)\Delta H^{h*}_{c,t} \quad \text{with} \quad \mu = \frac{A^f_{c,t-1}}{A^f_{c,t-1} + A^{h*}_{c,t-1}}, \tag{8}$$

where μ denote the size of outbound equity investments relative to the sum of outbound and inbound investments.[20] Empirically, the average value of μ is 84.6%, 17.1%, 42.3%, and 18.9% for the U.S., U.K., Eurozone, and Canada, respectively.

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

$$-\Delta E_{c,t} = \alpha_1 \Delta H^f_{c,t} + \alpha_2 \Delta H^{h*}_{c,t} + \epsilon_{c,t}, \tag{9}$$

where we pool observations across the four currency areas U.S., U.K., Eurozone and Canada. As the data coverage is very sparse for the period 1999-2005, we only include quarterly observations for a currency area if at least 10 fund observations are recorded.[21] In the pooled specification, each currency area is in turn considered the home country with home funds accounting for aggregate rebalancing flows $\Delta H^f_{c,t}$ and oversea funds contributing an aggregate rebalancing flow $\Delta H^{h*}_{c,t}$. The effective exchange rate $E_{c,t}$ for each currency is calculated based on fixed weights for the 10 most important outbound equity investment destinations. In line with the model assumption in Eqs. (3) and (4), we predict $\alpha_1 > 0$ and $\alpha_2 < 0$. For a symmetric exchange rate impact of outbound and inbound flows we expect to find $\alpha_1 = \mu/\kappa$ and $\alpha_2 = -(1-\mu)/\kappa$ or $\alpha_1/\alpha_2 = -\mu/(1-\mu)$,where κ is the price elasticity of excess supply of currency defined in Eq. (4).

In Table 4, Column (1), we show the OLS coefficients separately for the aggregate foreign holding change $\Delta H^f_{c,t}$ of funds incorporated in the home country and the for home country holding change $\Delta H^{h*}_{c,t}$ of foreign funds. Column (2) reports corresponding results for the net flows $\Delta H^{Net}_{c,t}$. The aggregate foreign holding decrease $\Delta H^f_{c,t} < 0$ (or investment repatriation) indeed correlates (weakly) with an appreciation of the domestic currency and a decrease in foreign fund investment at home $\Delta H^{h*}_{c,t} < 0$ correlates with a depreciation of the domestic

[20]For the symmetric two-country model presented in Section 2 with equal home and foreign equity market size, we have $\mu = \frac{1}{2}$.

[21]As a consequence, we record 48 country quarters with aggregate in- and outflow data for the period 2002-2008, and 100 country quarters for the period 2009-2015.

currency. However, statistical significance at the conventional one percent level is obtained only for the net flows in Column (2). A net equity repatriation flow of one standard deviation ($= 0.389$) implies an effective domestic exchange rate appreciation of 1.01% ($= 0.026 \times 0.389$).[22] The overall explanatory power of the fund flow channel for exchange rate movements is modest, as illustrated by the low regresssion R^2.

The rebalancing model in Section 2 predicts a perfect negative correlation between $\Delta H^f_{c,t}$ and $\Delta H^{h*}_{c,t}$, but the empirical correlation is only -0.36. Conceptually, any decrease in foreign equity ownership should be matched by an increase in home ownership—yet our data only captures only institutional equity ownership (based on fund residence) and even the latter only incompletely and with measurement error. The imperfect negative correlation reflects our measurement problem.

4.6 Exchange Rate Effects for Predicted Flows

Aggregate equity fund flows are only measured with error and may occur because of motives other than the risk rebalancing outlined in the theory part. Measurement error for equity flows implies an attenuation bias for the OLS coefficient (towards zero), whereas aggregate equity flows based on alternative trading motives produce a positive coefficient bias as such flows tend to move the exchange rate and the foreign equity price in the same direction. To deal with both issues, we apply an 2SLS approach where we (i) predict (in a first-stage regression) the fund specific rebalancing and then (ii) aggregate the predicted fund-level flows to predicted aggregate flows $\Delta \widehat{H}^f_{c,t}$ and $\Delta \widehat{H}^{h*}_{c,t}$. The latter become our new regressors in the second stage.

We depart from the pooled regression reported in Table 2 for funds domiciled in currency area c ($j \in D_c$) as we now use the return differentials in the currency of the stock in order not to have the exchange rate enter the first stage regressions. Interest differentials in stock currencies are used to estimate the rebalancing flows at the fund level. The results for the four currency areas (of this first stage regression) are reported in Table 5, Columns (1)-(4). The predicted

[22] We can compare the exchange rate impact of net equity fund flows with elasticity estimates of FX order flow reported by Evans and Lyons (2002). For the deutsche mark/dollar spot market, they find that \$1 billion of net dollar purchases increases the deutsche mark price of a dollar by 0.5 percent. We find that it needs net equity flows of half a standard deviation ($= 0.1945$) to obtain the same 0.5 percent change for the effective exchange rate. Half a standard deviation of the quarterly net absolute equity flows from 2002 to 2015 corresponds to \$35 billion for the effective dollar exchange rate. The deutsche mark/dollar rate amounted only to 6.4% of the effective dollar exchange rate in 1998. Scaling the \$35 billion to a 6.4% component rate yields \$2.24 billion in net flows compared to the \$1 billion estimated by Evans and Lyons.

rebalancing into foreign equity of funds domiciled in currency area c then follows as

$$\Delta\widehat{h}^{f}_{j,t} = \widehat{\beta}^{c}({r^{f*}}_{j,t} - {r^{h}}_{j,t}) + \varepsilon_j + \mu_{j,t}, \quad \text{for } j \in D_c, \tag{10}$$

where $r^{f*}_{j,t}$ denotes the foreign portfolio returns in stock currency and $r^{h}_{j,t}$ the home country portfolio returns. The F-statistics for these first stage regressions are generally large for those regressions involving a large number of fund observations, for example U.S. funds invested abroad ($n = 44,396$, F-statistics $= 75.125$) or foreign funds invested in the U.K. ($n = 77,513$, F-statistics $= 94.003$).

