

Capital Flows and Exchange Rates: An Empirical Analysis^{*}

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ABSTRACT

This paper investigates the empirical relationship between capital flows and nominal exchange rates for five major countries. This is motivated by the recent international finance theory which suggests that currencies are as much influenced by capital flows as by current account balances and long-term interest rates. Using unrestricted VAR's we document the following: a) Incorporating net cross-border equity flows into standard linear empirical exchange rate models can improve their in-sample performance, whereas net cross-border bond flows are immaterial for exchange rate movements; b) Positive innovations to home equity returns (relative to the foreign markets) are associated with short-run home currency appreciations and equity inflows, whereas positive shocks to home interest rates (relative to the foreign countries) cause currency movements that are consistent with the long-run interpretation of uncovered interest rate parity (UIP); c) An equity-augmented linear model provides support for exchange rate predictability and outperforms a random walk in several cases. However, the particular specification that can produce such superior forecast performance depends on the exchange rate and the forecast horizon. Our results are robust to a number of specifications.

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Keywords: Net equity flows, net bond flows, equity returns, interest rates, and nominal exchange rates.

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1 Introduction

Explaining movements of nominal exchange rates is perhaps one of the most intriguing themes in international macroeconomics. This paper investigates the empirical relationship between capital flows and nominal exchange rates. This relation is often stressed as important—Dornbush (1976, p. 1166), for example, states that ‘*the exchange rate adjusts instantaneously to clear the asset market*’—but the available empirical evidence on such a link is scarce. We model net capital flows and nominal exchange rates in a unified empirical framework, in which the same forces that drive exchange rates also influence countries’ cross border asset holdings, and argue that a great deal can be learned about foreign exchange markets by examining capital markets.¹

We document that incorporating net cross-border *equity* flows into standard linear empirical exchange rate models can improve their in-sample performance, whereas net cross-border *bond* flows are immaterial for exchange rate movements. Positive innovations to home equity returns (relative to the foreign markets) are associated with short-run home currency appreciations and equity inflows, whereas shocks to home interest rates (relative to the foreign countries) cause long-run currency movements that are consistent with a long-run interpretation of uncovered interest rate parity (UIP). Furthermore, the empirical model outperforms a random walk in out-of-sample forecasting ability in several cases, a finding that is extremely interesting in light of the seminal contribution by Meese and Rogoff (1983). Our findings are consistent with the recent international finance literature but our empirical methodology deviates from it in some important dimensions.² Treating all variables as endogenous, we formally test which asset flow is relevant for monthly exchange rates, we decompose the dynamic effects that a structural shock to net capital flows has on exchange rates, and we assess theoretical implications for the dynamic cross-correlations of exchange rates with both equity return differentials and interest rate differentials.

More specifically, for five countries (U.S., U.K., Japan, Germany and Switzerland),³ we examine the bilateral exchange rate of the U.S. dollar defined against the pound, yen, mark

¹In 1975 cross border transactions in bonds and equities for U.S. were only 4% of GDP. In 1990’s went up to 100% and in 2000 reached 245% (source USTO). See also Portes and Rey (2002) and Portes, Rey and Oh (2001), who document that cross border capital flows have increased sizably in the last decade.

²See the recent work from Bailey, Millard and Wells (2001), Hau and Rey (2002) and Pavlova and Rigobon (2003).

³These are the top 5 currencies as regards the daily turnover of all pairs worldwide (see also Table 1).

and Swiss-franc, introducing bilateral net cross-border capital flows into a standard linear framework. We use unrestricted VAR's to study empirically the dynamic interactions of net cross-border capital flows, equity return differentials, exchange rates and interest rate differentials in a unified framework. The paper examines whether net cross-border flows can indeed explain nominal exchange rate movements in these economies, and whether augmenting standard linear models with net capital flows improve their in-sample fit and out-of-sample forecast performance. We ask the following questions. First, do net cross border capital flows explain exchange rate movements and if yes, is it net bond flows or net equities flows that matters? Second, is it the net accumulation of foreign assets or that of U.S. assets that matter? Thirdly, through which channels do equity return differentials and interest rate differentials affect the nominal exchange rate? Fourthly, does the capital flows-augmented model outperform naive random walks?

Our main findings are as follows, and are robust to a number of specifications, including identification and lag length of the VAR, structural breaks, data mis-reporting and measurement error in the regressors.

First, we show that for U. K., Germany and Switzerland, net purchases of U.S. equities appear to have a stable and consistent impact on the value of their currencies. Net purchases of U.S. or foreign bonds are irrelevant for exchange rate movements, probably because they are hedged against exchange rate risk.⁴ For the dollar/pound, dollar/Swiss-franc and the dollar mark, a one standard deviation positive shock in net U.S equity purchases is associated with an appreciation of the U.S. currency by roughly 10% that is statistically significant for on average 13 months. The evidence for Japan is at odds with what theory predicts since net purchases of U.S. assets from Japanese residents are associated with a strong yen.⁵

Second, pooling the data shows that positive innovations in U.S. equity returns (relative to the foreign markets) are associated with short-run U.S. currency appreciations and equity inflows, whereas positive shocks to U.S. interest rates (relative to the foreign countries) cause U.S. currency appreciations consistent with the long-run interpretation of

⁴A survey was conducted to see if there is any market evidence for this finding. Use of proprietary data from a Fund of Funds that invests in more than 200 Funds around the globe every year, for the last 10 years, shows that cross border bond holdings are heavily hedged (more than 90%) whereas equity holdings are not (less than 12%). For a first documentation see Hau and Rey (2002).

⁵Hau and Rey (2002) show that purchases of U.S. assets from foreign residents should lead to U.S. currency appreciations.

uncovered interest rate parity (UIP), that become statistically significant after 18 months.

Third, dynamic forecasts from an equity augmented-VAR provide support for exchange rate predictability and outperform a random walk and a standard VAR that includes only exchange rates and interest rate differentials. Forecast performance is evaluated with the root mean square error criterion and the Diebold and Mariano (1995) statistics. However, the particular specification that can produce such superior forecast performance depends on the exchange rate and the forecast horizon.

In terms of the general context, our work relates to the vast literature in explaining nominal exchange rates. Traditional exchange rate models based on macroeconomic fundamentals lead to poor in-sample performance for floating exchange rates.⁶ Additionally, a random walk forecast generally outperforms models based on purchasing power parity (PPP), uncovered interest rate parity (UIP), and simple versions of the monetary and portfolio balance models of exchange rates (Meese and Rogoff (1983)). Research has not been able to convincingly overturn this finding at least for shorter horizons than four to five years. This has led Frankel and Rose (1995) to note that *“[t]he dispiriting conclusion is that relatively little explanatory power is found in models of the exchange rate with traditional observable macroeconomic fundamentals, whether based on the monetary or portfolio-balance models.”* This paper presents evidence that for some major OECD countries a good portion of their exchange rate movements can be explained by net equity flows.

In terms of empirical focus, our work is close to the microstructure approach. These studies show that investor order flows cause exchange rate changes through private information which, when released, permanently impacts exchange rates. Evans and Lyons (2002) find that daily inter-dealer order flow explains an astonishing 60% of daily exchange rate changes and consequently argue that flows are a proximate cause of exchange rate movements. Rime (2001) finds that weekly flows help explain exchange rate movements. Others, such as Wei and Kim (1997) and Cai, Cheung, Lee and Melvin (2001) find that the positions of large traders explain currency volatility far better than do news announcements or fundamentals. Froot and Ramadorai (2002) conclude that investor flows

⁶For a good survey see Frankel and Rose (1995). Recent studies do find some weak relation between exchange rates and easily observable fundamentals in horizons greater than three to four years (see, for example, Clarida and Gali (1994), Eichenbaum and Evans (1995), Kim and Rubini (1997) and Mark and Sul (2001)). However, many researchers remain sceptical about these findings (e.g. Rapach and Wohar (2001b) and Faust, Rogers, and Wright (2003)).

are important for understanding deviations of exchange rates from fundamentals, but not for understanding long-run currency values. These studies, however, do not consider asset trade which enables us to identify the flow that is relevant for exchange rates and they do not study any dynamics. Another advantage is that we use publicly available data. The capital flow data is obtained from the U.S. Department of Treasury, and consists of monthly observations over 1988-2000.

In terms of the overall objective to study empirically the link between exchange rates and capital flows, we know of three papers that are similar in spirit to our work. Hau and Rey (2002) find that for daily, weekly and monthly data for 17 OECD countries, equity flows have become increasingly important over time and correlate strongly with exchange rates. Brooks, Edison, Kumar and Slok (2001) estimate OLS regressions using yearly bilateral flows for three major currencies and show that equity flows correlate weakly with the euro/dollar exchange rate. Last, Pavlova and Rigobon (2003) also estimate OLS regressions to show that demand shocks, associated with increased equity returns and capital inflows, correlate strongly with nominal exchange rates.

The paper proceeds as follows. Section 2 describes the data and our methodology. Section 3 reports the results from simple OLS regressions and from VAR analysis. Section 4 presents sensitivity analysis. Section 5 concludes.

2 Data and Methodology

2.1 Data description

Most of the exchange rate puzzles concern countries with unrestricted commodity trade and liberalized capital markets, where currency values are most likely to reflect macroeconomic market forces. For this reason we focus our analysis on five OECD countries: U.S., U.K., Germany, Japan and Switzerland. These countries have unrestricted capital flows for the entire sample period and furthermore, they are the top five in foreign exchange market turnover worldwide. Table 1 reports the total turnover by currency pair adjusted for total and cross border double counting. In 1998, the total forex turnover of these four currency pairs exceeds 50% of the total turnover of all currency pairs worldwide.

The data covers the period from January 1988 to December 2000. The data for

exchange rates consists of monthly averages from the International Financial Statistics (IFS), published by the IMF. To have a sufficiently long time series for all currencies we use the Euro exchange rate (from January 1999 onwards) and calculate monthly averages for the dollar/mark. We are not able to construct all cross rates due to the unavailability of capital flow data. Interest rates are three month money market rates obtained from IFS.⁷ As a proxy for the relative stock market performance between two countries we use equity return differentials, calculated based on equity returns from Global Financial Data Inc.⁸ The data on bilateral asset flows is from the U.S. Department of Treasury. The broadest measure we construct is the net total purchase of equities and bonds for all four pairs, given by the following expression:

$$(1) \quad NF = NB + NE$$

where NF is the net capital flow between US and a foreign country. NB and NE are the net accumulation of bonds and equities respectively. These can be further decomposed to:

$$(2) \quad NB = NAUSB - NAFB$$

where $NAUSB$ are the net purchases of U.S. bonds from foreign residents, and $NAFB$ are the net purchases of foreign bonds from U.S. residents, and:

$$(3) \quad NE = NAUSE - NAFE$$

where $NAUSE$ are the net purchases of U.S. equities from foreign residents, and $NAFE$ are the net purchases of foreign equities from U.S. residents. So for NF , NB and NE , a positive value indicates a net inflow in the U.S. (see also Figure 2 for a schematic representation). We next proceed with the empirical methodology followed by the results.

2.2 Methodology

Our reduced form model is an unrestricted VAR as this is a good approximation for the dynamic process of any vector of time series as long as enough lags are included.⁹ More

⁷Long-term interest rates may be more appropriate for capturing inflation premia. We also did the analysis with money supply differentials and the results do not depart in any significant way from the ones reported.

⁸See Appendix A for more details on data definitions and sources.

⁹See, for example, Canova (1995). Although the optimal lag length obtained with the Schwarz Bayesian (SBC) and the Hannan-Quinn (HQC) information criteria is one lag for all systems, we use two lags in order to accommodate problems that arise with near unit root regressors. We also experiment with higher orders (up to 4 lags) to check the robustness of our results. All tests are available upon request.

formally, consider the Wold moving average representation of the system:

$$(4) \quad Y_t = \phi + B(l_p)\tilde{e}_t \text{ with } \tilde{e}_t \sim (0, \Sigma)$$

where \tilde{e}_t is an error process with variance-covariance matrix Σ , Y_t is a vector defined as $[ncf_t, (er^* - er)_t, s_t, (i^* - i)_t]'$, with ncf_t the net cross border capital flow, $(er^* - er)_t$ and $(i^* - i)_t$ are the realized equity return differential (in home currency) and the interest rate differential between the foreign country and the U.S., s_t is the log home (U.S.) currency price of a unit of foreign currency.¹⁰ $B(l_p)$ is a matrix polynomial in the lag operator. Any orthogonal decomposition of the Wold representation with contemporaneously uncorrelated unit variance-covariance matrix is of the form:

$$(5) \quad Y_t = \phi + D(l)e_t \text{ with } e_t \sim (0, I)$$

where $D(l) = B(l)S$, and $e_t = S^{-1}\tilde{e}_t$ with an orthonormalized matrix $\Sigma = SS'$. There is an infinite number of such orthonormal decompositions since for any orthonormal matrix Q , with $QQ' = I$: $\Sigma = \hat{S}\hat{S}' = SQQ'S'$ is also an admissible decomposition of Σ . In this study we will use the ‘naive’ orthogonal decomposition where $S = L$ (so S is a lower triangular). This identification scheme implies an ordering of the variables in the VAR. However, it is crucial to note that the importance of the ordering depends on the magnitude of the estimated correlation coefficient between the variables included in the VAR. If this correlation is low, then the ordering is immaterial.¹¹

Optimally, one might identify the shocks based on a structural approach, but there are no theoretical results strong enough to be used for identification. At best models have implications for the contemporaneous correlation structure between exchange rates, capital flows and equity return differentials but not the dynamic interactions. We start with the ‘naive’ approach to gain a first insight on the dynamics of the cross-correlations of the variables included in the model. The ordering we choose is: net capital flows, equity return differentials, exchange rates and interest rate differentials. Section 5.1 presents sensitivity analysis that checks the robustness of our main results using different identification schemes.

¹⁰For a detailed documentation of our choice to use levels see Appendix B. Although we argue against differencing the variables included in the VAR, particular caution has to be paid in the stationarity of the system. Phillips (1995) showed that in nonstationary VAR models with some roots at near unity the estimated impulse response matrices are inconsistent at long horizons and tend to random matrices rather than the true impulse responses. However, it is well known that even if the estimated coefficients are biased, their distribution will be exact. So a Monte Carlo procedure will produce sensible standard error bands. For more details see also Appendix C.

¹¹For more details on this issue see Enders (2003).

3 Exchange rates determinants

3.1 Which flow is relevant for exchange rates?

Fluctuations of exchange rates in the presence of large shocks to un-hedged foreign-currency denominated equity may be distinctly different than that from hedged bond flows.¹² To study which form of capital flow is most relevant for exchange rate movements, we decompose the net total accumulation into its parts as described in section 2.1. Thus, U.S. residents transact internationally by buying and selling equities and bonds. Furthermore, these assets can be decomposed to foreign and U.S. assets (see also Figure 2).

Figures 1a, 1b, and 1c illustrate the bilateral exchange rates and different net asset flows for the four countries against the U.S.¹³ Capital flows are clearly correlated with exchange rates. Table 2 reports the simple contemporaneous unconditional correlations for the full sample and two sub-periods: 1988:1-1994:12 and 1995:1-2000:12. The similarity of the coefficient estimates for net flows in U.S. assets across all currency pairs is remarkable; a one percent increase in purchases of U.S. assets from foreign residents cause a contemporaneous appreciation of the home currency by around 20 to 30 basis points for all countries except Japan.

To assess which asset flow is relevant for the modelling of the nominal exchange rate, we perform a number of likelihood ratio tests (see Figure 2). We first estimate bilateral VAR's for all four currency pairs including capital flows, exchange rates, equity return differentials, and interest rate differentials. We then test linear restrictions on the coefficients of the different forms of capital flows within the estimated VAR's as described in Table 3.¹⁴

The test if it is the net total asset purchases that matter for exchange rates or equities have a different effect than bonds is reported in the first column. The test indicates that, for all currency pairs and at the 1% significance level, equity flows dynamics are distinctly different from bond flows dynamics. The second and third columns report the

¹²See, for example, Bailey, Millard and Wells (2001), Hau and Rey (2002), and Pavlova and Rigobon (2003).

¹³A Box-Cox transformation test indicates that the logarithmic transformation is slightly preferable to levels for all the exchange rate pair and all capital flows we study.