Table 5, Columns (5)-(8) report analogues regressions for the rebalancing flows of all funds domiciled outside currency area c ($j \in F_c$). For these funds $r^{h*}_{j,t}$ denotes the portfolio return for currency area c expressed in currency area c money, and $r^{f*}_{j,t}$ the portfolio return outside currency area c (in local stock currency), The predicted rebalancing of foreign funds into equity positions in currency area c follows as:

$$\Delta\widehat{h}^{h*}_{j,t} = \widehat{\beta}^{c*}(r^{h*}_{j,t} - r^{f*}_{j,t}) + \varepsilon_j + \mu_{j,t}, \quad \text{for } j \in F_c. \tag{11}$$

All portfolio returns are always measured as nominal returns in the currency of the stock listing. Aggregating the predicted rebalancing over all funds according to Eq. (7) yields the aggregate *predicted* rebalancing terms $\Delta\widehat{H}^{f}_{c,t}$ and $\Delta\widehat{H}^{h*}_{c,t}$ used as the second stage regressors in Table 4, Columns (3)-(4).

The 2SLS regressions for the exchange rate produce the correct positive sign for the instrumented foreign holding change of domestic funds $\Delta\widehat{H}^{f}_{c,t}$ at the 1% level of statistical significance and also the correct negative sign for the instrumented domestic holding change of foreign funds $\Delta\widehat{H}^{h*}_{c,t}$. For the predicted net rebalancing flows $\Delta\widehat{H}^{net}_{c,t}$ in Column (4) we obtain the point estimate of 0.147. Hence, a one standard deviation ($= 0.067$) increase in the *predicted* net equity repatriations appreciated the effective exchange rate contemporaneously by 0.98% ($= 0.147 \times 0.067$). We also highlight the positive autocorrelation of the exchange rate (absent in the OLS regressions) increases to 0.177 in the 2SLS regressions so that the permanent exchange rate effect of the net equity flows is somewhat higher [$1.2\% = 0.98\%/(1 - 0.177)$].

The point estimate for the predicted net equity flow coefficient is five times larger than for the measured net equity flows. The former filters equity trading motives different from risk rebalancing as well as any negative coefficient bias originating in the reverse effect of equity flows on return differences. However, observed net flows feature a six times larger standard deviation (0.389) compared to predicted net equity flows (0.067), so that their economic effect on exchange rates is comparable.

A comparison of the flow effect for the recent period 2009-2015 in Column (10) with the pre-crisis period 2002-2008 in Column (7) does not indicate any dramatic change in the flow sensitivity of the four exchange rates considered. Columns (5), (8), and (11) use time-varying weights in the second stage regression given by the (lagged) ratio of country's annual equity portfolio flows to total annual FX transaction volumes (obtained from interpolated triannual BIS statistics). The weighted coefficients (W2SLS) are clearly larger as they put more weight on episodes when equity rebalancing drives a larger share of FX trading.

Finally, we note that the standard errors reported in Table 4, Columns (3)-(8), result from block bootstrapping. A constant number of fund histories for each currency area are (i) drawn randomly, (ii) used for first-stage equations (as reported in Table 5) to generate predicted fund-level flows for the consecutive quarter and then (iii) aggregated to predicted aggregate (net) equity flows. Aggregation implies that aggregate flows show relatively little variations across the bootstrapping samples. The bootstrapped standard errors for the (second-stage) exchange rate regression are obtained for 1,000 replications.

4.7 Alternative Interpretations

Our empirical results provide strong support in favor of portfolio rebalancing. Can the observed rebalancing result from a simple behavioral hypothesis? One such behavioral hypothesis concerns "profit-taking" on appreciating stocks. Fund managers might sell stocks once a certain target price is reached. The evidence presented here reflects the decisions of investment professionals who should be less prone to behavioral biases compared to households. But we can identify two additional aspects of the data that cannot be easily reconciled with a "profit-taking motive" as an explanatory alternative. First, this behavioral hypothesis does not explain why funds buy foreign equity shares when these assets underperform domestic holdings, as documented in Section 4.1. Second, the "profit-taking motive" evaluates each stock in isolation from the other portfolio assets, unlike our risk-based paradigm, which looks at the portfolio of all foreign equity holdings. Third, we also show that higher exchange rate risk interacts with the rebalancing motive, while it is unclear why it should matter for a "profit-taking motive".

A second alternative interpretation concerns exogenous investment policies and mandates for the funds. Could the observed rebalancing behavior result from investment policies that commit a fund to a certain range of foreign stock ownership? French and Poterba (1991) note that fund mandates are an unlikely explanation for the home bias in equity. This does not preclude their greater importance for the rebalancing dynamics documented in this paper. To the extent that such mandates exist, we can interpret them as reflecting the risk management objectives of the ultimate fund investors. As such they can be interpreted as direct evidence for limited asset substitutability and support, rather than contradict, the main message of our study. But rationalizing such mandates in the context of agency problems is beyond the scope of this paper. Distinguishing between mandated rebalancing and autonomous fund-based rebalancing presents an interesting issue for future research. To make progress on these issues we doubtless need a better theoretical understanding of delegated investment strategies and one that is compatible with the stylized facts that we uncover in this paper: 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.[23]

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

[23]Important progress has been made in that direction: see, for example, **Basak and Pavlova (2013)**, Bruno and Shin (2015), Gabaix and Maggiori (2015), **Coimbra and Rey (2017)** and Koijen and Yogo (2017), (2019).