¹⁴See also Lutkepohl (1993) for more details on linear restrictions in VAR's.

test statistic for the null hypothesis that bond flows do not matter for exchange rates in the presence of equity flows and vice-versa. For three out of four currencies and at the 5% significance level, equity flows matter for exchange rate movements, whereas bond flows do not. This evidence supports Hau and Rey (2002)'s assumption that cross-border bond holdings are usually hedged and do not matter for exchange rates.

Next, we test if it is the net total purchases of equities that matters or net purchases of foreign assets behave differently from net purchases of U.S. assets (column four). For all currency pairs and at the 1% significance level, the two types of assets have asymmetric effects on exchange rate movements. Columns five and six report the test statistic for the null hypothesis that foreign equities do not matter for exchange rates in the presence of U.S. equities and vice-versa. For Germany, Japan and Switzerland, purchases of U.S. equities are much more important than purchases of equities from these countries by U.S. residents. For the U.K. both flows are relevant, reflecting probably the importance of this market as a financial center (see Warnock and Mason (2000) for an empirical analysis of the importance of financial centers). We also tested the usual practise of normalizing capital flows with market capitalization to conclude that they indeed correlate stronger with exchange rates. Some authors (e.g. Portes and Rey (2002) and Hau and Rey (2002)) have also proposed the use of GDP as a measure for standardizing capital flows to show that they do not change the empirical results. Given that we want to analyze monthly data, the use of interpolated monthly GDP forecasts will add noise to our data sets.

Summarizing, we find evidence that for all pairs but the dollar/yen, changes in net purchases of U.S. equities by foreign residents are important for bilateral exchange rate movements. Moreover, net purchases of U.K. assets, or assets traded in this market by U.S. residents, have important implications for the dollar/pound exchange rate. For Japan, capital flows seem to have an effect opposite to that expected in theory (e.g. Hau and Rey (2002) and Pavlova and Rigobon (2003)). Brennan and Cao (1997) and Brooks, Edison, Kumar and Slok (2001) also document that, during the 1990's, Japanese residents were buying US assets even as the yen strengthened.¹⁵

¹⁵Some commentators claim that this is the outcome of strategic interventions from the central bank of Japan to keep the yen low relative to the dollar to boost exports (see, for example, *The Economist*, September 20th-26th, 2003).

3.2 How important are equity flows for exchange rates?

This section examines the relationship between nominal exchange rates and capital flows.

3.2.1 Impulse responses and variance decomposition

The model's inference about the information content of capital flows is drawn from two main sources. First, the model identifies informed flows from impulse responses of exchange rates to capital flows. Specifically, informed flow is the one that induces a significant response in exchange rates. Second, variance decompositions allow one to determine what proportion, of monthly exchange rate movements, is accounted for by capital flows. This statistic represents the overall contribution of equity flows to currency determination.

More formally, if the shocks are orthonormalized, the impulse response of each variable to any shock is given by the coefficients of the vector of lag polynomials $C(l)a$, with $a'a = 1$.¹⁶ The variance decomposition of Y_{it} , as given in (2), allocated to a at horizon τ is given by:

$$(6) \quad x_\tau(i, a) = \frac{\sum_{s=0}^{\tau-1} (C_a^i)^2}{\sigma_{i\tau}^2}$$

where $\sigma_{i\tau}^2$ is the forecast error variance of Y_t at time t .

For each currency pair we specify the capital flow by the one indicated as the more important one by the likelihood ratio tests. We use the net purchases of U.S. equities for the dollar/Swiss-franc and dollar/mark, the net purchases of foreign as well as U.S. equities for the dollar/pound, and the net purchases of U.S. equities for the dollar/yen.

Figure 3 plots the estimated impulse responses of nominal exchange rates to one standard deviation shocks to all other variables. For U.K., Germany and Switzerland, a one standard deviation shock to net purchases of U.S. assets has a significant effect on exchange rates that lasts between 10 and 17 months. Monthly net purchases of 100 million worth of U.S. equities is accompanied by, on average, a 10% appreciation of the U.S dollar against the mark, pound and swiss-franc. This finding is in line with portfolio balance models as well as with recent empirical evidence from Froot and Ramadorai (2002), Rime

¹⁶Throughout this paper, the lag orders for the Monte Carlo to obtain standard errors will be selected using the SBC and HQC allowing for up to 10 lags for all models. Since the Jarque-Bera test rejects the null of Gaussian innovations for some countries, all Monte Carlo inference will be based on non-parametric resampling of the residuals.

(2001) and Lyons and Evans (2002) although these studies use order flows and higher frequency data sets. It is also in line with Brooks, Edison, Kumar and Slok (2001), Hau and Rey (2002) and Pavlova and Rigobon (2003) that use a similar data sets but they do not study the dynamic interactions of exchange rates and equity flows. However, the behavior of the dollar/yen exchange rate quite differently and the results imply that Japanese residents were buying U.S. equities even as the yen strengthened.¹⁷

The same figure indicates that shocks to equity return differentials have small and insignificant effects on nominal exchange rates for all periods across all currency pairs. However for U.K. and Switzerland, the results are partially in line with Hau and Rey (2002), who claim that higher foreign equity returns relative to home-U.S. are associated with home currency appreciations. Shocks to interest rate differentials are also insignificant for exchange rates for all horizons, although responses are consistent with a long-run interpretation of UIP. The results will be discussed in more detail below in section 3.2.3.

Table 4 reports the percentage of the in-sample forecast error variance of exchange rates that can be explained by other variables. At the 24 month horizon,¹⁸ net equity flows explain on average 20%, equity return differentials 2%, and interest rate differentials 1%. To further illustrate the importance of net equity flows in explaining monthly nominal exchange rate movements we proceed with a counterfactual analysis.

3.2.2 Counterfactual analysis

Figures 4, 5 and 6 illustrate the in-sample prediction for the nominal rate when only one of the following variables enter the estimated equation for exchange rates: net equity flows, interest rate differentials, equity return differentials. We also report the monthly contemporaneous correlation between the value of the exchange rate predicted by each variable and the actual one. For equity flows (Figure 4), the estimated correlation is on average 48% (and goes up to 55% if we exclude Japan) and can be contrasted with Evans and Lyons (2002)'s findings, who document that daily inter-dealer order flow explains an astonishing 60% of daily exchange rate changes.

Figure 4 illustrates that in early 1990s equity flows are one of the main determinants of the dollar/pound exchange rate. In the second part of 1990s, although capital flows

¹⁷Brooks, Edison, Kumar and Slok (2001) document the same finding at the annual frequency.

¹⁸We report up to 24 periods since the variance decomposition stabilizes around this value.

capture the long-run trend of this exchange rate, they correlate weaker with its monthly movements. For Germany, equity flows seem to have played a crucial role in the appreciation of the German mark in mid-1990s and the almost monotonic depreciation thereafter. For Switzerland, equity flows are very informative for the dollar/swiss-franc. For the entire sample period, the equity flows-predicted exchange rate follows closely the actual one. For Japan, equity flows track the long-run trend but fail to explain any short-run movement of the exchange rate.

Interestingly, interest rate differentials are not very informative for explaining any movement of the dollar/pound and the dollar/yen, but they do capture longer swings of the dollar/mark and the dollar/swiss-franc exchange rates (see Figure 5). Equity return differentials are immaterial for exchange rates, although a weak negative correlation is present in three out of four currencies, indicating that higher equity returns in the foreign (relative to the U.S.) market are associated with dollar appreciations (see Figure 6). This channel is particularly interesting since, theoretically, the correlation can go to either direction. A pooled VAR, as analyzed below, provides stronger implications for the dynamics of equity returns and exchange rates.

3.2.3 Pooled VAR

Given the relatively short data set available, the estimated impulse responses are likely to be very imprecisely estimated. One way to improve the estimates is to pool the data from all countries. If one pools the data, the resulting estimator collapses to a standard OLS estimator of the structural impulse responses, unit by unit, when there is no information in the cross section, and to a pooled estimator, when the cross sectional information swamps the one present in a single unit.¹⁹ We pool all countries except Japan, given the distinct dynamics of capital flows compared with the other countries, and we perform a Hausman-type test for the presence of country fixed effects.²⁰ The test indicates that

¹⁹See, for example, Canova and Ciccirelli (2003). Note that pooling countries into a panel setup can indeed increase the statistical power of tests and overcome part of the inference difficulties. However, it is unclear that a panel approach would necessarily draw the relevant variation, as currency values in different countries may be driven by very different forces (such as monetary policy and exchange rate regimes) and have different underlying data generating processes. Rapach and Wohar (2001) and Neely and Sarno (2002) discuss this issue and cast doubt on the validity of pooling data across countries. Given the countries we consider in our analysis, pooling the data for U.K., Germany and Switzerland, seems plausible.