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 exchange rate risk (measured by realized FX volatility) reinforces the rebalancing channel. The same is true for a higher volatility of global stock returns. Second, the largest correlation between rebalancing and foreign excess returns is found at the tails of the rebalancing distribution—suggesting a non-linear relationship. In other word: the rebalancing motive of equity funds increases as their return differential between foreign and domestic fund positions becomes more extreme. Third, we find that smaller funds and funds with a higher concentration of their investments in fewer stocks have the largest rebalancing propensity in reaction to return differentials. By contrast, rebalancing is observed equally across funds with very heterogeneous foreign investment shares. Last, we show that the aggregate fund flows induced by rebalancing behavior move exchange rates in line with the model prediction and in an economically significant manner: an increase in the predicted quarterly net equity inflows by one standard deviation generates a 1% domestic exchange rate appreciation.

We speculate that our evidence potentially casts some light on international financial linkages. Gourinchas and Rey (2007) shows that generally the external adjustment of countries goes through a trade channel and a financial adjustment channel, which has become more important over the recent years. In the presence of a foreign asset market boom which is usually associated with a real appreciation, domestic investors will at some point repatriate their funds, thereby depreciating the foreign currency and having a stabilizing effect. Much remains to be done to better comprehend the complexity of international links across financial asset markets.

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Appendix A: Model Solution

To solve the model we conjecture a linear solution for asset returns. The existence and uniqueness of equilibrium in the class of linear equilibria can be 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

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

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

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

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:

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

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

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

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

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

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

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

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

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

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.[24] 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

[24] 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.

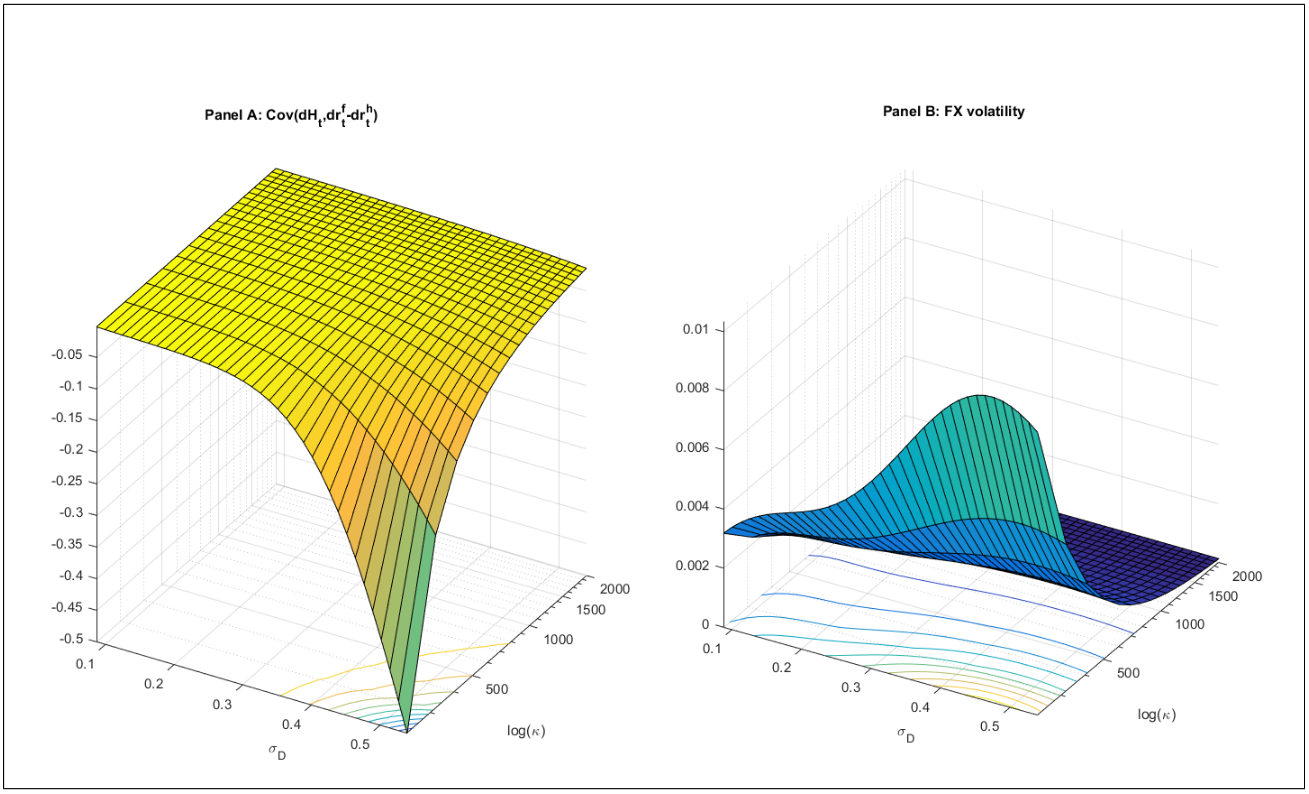

Figure 1: Panel A depicts the covariance between the rebalancing statistics $\Delta H^f_{j,t}$ and the excess return $dr^f_t - dr^h_t$ on the foreign, relative to the domestic, component of the portfolio share as a function of the standard deviation of the dividend process σ_D and the (log) elasticity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