²⁰We choose not to report these tests to save space. All tests are available upon request. Note also that in the pooled VAR's we include both the U.S. and foreign assets flow.

different intercept terms must be included. One easy way to do that in a VAR is the inclusion of country specific dummies. Figure 7 plots the impulse responses of exchange rates to one standard deviation shocks in all other variables. Shocks to net purchases of U.S. equities cause a significant appreciation of the dollar, against the mark, the swiss-franc and the pound, that lasts up to 30 months. Moreover, net purchases of foreign equities increase the value of the foreign currency, and they become marginally significant from the 8th month and last up to the 30th.

In addition to the significant effect of net equity flows, positive shocks to home-U.S. equity returns are now associated with appreciations of the U.S. currency that are significant for almost 18 periods. This is consistent with Pavlova and Rigobon (2003), who show that if a country has a positive demand shock, then home (U.S.) consumers will want to consume more (biased toward the home good) and bid up the price of the home good relative to the foreign. The terms of trade of home improve and its exchange rate appreciates. Leaving unaffected the home output, the appreciation of the exchange rate increases the value of the home output and hence there is going to be a positive return on the home stock market associated with capital inflows. This channel is not robust to the ordering of the VAR. We do not report it here, but we also did the analysis by including dividend yield differentials as a proxy for the relative performance of the two capital markets. A positive shock in dividend yield differentials (defined as foreign minus U.S.) results in a significant appreciation of the pound and the mark against the dollar. We also find that shocks in equity flows are associated with decreases in dividend yields differentials, implying that net equity flows are associated with decreases in the dividend yield. We are not aware of any other study that documents this link for these countries. This result is in line with Bekaert, Harvey and Lumsdaine (1999) which show that the same result holds for a number of emerging economies.

Positive shocks to U.S. interest rates cause an appreciation of the U.S. currency that is significant after the 18th month and lasts up to the 35th month. This finding is in line with Froot and Ramadorai (2002), who document the importance of interest rate differentials in the long-run as an indication of a permanent component in institutional investor's flows shocks. It is also consistent with Bailey, Millard and Wells (2001), who claim that following a positive productivity shock in the home tradeables sector relative to the foreign, home interest rates will increase and the home currency will appreciate accompanied by capital inflows.

Impulse responses, obtained from the pooled-VAR, provide empirical evidence that equity flows affect exchange rates through two channels. In the short-run, equity return differentials seem to play the most important role, whereas in the long-run, interest rate differentials dominate. In Table 5 we report the percentage of the in-sample forecast error variance of exchange rates that can be explained by all other variables. These results support the view that at least for U.K., Germany and Switzerland, net equity flows are important for explaining their exchange rate behavior vis-a-vis the U.S., and that their omission may explain some of the earlier failures of exchange rate equations.

4 Exchange rate predictability

In a seminal paper, Meese and Rogoff (1983) showed that a random walk model outperforms, in out-of-sample exchange rate forecast, structural models including the flexible-price and sticky-price monetary models, and the sticky-price model which incorporates the current account, for major countries with floating exchange rates. Two decades of empirical work of post-Meese-Rogoff (1983) research show that their original finding is remarkably robust. While several strands of the literature claim to have found models with forecast performance superior to that of a random walk (especially at horizons greater than 3-4 years), the inference procedures and methods used are still debated.²¹ The main problem that empirical research faces is the relatively short period of floating exchange rate regimes and, in the present paper, the even shorter period of data on cross border international capital flows in monthly frequency. A few recent papers have shown some success in outperforming a random walk forecast, but their approaches depart significantly from the linear time series framework.²² The conclusion from this work is that although possible, it is indeed difficult to beat the random walk forecast especially when using fundamentals-based specifications.

In this section, we return to our conventional linear time series setup for analyzing exchange rate predictability. We look at out-of-sample point forecasts based on our empirical specification, and compare them to the results from a univariate random walk.

²¹For a good coverage of the debate see, among others, Berden and Dijk (1998), Kilian (1999), and Rossi (2002).

²²See, for example, Kilian and Taylor (2001), Mark and Sul (2001) and Faust, Rogers, and Wright (2001). An exception is the recent work of Chen (2002), who uses differences in commodity prices to show that standard linear models of the exchange rate outperform the random walk for the currencies of Australia, Canada, and New Zealand.

Out-of-sample accuracy is measured, as in Meese and Rogoff (1983), by the root mean square error (RMSE) as defined below:

$$(7) \quad RMSE = \left\{ \sum_{s=0}^{N_k-1} [F_{t+s+k} - A_{t+s+k}]^2 / N_k \right\}^{1/2}$$

where $k = 1, 3, 6, 12, 18$ denotes the forecast horizon, N_k the total number of forecasts in the projection period for which the actual value A_t is known, and F_t the forecast value. As Meese and Rogoff (1983) note, since we forecast the logarithm of the exchange rate, this statistic is unit-free, approximately in percentage terms, and comparable across currencies.

Table 6 reports the root mean square error statistics for the five forecast horizons over the period January 2001 to May 2003. The linear model beats the random walk for some currency pairs and for different horizons for each currency pair. The stronger result comes from the dollar/swiss-franc and indicates that the capital-augmented VAR beats the random walk at all 5 forecasting horizons. For the dollar/mark, the VAR beats the random walk after the 6th month, whereas for the dollar/pound after the 23rd. Recall that the in-sample significance of net equity flows in explaining exchange rates mimics closely their ability to forecast them.²³ The failure of the equity augmented-VAR for the dollar/yen comes at no surprise, given the poor in-sample performance of capital flows in explaining movements of this currency against the dollar.²⁴

The empirical evidence that a linear VAR with net equity flows and interest rate differentials outperforms a univariate random walk can be due to the fact the data generating process has become more responsive to interest rate differentials in recent years. To partially address this point, we use the Diebold-Mariano (1995) statistics to compare an equity augmented-VAR, a standard VAR that includes only exchange rates and interest rate differentials and a univariate random walk. The test indicates which forecast is the best according to the mean square error criterion and tests the null hypothesis that there exists a significant difference between two tested forecasts. Table 7 presents the test statistics with their associated *p-values* for $k = 3, 6, 12, 18, 24$ forecast horizons. We see that

²³We also note that the conventional wisdom of increased validity of out-of-sample predictions relative to in-sample ones has been questioned. See the recent work of Inoue and Kilian (2003).

²⁴Many theorists will claim that nominal exchange rates are indeed a random walk in the short-run, driven from factors irrelevant to any economic variable. Since we provide empirical evidence of the contrary we also tried to address partially this concern by imposing a unit root prior for all currency pairs (a Litterman prior) and we repeated the forecasting exercise. The results are robust. We do not report them to save space but they are available to the reader upon request.

an equity augmented specification indeed provides support for exchange rate predictability and outperforms a random walk and a standard VAR. However, we also note that the particular specification that can produce such superior forecast performance appears to depend on the exchange rate and the forecast horizon under investigation. This implies that the predictive power may not necessarily be exploitable.

5 Sensitivity analysis

The results we obtained for the impact of net equity flows on exchange rates are striking: our estimates show that nominal exchange rates greatly depend on capital flows in the monthly frequency. In this section we investigate the robustness of our findings. We first assess the potential problems related to the ‘naïve’ identification scheme we employ. Second, we assess the validity of our results in different sub periods; third, we investigate the of data misreporting and fourth, we develop a methodology to deal with measurement error in the regressors.²⁵

5.1 Identification

The employed identification together with the ordering of the variables in the VAR implies that an exchange rate shock has no contemporaneous effects on equity flows and/or equity return differentials. It is well known that the importance of the ordering depends on the magnitude of the correlation coefficient between the variables included in the VAR. If this correlation is high then the ordering may affect the estimated impulse response functions.