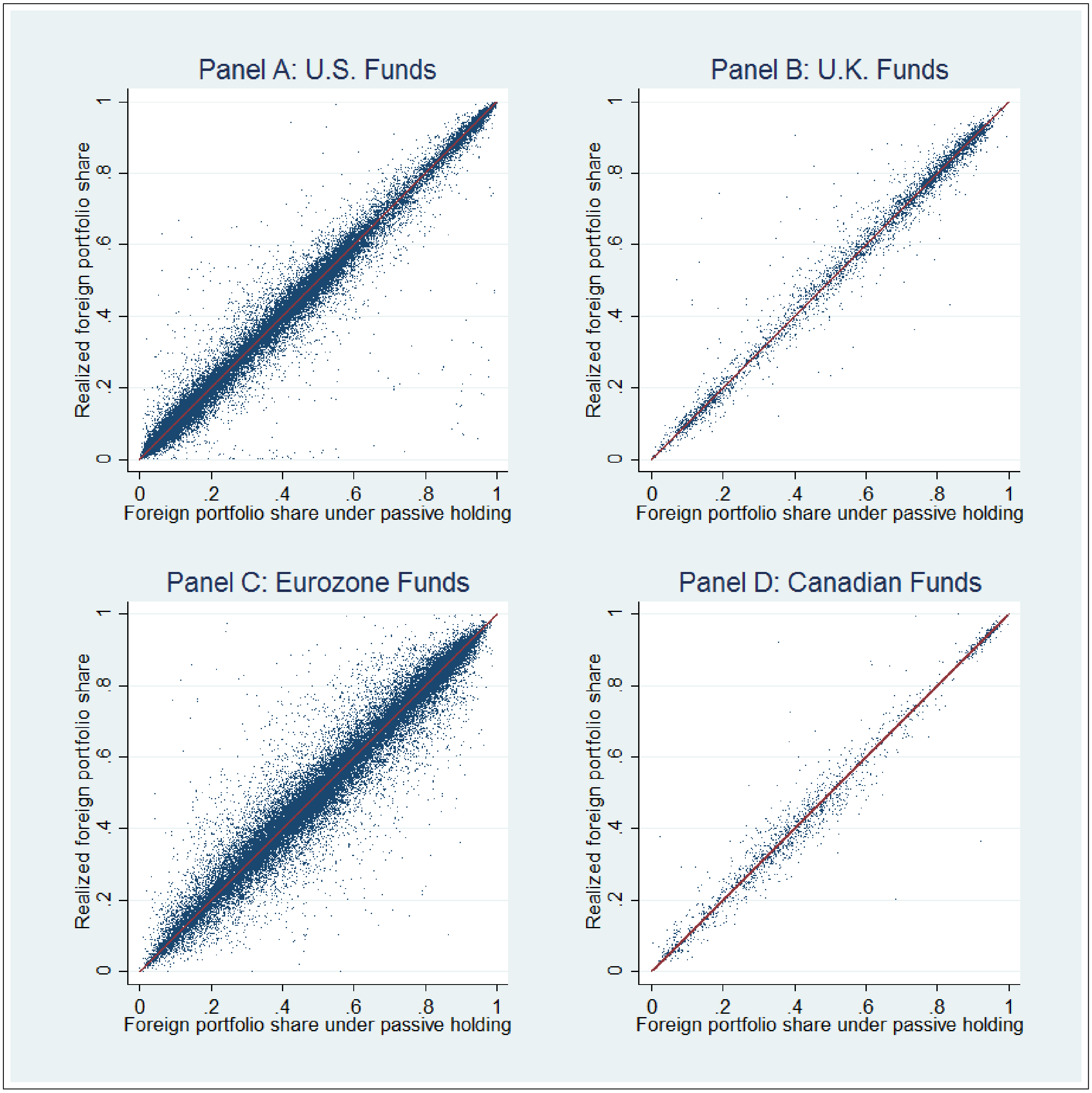

Figure 2: We plot the realized foreign portfolio share $w^f_{j,t}$ (y-axis) relative to the portfolio share implied by a passive holding strategy $\widehat{w}^f_{j,t}$ (x-axis) or funds domiciled in the U.S. (Panel A), the U.K. (Panel B), the Eurozone (Panel C), and Canada (Panel D). The vertical distance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

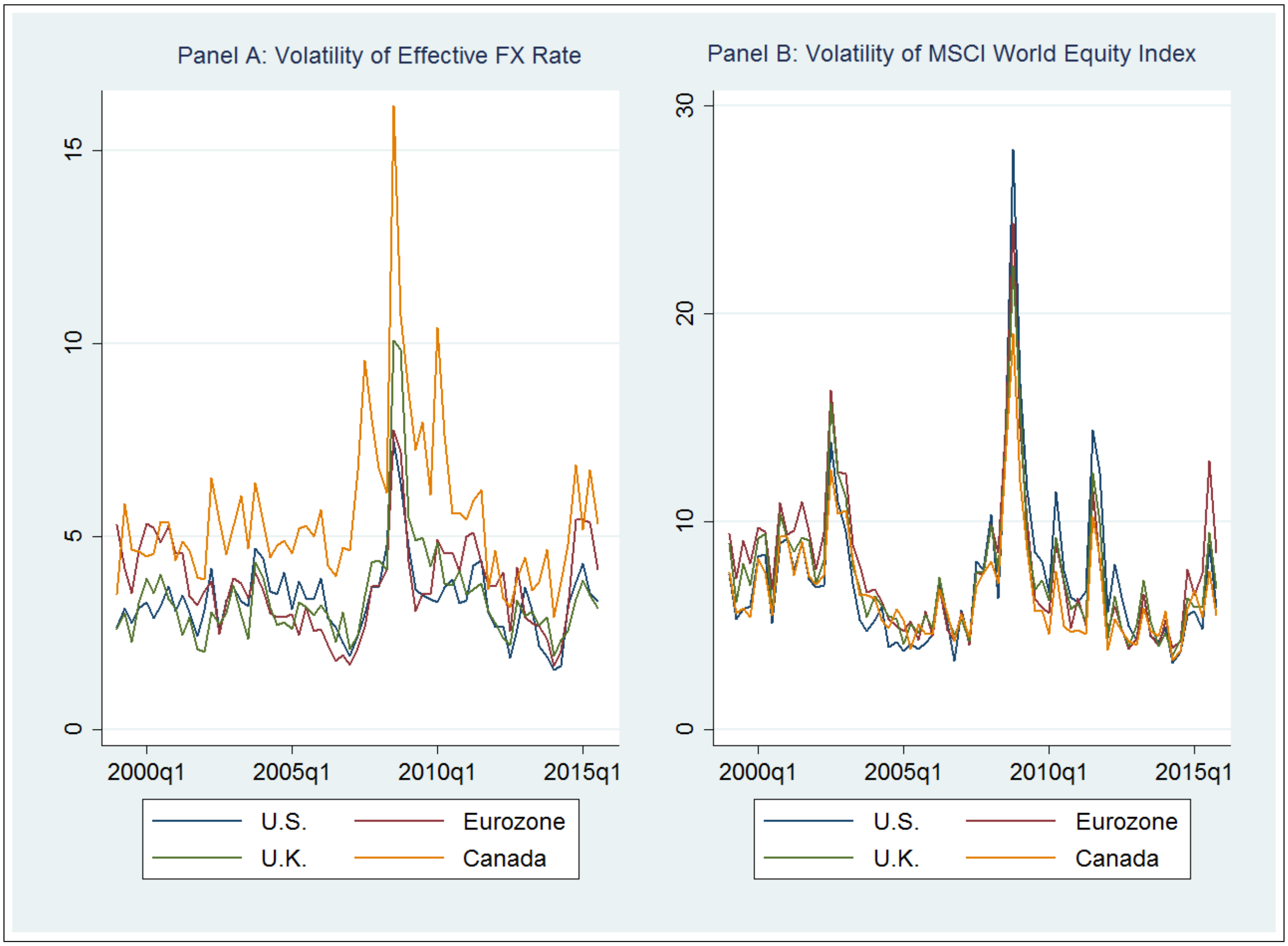

Figure 3: Panel A plots the quarterly realized volatility $VOL_{c,t}^{FX}$ of the effective exchange rate for the U.S., U.K., Eurozone, and Canada, respectively. Panel B shows the quarterly realized volatility $VOL_{c,t}^{EQ}$ for the MSCI global equity index (in local currency) for the same four currency areas.

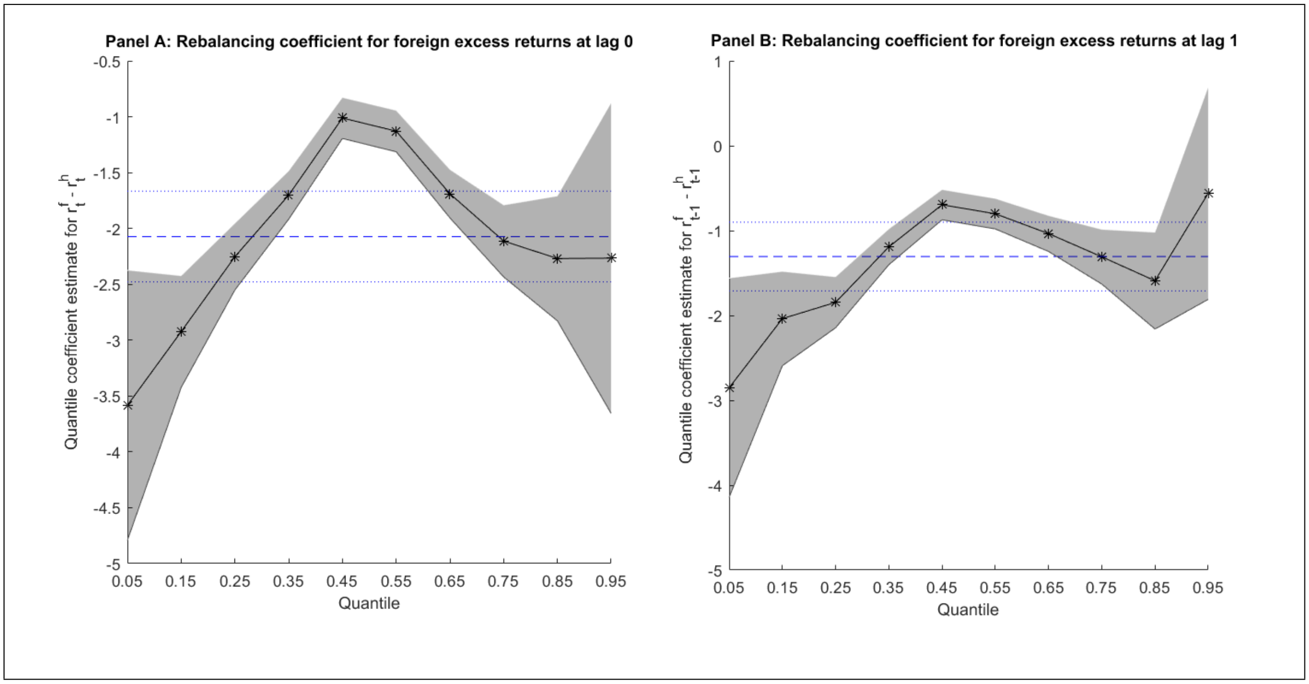

Figure 4: Panels A and B shows the rebalancing coefficients β_0 and β_1 for the foreign excess return and the lagged foreign excess return, respectively, for the 10 quantile regressions at quantiles $\tau = 0.05, 0.15, 0.25, ..., 0.95$ together with a confidence interval of two standard deviations. The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