In order to evaluate the sensitivity of the results to the ordering of the variables, we estimate the equity augmented-VAR using alternative orderings. First we assume the ordering: net equity flows in foreign assets, net equity flows in U.S. assets, equity return differentials, exchange rates and interest rate differentials. Table 8 reports the estimated residual correlation matrix. We then reverse the ordering of net equity flows in U.S. assets with that of exchange rates and interest rate differentials, since they exhibit the highest correlation. Next, we obtain the new set of impulse responses and illustrate them in Figure 9. Re-ordering attenuates the effect of equity return differentials which is now significant for only 1 period and brings forward the effect of interest rate differentials

²⁵For illustrative purposes and to save space we use the pooled data set when possible.

which now becomes significant after the 8th period and lasts up to the 30th. The effect of foreign equities becomes insignificant for all horizons but the effect of U.S. equities remains significant for almost 40 periods.²⁶

Lyons (2001) uses the same ordering but for order flows and Froot and Ramadorai (2002) use the Cambell-Shiller decomposition of permanent and transitory effects. To further asses the robustness of our results we also did the analysis using the Canova and DeNicolò (2002) method. This method involves the estimation of the pooled-VAR using sign restrictions based on the estimated correlations from the true data. Figure 6, shows that the impulse response of exchange rates to shocks in net equity flows is almost identical to the one obtained with a triangular decomposition (Figure 4).

5.2 Structural Breaks

Some authors (e.g. Hau and Rey (2002)) have proposed that capital flows should become more important for exchange rates in recent years due to the increased integration of the global financial system. This implies that the relationship between capital flows and exchange rates may change over time. In order to assess the robustness of our results in this direction, we split the data into two sub samples and estimate a VAR for all currency pairs including net equity flows (in foreign and U.S. assets), equity return differentials, exchange rates and interest rate differentials. We report only the sub samples generated when we split the data in the last month of 1994 as in Hau and Rey (2002).²⁷

Table 9 reports the historical decomposition of nominal exchange rates for the two sub-periods. Four features are evident: first the increased importance of equity flows (from 12% on average, to 18% in a 36 month horizon); second the slight increase in the importance of net flows in foreign assets relative to U.S. assets (reflecting probably the rise of U.K. and Germany as European financial centers); third the increased importance of interest rate differentials (reflecting probably the run of investors to fundamentals as a guidance of economic prosperity and future growth perspectives)²⁸; and fourth the relative

²⁶We do not report it but we also employed the Sims-Bernanke identification method. This method involves the treatment of the contemporaneous coefficients as free parameters that can be estimated with non-linear least squares and then use these estimates to identify the system. The results resemble the ones reported here.

²⁷Hau and Rey (2002) report that the correlation of equity flows and exchange rates for 17 OECD countries has indeed become stronger in recent years.

²⁸See also the article of Jeffrey Garten on the "The Economist" of the 4th of January 2003, pp. 54.

large increase in the explanatory power of equity return differentials in the recent period, reflecting mainly the run up in US assets due to the downturn of the Japanese and the European economy in the second half of the 90s. The results validate the dominant role of capital flows in explaining exchange rates regardless of the time period we examine, and are in line with Hau and Rey (2002) about increased international capital markets integration which Portes and Rey (2002), evidence on the increased importance of cross-border equity flows in recent years.

5.3 Data mis-reporting

The TIC data is well-known to suffer from measurement problems related to capital flows of nationals. For example, if a Japanese CEO of Toyota USA – a Japanese national – gets a salary in US dollars and decides to invest in the US stock market. In the TIC system, he/she will be counted as a US national. On the other hand, a US national having an account in Cayman Islands and buying US equities is a foreigner for TIC accounting purposes. These accounting standards disagree with those employed on the national income and product accounts. This limitation is likely to introduce a bias in our analysis, but the bias is likely to be small as long as any failure of the TIC system to recognize correctly the nationality of the investor is small relative to the flows that correctly records.

Another problem related to the TIC system is that it captures portfolio transactions between U.S. and foreign residents, but does not take into account that U.S. residents may also acquire stocks through merger-related stock swaps. When a company, based on a foreign country (from the US perspective) acquires a U.S. firm, one form of financing is an exchange of equity in which shareholders of the target (U.S.) firm are given stocks in the acquiring (foreign) firm. Such acquisitions of foreign stocks are not reported to the TIC system but the acquisition of the US company is recorded as a foreign direct investment in US.

If the acquisition of foreign stocks through swaps results in a portfolio with higher risk due to the inclusion of foreign equities or if US residents are reluctant to hold foreign stock then they will subsequently sell foreign equities to rebalance their portfolios, and such sales are reported to the TIC system. The shortcoming is that since the TIC system

Brooks, Edison, Kumar and Slok (2001) report similar results but for long term interest rate differentials.

does not record the initial acquisition, but does capture subsequent sales, measures of stock swaps might be important.

This form of financing cross-country mergers and acquisitions is a recent strategy that evolved in importance in 1998 and 1999. Some of the most important mergers and acquisitions took place in these years and include that of Daimler Chrysler, BP Amoco, and Airtouch Vodafone. Prior to 1998 there was only one deal that involved a substantial exchange of stocks, the 1989 Beecham/SmithKline merger. To assess the importance of such flows in our analysis we collected data in all gross cross-border foreign direct investments (FDI hereafter) between US and the four counter parts. Figure 10 plots the volume of cross-border transactions in equity and debt flows and that of FDI's (we also report the cross correlation of portfolio flows and FDI's). It is clear that the data on FDI does pick up the unusual megamerger wave of the late 1990s. However the percentage of FDI's in gross cross-border transactions does not exceed 5%. and this problem is therefore unlikely to affect the results significantly. Furthermore, Warnock and Mason (2001) and Edison, Brooks, Kumar and Slok (2001) document that equity swaps are insignificant and do not entail any large bias in the reported TIC data.

5.4 Errors in variables

A more serious concern that is neglected in most of the studies that are using the TIC data is the effect of measurement errors in the regressors. Recall the simultaneous equation setup of an unrestricted VAR(p). If $z_t = (x_{t-1}, x_{t-2}, \dots : y_t)$ and $\Gamma = (D'_1, D'_2, \dots, a)'$ is a $(q + pN) * N$ matrix then:

$$(8) \quad x_t = z_t \Gamma + e_t$$

where $e_t \sim (0, \Sigma_e)$. This model can be identified (as shown in section 2) and estimated equation by equation with OLS. For linear regression models, Wansbeek and Meijer (2002) show that in the presence of measurement error in one or more of the regressors, in a system of equations, the estimate of the coefficients relating to the mismeasured regressor is asymptotically biased towards zero. This phenomenon is called attenuation. The size of the coefficient on the dependent variable is underestimated and the explanatory power of the model is underestimated too. Moreover, in VAR's, the measurement error will accumulate when calculating the impulse response functions and will obscure the true response of any structural innovation.

One way to circumvent this problem is to generate impulse responses from the theoretical asymptotic distribution of the regression coefficients and compare them with the one obtained by estimating a model with a regressor perturbed by an i.i.d. measurement error. Suppose that capital flows are measured with error and let x^* denote the vector of regressors that contains the observed value of capital flows and x the vector that contains its true value. Then the model is given by:

$$(9) \quad x_t^* = z_t^* \Gamma + e_t$$

where $z_t^* = (x_{t-1}, x_{t-2}, \dots : y_t)$, where equity flows which are contained in x_{t-i} are augmented with an i.i.d. measurement error, u , with zero mean and constant variance σ_u^2 . We first estimate (6) and calculate the impulse response function of exchange rates to innovations in capital flows. We then use bootstrap techniques to construct 2 standard error bands for the impulse responses resulting from the presence of measurement error.²⁹

Figure 11 shows the impulse response of exchange rates to one standard deviation shocks in net equity flows and the two standard error bands obtained from equity flows perturbed by three different i.i.d. measurement errors. The significance of responses of exchange rates to innovations in net equity flows is mitigated and eventually disappears for i.i.d. errors with standard deviation (*sigma* in the graph) greater than 0.25. Given that all variables are in logs, in order for the effect of equity flows to exchange rates to disappear, we need more than 5% monthly measurement error in equity flows.

6 Conclusion

This paper presents evidence that for four major countries a good portion of their exchange rate movements can be explained by net cross-border equity flows. We use Vector Auto Regressions to estimate dynamic models including a measure of net capital flows, the nominal exchange rate, equity return differentials and interest rate differentials.