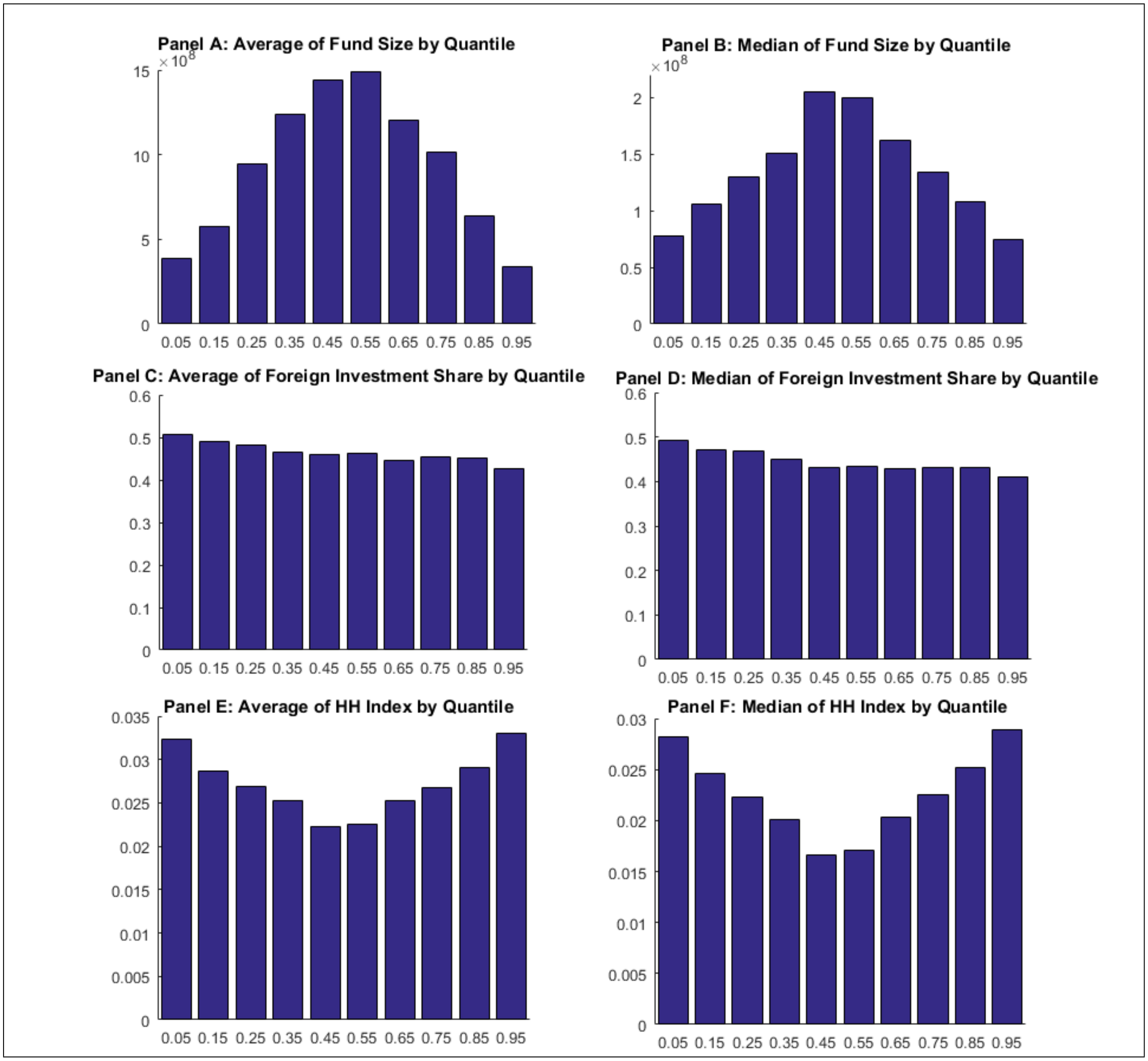

Figure 5: Panels A and B characterize the mean and median fund size around a quantile regression at the quantiles $\tau = 0.05,\ 0.15,\ 0.25, ..., 0.95$, where the interquantile range of mean and median calculation is from $\tau - 0.05$ to $\tau + 0.05$. Panels C and D show the mean and median estimates 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 101,238 fund-quarter observations for the period 1999–2015. We considered are all funds domiciled in four different currency areas c, namely the U.S., the U.K., the Eurozone, and Canada. Reported are total fund assets, the fund assets invested in equity at home (h) (i.e., the fund domicile) and in any foreign country (f) (i.e., anywhere outside the fund domicile), respectively; the portfolio shares held in the home (w_j^h) and foreign country (w_j^f) equity, respectively; the active equity rebalancing ($\Delta h_{j,t}^f$) in quarter t of the foreign investment share toward the home country by fund j domiciled in c (scaled by the factor of 100); the fund-level excess returns on foreign minus home-country investment positions ($r_{j,t}^f - r_{j,t}^h$) in quarter t; and the positive ($\times 1_{\geq 0}$) or negative ($\times 1_{<0}$) component of the foreign excess returns. Panel B reports aggregate summary statistics for the four currency areas. The effective quarterly exchange rate change ($\Delta E_{c,t}$) of currency area c is based on weights calculated from the aggregate foreign investment position of domestic funds in the 10 most important foreign investment destinations. The aggregate rebalancing flows $\Delta H_{c,t}^f$ ($\Delta H_{c,t}^{h*}$) measure the aggregate change in foreign (domestic) investment positions held by all domestic (foreign) equity funds domiciled in (outside) currency area c. The aggregate net equity flows $H_{c,t-1}^{Net} = \mu \Delta H_{c,t-1}^f - (1-\mu)\Delta H_{c,t-1}^{h*}$ are calculated based on the ratio μ of aggregate outbound equity holdings relative to the sum of outbound and inbound equity holdings. We also report the predicted aggregate rebalancing flows, i.e. $\Delta \widehat{H}_{c,t}^f$ and $\Delta \widehat{H}_{c,t}^{h*}$, estimated from fund specific excess returns on foreign portfolio shares. We denote $Vol_{c,t}^{FX}$ the quarterly realized volatility of the effective exchange rate and $Vol_{c,t}^{EQ}$ the quarterly realized volatility of the global MSCI index denominate in currency c.