We document that for U.K., Germany and Switzerland, a positive shock to net purchases of U.S. *equities* have a significant effect on exchange rates that lasts between 10 and 17 months. Monthly net purchases of 100 million worth of U.S. equities is accompanied by, on average, a 10% appreciation of the U.S dollar against the mark, pound and

²⁹Sampling error is also included in the two standard error bands. For more details on the methodology, see Appendix C.

Swiss-franc. On the contrary, net purchases of U.S. *bonds* are immaterial for exchange rate movements. The evidence for Japan is not consistent with what theory predicts since net purchases of U.S. assets from Japanese residents are associated with a strong yen.

We also show that positive shocks to home-U.S. equity returns (relative to the foreign markets) are associated with a 2% appreciation of the U.S. currency that is significant for almost 18 months and that positive shocks to U.S. interest rates (relative to the foreign countries) cause U.S. currency appreciations consistent with the long-run interpretation of uncovered interest rate parity (UIP) that become marginally significant after 18 months. The results support the recent theoretical and empirical work on the effects that capital markets have on foreign exchange markets.³⁰

In terms of the predictive content of the empirical model in short to medium-horizon forecasts (1 month to 2 years), we show that dynamic forecasts from an equity augmented-VAR provide support for exchange rate predictability and outperform a random walk and a standard VAR that includes only exchange rates and interest rate differentials, a finding that is extremely interesting in light of the seminal contribution by Meese and Rogoff (1983). Forecast performance is evaluated with the root mean square error criterion and the Diebold and Mariano (1995) statistics. However, the particular specification that can produce such superior forecast performance depends on the exchange rate and the forecast horizon.

Overall, the empirical results are indicative of the effects that increased capital mobility, seen in recent years, has on exchange rate movements. As net purchases of cross-border equities increase their share in total flows (including foreign direct investment, bank flows etc.), their effect on nominal exchange rates is becoming increasingly important. If monetary policy makers respond explicitly to deviations of asset prices from their steady-state or fundamental levels, as part of their pursuit for inflation and output gap stability,³¹ particular attention should be paid in equity flows as a determinant of exchange rate movements.

³⁰See, for example, Hau and Rey (2002) and Pavlova and Rigobon (2003).

³¹See Abreu and Brunermeir (2003), Rigobon and Sack (2003), Bernanke and Gertler (2000), and Cecchetti, Genberg, Lipski, and Wadhwani (2000) for a recent debate on this subject.

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A Data sources

Capital Flows: The data series is based on submissions of monthly TIC Form S, ‘Purchases and Sales of Long-Term Securities by Foreigners’ millions of US dollars. These reports are mandatory and are filed by banks, securities dealers, investors, and other entities in the U.S. who deal directly with foreign residents in purchases and sales of long-term securities (equities and debt issues with an original maturity of more than one year) issued by U.S. or foreign-based firms. The data series are revised for up to 24 months after the initial ‘as of’ reporting date.

The data reflect only those transactions between U.S. residents and counterparts located outside the United States. The data cover transactions in six classifications of securities: There are four domestic types of securities, which include U.S. Treasury bonds and notes, bonds of U.S. government corporations and federally-sponsored agencies, U.S. corporate and other bonds, and U.S. corporate and other stocks; and two foreign types of securities, namely foreign bonds and foreign stocks.

Please note that the geographical breakdown of Form securities transactions indicates country of location of the foreign buyers and sellers who deal directly with entities resident in the U.S. (i.e., reporting institutions). The data do not necessarily indicate the country of beneficial owner or issuer, or the currency of denomination of securities. For instance, a U.S. purchaser’s order for Japanese securities may be placed directly with an intermediary in London. In this instance, the transaction for Form S reporting purposes would be recorded opposite the U.K. and not opposite Japan. Similarly, purchases and sales of U.S. securities for the account of an Italian resident may be placed, for example, in the Swiss market. In such an arrangement, the trades would be reported opposite Switzerland and not opposite Italy

(Available at <http://www.treas.gov/tic>)

Exchange Rates: Monthly averages of nominal exchange rates obtained from IFS, CD-Rom

Stock returns indices: Germany: CDAX Composite Price Index, Japan: Nikkei 225 Stock Average, UK: FT-Actuaries All-Share Index, Switzerland: Swiss Market Index and S&P 500 Composite index. All obtained from Global Financial Data, Inc.

Stock market capitalization: monthly averages in millions of US dollars obtained from Global Financial Data, Inc.

Interest rates: Monthly averages of short term money market rates obtained from IFS, CD-Rom.

B Non-Stationarity and data filtering

The issue of whether the variables in the VAR need to be differenced exists. We estimate a VAR model in levels as many economists such as Sims (1980) and Doan (1992) recommend against differencing even if the variables contain a unit root. The main argument against differencing is that it “*throws away*” information concerning the comovements in the data and removes any cointegrating relationships. It is also noted that the goal of a VAR analysis is to determine the interrelationships among the variables, not the parameter estimates, as it is the case in this paper. Moreover, Fuller (1976) shows that differencing produces no gain in asymptotic efficiency in an autoregression, even if it is appropriate. He notes that in a VAR, differencing throws information away while it produces almost no gain.

Conventional unit root tests fail to reject the presence of nonstationary components in nominal exchange rates. However, we do know that long-run tests run over a century and more of data can reject a unit root (e.g. Lothian and Taylor (1996)). Taylor (2001) documents that in the short samples that have been used in empirical studies, unit root tests have very low power. The main determinant of the power of a conventional unit root test is neither the length nor the frequency of a dataset, but its span (e.g. Shiller and Perron (1985)). Moreover, Taylor (2001) shows how the power of a standard unit root test is affected by a variety of spans. With an autoregressive coefficient of 0.846, which is the highest in our sample, the power of the test would be 0.5-0.6 if we had 300 observations! Many concerns have been also expressed for the first difference filter that is usually applied to nonstationary time series, particularly when non-stationarity has been indicated by conventional unit root tests. Baxter (1994) emphasized that differencing of a near unit root process would be inappropriate and would discard valuable information. Although first differencing will remove unit root components, this filter has several drawbacks. It alters timing relationships between variables by inducing a substantial phase shift and it

involves a dramatic re-weighting of frequencies – high frequency (noise) components are emphasized at the expense of down-weighting lower frequencies: in particular, much of the ‘*cyclic*’ variation is removed. To understand how application of this filter alters the data consider any filter $H(L)$, and two time series Y_t and X_t such that $Y_t = H(L)X_t$ with population spectrums:

$$\begin{aligned} S_{yy}(\varpi) &= h(e^{-i\varpi})h(e^{-i\varpi})S_{xx}(\varpi) \\ (10) \quad S_{yx}(\varpi) &= h(e^{-i\varpi})S_{xx}(\varpi) \end{aligned}$$

where $h(e^{-i\varpi})$ is the *transfer function* or *frequency response function* with gain $R(\varpi) = |h(e^{-i\varpi})|$ and phase $\theta(\varpi) = \arg[h(e^{-i\varpi})]$, with $0 \leq \varpi \leq \pi$. In the special case of a first difference filter $H(L)$ reads: $H(L) = 1 - L$. If we apply this filter to a stationary process Y_t , this imposes certain gain and phase transformations on the spectrum of the raw series (see also Baxter (1994) and Obstfeld and Taylor (2001)). From (13) we can obtain the transfer function as well as the phase and the gain of a first difference filter. When $H(L) = 1 - L$ then (13) reads:

$$(11) \quad h(e^{-i\varpi}) = (1 - \cos \varpi) + i \sin \varpi$$

and:

$$(12) \quad R(\varpi) = 2 - 2 \cos \varpi$$

$$(13) \quad \theta(\varpi) = \frac{\pi}{2} - \frac{\varpi}{2}$$

The first difference filter has very low gain at low frequencies such that regressions involving the filtered data tend to pick up correlations between two variables only at the high end of the frequency spectrum. The main concern that is related to our analysis is that, with monthly data, the differenced exchange rates, when regressed with capital flows data, might lead to a correlation that is greatly biased towards high frequencies. To put it differently, the relationship between capital flows and exchange rates might be tighter at lower frequencies but it could remain obscured since this range of the spectrum is deeply attenuated when a first difference filter is applied.