		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	101,238	1,002	4,794	10	19	130	1,489	145,289
Fund assets at home	Mio USD	101,238	677	3,679	0	7	53	902	109,235
Fund assets abroad	Mio USD	101,238	325	1,966	0	6	45	489	122,816
Home asset share	w_j^h	101,238	0.540	0.290	0.000	0.123	0.546	0.932	1.000
Foreign asset share	w_j^f	101,238	0.460	0.290	0.000	0.068	0.454	0.877	1.000
Fund rebalancing	$\Delta h_{j,t}^f$	101,238	0.064	4.557	−89.015	−3.495	0.017	3.686	72.833
Excess returns									
$r_{j,t}^f - r_{j,t}^h$	(quarterly)	101,238	−0.002	0.069	−0.602	−0.081	−0.002	0.078	0.676
$(r_{j,t}^f - r_{j,t}^h) \times 1_{<0}$	(quarterly)	101,238	−0.026	0.042	−0.602	−0.081	−0.002	0.000	0.000
$(r_{j,t}^f - r_{j,t}^h) \times 1_{\geq 0}$	(quarterly)	101,238	0.025	0.041	0.000	0.000	0.000	0.078	0.676
Panel B: Aggregate statistics									
Exchange rate change	$\Delta E_{c,t}$	148	0.000	0.036	−0.084	−0.047	−0.004	0.047	0.102
Observed rebalancing									
All fund in c	$\Delta H_{c,t}^f$	148	−0.017	0.596	−2.300	−0.762	−0.013	0.597	2.200
All funds outside c	$\Delta H_{c,t}^{h*}$	148	−0.076	0.539	−3.830	−0.624	−0.052	0.433	1.260
Net flows	$\Delta H_{c,t-1}^{Net}$	148	0.029	0.389	−0.795	−0.403	0.008	0.453	2.45
Predicted rebalancing									
All fund in c	$\Delta \widehat{H}_{c,t}^f$	148	0.056	0.104	−0.311	−0.078	0.068	0.170	0.459
All funds outside c	$\Delta \widehat{H}_{c,t-1}^{h*}$	148	−0.022	0.052	−0.258	−0.079	-0.018	0.036	0.095
Net flows	$\Delta \widehat{H}_{c,t-1}^{Net}$	148	0.037	0.067	−0.173	−0.036	0.032	0.124	0.256
FX volatility	$Vol_{c,t}^{FX}$	280	4.051	1.707	1.564	2.448	3.688	6.002	16.151
Global equity volatility	$Vol_{c,t}^{EQ}$	272	7.298	3.310	3.210	4.278	6.481	10.982	27.912

Table 2: Rebalancing Dynamics

Fund rebalancing of the foreign investment share $\Delta h^f_{j,t}$ of fund j 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 fund domicile fixed effects and Columns (3)-(7) add 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 clustered 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)
$r^f_{j,t} - r^h_{j,t}$	-2.256^{***}	-2.901^{***}	-2.721^{***}	-2.761^{***}		-2.230^{***}	-2.844^{***}
	(0.246)	(0.292)	(0.317)	(0.327)		(0.648)	(0.370)
$r^f_{j,t-1} - r^h_{j,t-1}$		-1.341^{***}	-1.145^{***}	-1.312^{***}		-1.933^{***}	-0.947^{***}
		(0.276)	(0.303)	(0.313)		(0.604)	(0.365)
$r^f_{j,t-2} - r^h_{j,t-2}$				-0.719^{**}			
				(0.299)			
$(r^f_{j,t} - r^h_{j,t}) \times 1_{\geq 0}$					-3.035^{***}		
					(0.567)		
$(r^f_{j,t} - r^h_{j,t}) \times 1_{<0}$					-2.384^{***}		
					(0.524)		
$(r^f_{j,t-1} - r^h_{j,t-1}) \times 1_{\geq 0}$					0.098		
					(0.547)		
$(r^f_{j,t-1} - r^h_{j,t-1}) \times 1_{<0}$					-2.442^{***}		
					(0.512)		
Time × Fund Domicile 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	101,238	89,175	89,175	79,432	89,175	15,984	73,191
Adjusted R^2	0.001	0.067	0.134	0.143	0.135	0.170	0.142

Table 3: Rebalancing and Exchange Rate Volatility

Fund rebalancing of the foreign investment share $\Delta h^f_{j,t}$ of fund j in quarter t is regressed on the excess return of the foreign over the domestic investment share, $r^f_{j,t} - r^h_{j,t}$, the realized quarterly (FX or Global Equity) volatility $Vol^{FX/EQ}_{c,t-1}$ in the previous quarter $t-1$, and the interaction between foreign excess return and volatility, $(r^f_{j,t} - r^h_{j,t}) \times Vol^{FX/EQ}_{c,t-1}$. Columns (1)-(2) use the standard deviation of the realized (daily) volatility $Vol^{FX}_{c,t-1}$ of the effective exchange rate of the fund domicile country as the relevant volatility measure, whereas Columns (3)-(4) use the MSCI global equity index volatility measured in local currency, $Vol^{EQ}_{c,t-1}$. 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 clustered at the fund level and use ***, **, and * to denote statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable:	Fund Level Rebalancing $\Delta h^f_{j,t}$			
	FX Volatility (FX)		Global Equity Volatility (EQ)	
	(1)	(2)	(3)	(4)
$Vol^{FX/EQ}_{c,t-1}$	0.058^{***}	0.059^{***}	0.017^{***}	0.019^{***}
	(0.014)	(0.014)	(0.004)	(0.004)
$r^f_{j,t} - r^h_{j,t}$	0.343	0.334	-0.354	-0.371
	(0.730)	(0.731)	(0.459)	(0.457)
$(r^f_{j,t} - r^h_{j,t}) \times Vol^{FX/EQ}_{c,t-1}$	-0.547^{***}	-0.564^{***}	-0.165^{***}	-0.170^{***}
	(0.196)	(0.196)	(0.048)	(0.048)
$r^f_{j,t-1} - r^h_{j,t-1}$		-1.278		-0.074
		(0.781)		(0.563)
$(r^f_{j,t-1} - r^h_{j,t-1}) \times Vol^{FX/EQ}_{c.t-1}$		0.071		-0.108^{*}
		(0.201)		(0.063)
Time × Fund Domicile FEs	No	No	No	No
Fund FEs	Yes	Yes	Yes	Yes
Volatility measure	$Vol^{FX}_{c,t-1}$	$Vol^{FX}_{c,t-1}$	$Vol^{EQ}_{c,t-1}$	$Vol^{EQ}_{c,t-1}$
Observations	$89,175$	$89,175$	$89,175$	$89,175$
Adjusted R^2	0.074	0.074	0.074	0.074
F-statistics	18.473	15.703	22.409	17.525

Table 4: Regressions Effects of Rebalancing on Exchange Rate -

***,**,* coefficient estimates are statistically distinct from 0 at the 1%, 5% and 10% levels, respectively. Standard errors clustered at the fund level are shown in parenthesis.

	1st Stage IV - Rebalancing on foreign (into currency area) minus domestic (out of currency area) return								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	RB_{t+3}	RB^{US}_{t+3}	RB_{t+3}	RB^{UK}_{t+3}	RB_{t+3}	RB^{EU}_{t+3}	RB_{t+3}	RB^{CA}_{t+3}	$PooledRB_{t+3}$
$(r_f - r_h)_{t,t+3}$ Forward 3 months Excess Foreign Return (in local stock c	-1.881***		-1.100*		-0.880***		-3.217**		-1.528***
	(0.170)		(0.665)		(0.239)		(1.270)		(0.133)
$(r_f - r_h)_{t,t+3}$ Forward 3 months Excess US-nonUS Return (in local stock		-1.128***							
		(0.134)							
$(r_f - r_h)_{t,t+3}$ Forward 3 months Excess UK-nonUK Return (in local stock				-0.919***					
				(0.066)					
$(r_f - r_h)_{t,t+3}$ Forward 3 months Excess CA-nonCA Return (in local stock								-0.469***	
								(0.033)	
$(r_f - r_h)_{t,t+3}$ Forward 3 months Excess EU-nonEU Return (in local stock						-0.069			
						(0.073)			
Obs	44514	43366	4453	84845	44408	47631	1641	58362	102919
R^2	0.057	0.108	0.141	0.093	0.101	0.078	0.163	0.113	0.088
F	122.265	70.333	2.737	193.874	13.625	0.896	6.413	199.260	131.310
Fund/Currency area(s)	US/US	non-US/US	UK/UK	non-UK/UK	EU/EU	non-EU/EU	CA/CA	non-CA/CA	Domestic/outflows
Time FEs	no	no	no	no	no	no	no	no	no
Country FEs	no	no	no	no	no	no	no	no	no
Time x Country FEs	no	no	no	no	no	no	no	no	no
Fund FEs	yes	yes	yes	yes	yes	yes	yes	yes	yes
SEs Clustered at the Fund Level	yes	yes	yes	yes	yes	yes	yes	yes	yes

Table 5: Regressions Effects of Rebalancing on Exchange Rate -

***,**,* coefficient estimates are statistically distinct from 0 at the 1%, 5% and 10% levels, respectively. Standard errors clustered at the fund level are shown in parenthesis.

	Effects of Rebalancing on Exchange Rate - Dep var: $\Delta E_{c,t,t+3}$; WLS with FX trading volume (w4)										
	(1) OLS	(2) OLS	(3) 2SLS	(4) 2SLS	(5) W2SLS	(6) 2SLS:ES	(7) 2SLS:ES	(8) W2SLS:ES	(9) 2SLS:LS	(10) 2SLS:LS	(11) W2SLS:LS
$\Delta H^{f}_{c,t,t+3}$	0.010^{**}										
	(0.005)										
$\Delta H^{h*}_{c,t,t+3}$	-0.006										
	(0.006)										
$\mu\Delta H^{f}_{c,t,t+3} - (1-\mu)\Delta H^{h*}_{c,t,t+3}$		0.021^{***}									
		(0.008)									
$\Delta\widehat{H}^{f}_{c,t,t+3}$			0.241^{***}			0.178			0.267^{***}		
			(0.063)			(0.114)			(0.077)		
$\Delta\widehat{H}^{h*}_{c,t,t+3}$			-0.049			-0.244			0.045		
			(0.095)			(0.158)			(0.119)		
$\mu\Delta\widehat{H}_{c,t,t+3}{}^{f} - (1-\mu)\Delta\widehat{H}^{h*}_{c,t,t+3}$				0.306^{***}	0.447^{***}		0.382^{***}	0.388^{***}		0.279^{***}	0.512^{***}
				(0.074)	(0.109)		(0.131)	(0.137)		(0.091)	(0.152)
Obs	159	159	148	148	148	48	48	48	100	100	100
R^2	0.044	0.042	0.128	0.104	0.103	0.167	0.157	0.148	0.128	0.087	0.103
F	3.594	6.924	10.666	16.931	16.782	4.497	8.551	8.001	7.126	9.374	11.312
Currency area(s)	All	All	All	All	All	All	All	All	All	All	All