C Impulse responses with measurement error in the regressors

Recall the simultaneous equation setup of an unrestricted VAR(p). If $z_t = (x_{t-1}, x_{t-2}, \dots : y_t)$ and $\Gamma = (D'_1, D'_2, \dots, a)'$ is a $(q + pN) * N$ matrix then:

$$(14) \quad x_t = z_t \Gamma + e_t$$

where $e_t \sim (0, \Sigma_e)$. It is known that the distribution of the likelihood function of a VAR(p) is the product of a normal density, conditional on the OLS estimates, and an inverted Wishart distribution with $(T - \xi)$ degrees of freedom, T denoting the number of observations, and ξ denoting the number of estimated coefficients in each equation. More formally:

$$(15) \quad L(\gamma, \Sigma_e) \propto (Normal \times inverted Wishart)$$

where γ are the OLS estimates of $D's$. If we assume a flat prior for γ, Σ_e : $(\gamma, \Sigma_e) \propto |\Sigma_e|^{\frac{1(N+1)}{2}}$ then the posterior is equal to the likelihood multiplied by the prior and reads:

$$(16) \quad post(\gamma, \Sigma_e) = L(\gamma, \Sigma_e) \times flatprior(\gamma, \Sigma_e)$$

Note also that: $post(\gamma, \Sigma_e) = post(\gamma \mid \Sigma_e) \times post(\Sigma_e)$, where the posterior of Σ_e is distributed as an inverted Wishart with $(T - \xi)$ degrees of freedom and the posterior of $(\gamma \mid \Sigma_e)$ can be obtained from $x^* \sim N(\gamma_{OLS}, var(\gamma_{OLS}))$. Even if the estimated $\hat{D}'s$ are biased, the distribution will be exact.

Next, consider the following logical algorithm. Generate $T - \xi$ i.i.d. draws for e_t from the inverse $N(0, (X - Z\Gamma_{OLS})'(X - Z\Gamma_{OLS}))$. Form the second moments by taking $\Psi = \frac{1}{T-\xi} \sum_i (e_i - \frac{1}{T-\xi} \sum_i e_i)^2$. Then set $\Sigma^h = \Psi^{-1}$. Next construct $\gamma^h = \gamma_{OLS} + \mu_t$ by drawing μ_t from the $N(0, \Sigma^h)$. Now compute the h^{th} impulse response at step k for each draw h . If we repeat this algorithm for $H = 10000$ times we can generate the theoretical distribution of impulse responses from the asymptotic distribution of the estimated coefficients. The resulting 2 standard error band shows where the impulse response lives for any bias in the estimated coefficients due to measurement and sampling error in equity flows.

Figure 1a. Exchange rates (LFX) vs. log net total equity flows (foreign and U.S. assets included-NAUS). Sample: 1988:1-2000:12.

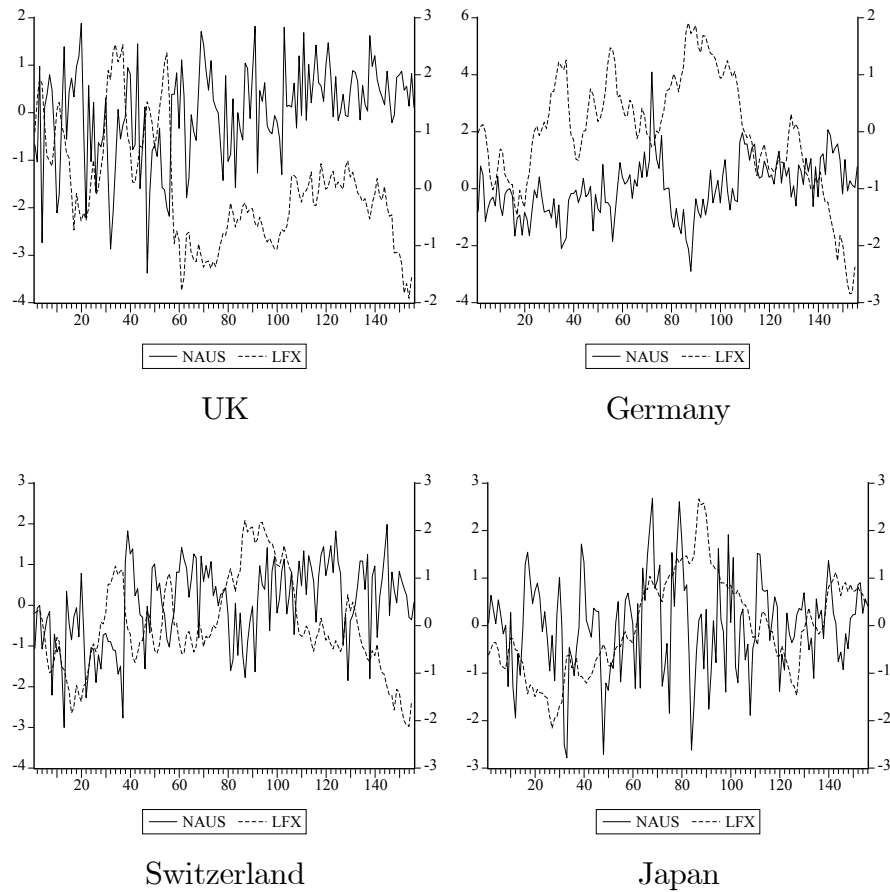


Figure 1b. Exchange rates (LFX) vs. log net normalized equity flows (in U.S. assets standardized by the respective market capitalization-NANORMUS). Sample: 1988:1-2000:12.

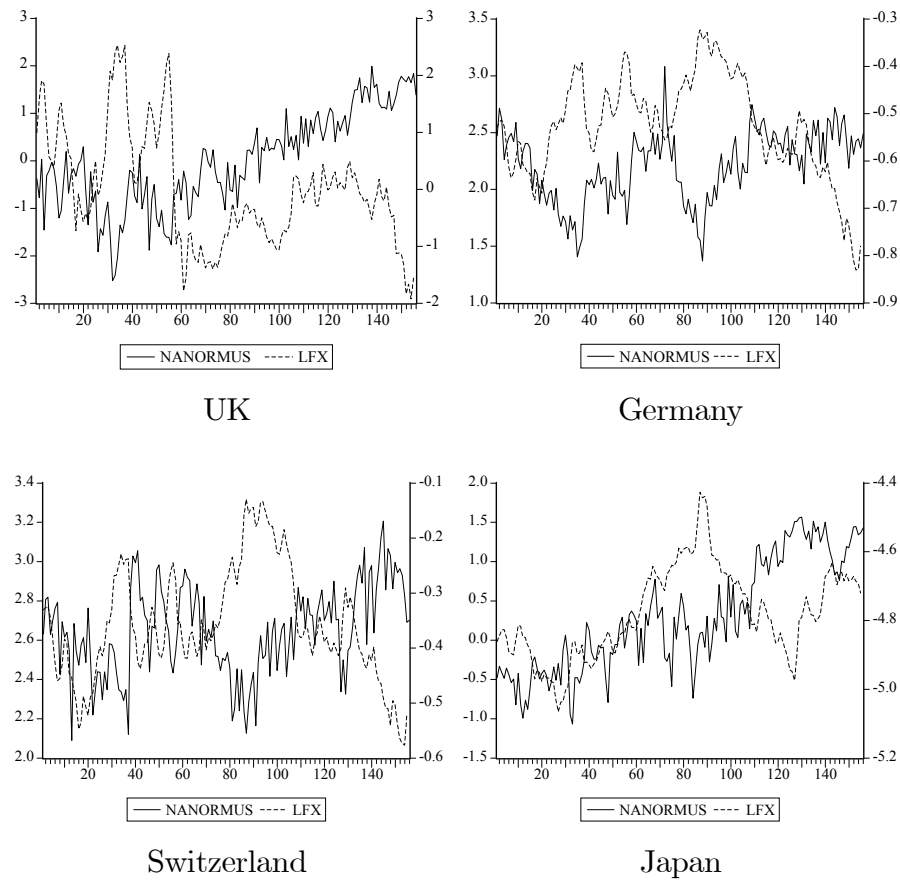


Figure 1c. Exchange rates (LFX) vs. net normalized bond flows (in U.S. assets standardized by market capitalization -NORMBUS). Sample: 1988:1-2000:12.

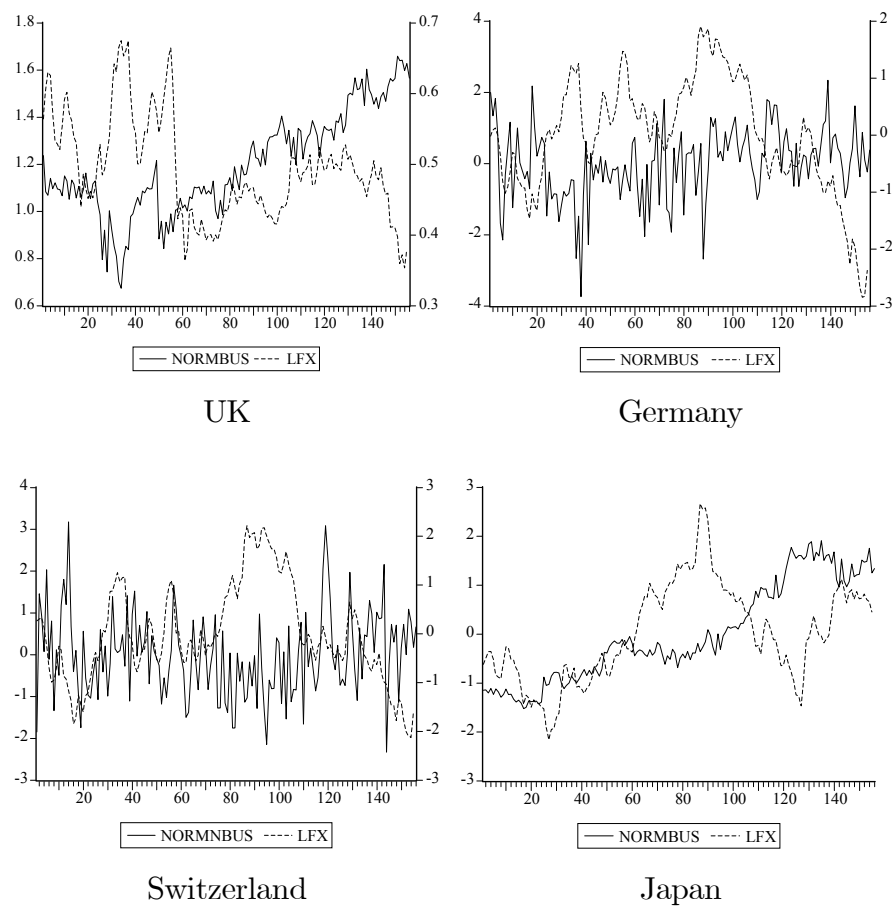


Figure 2. Schematic representation of the likelihood ratio tests for the form of capital flows that has the strongest joint dynamics with exchange rates.

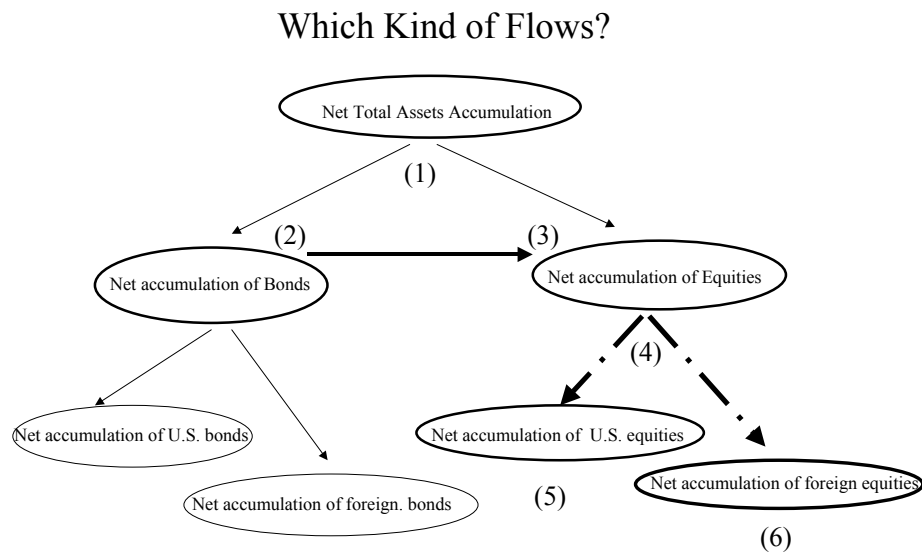
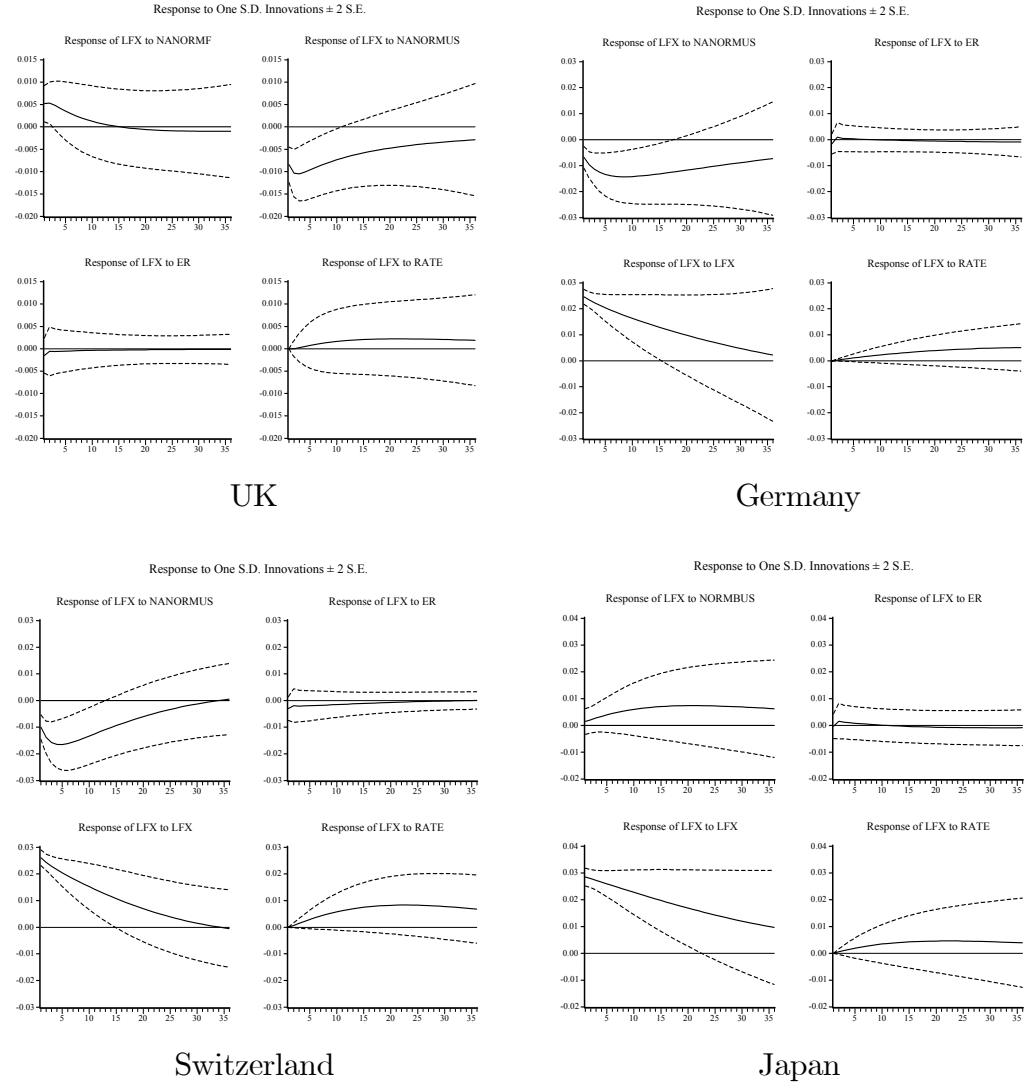
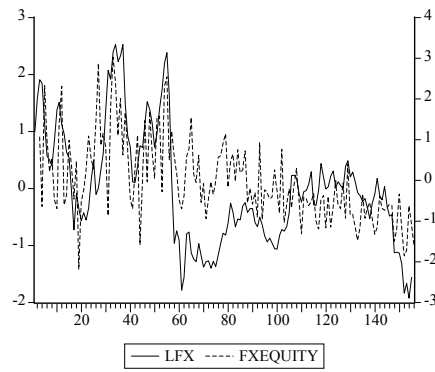


Figure 3. Impulse responses of exchange rates to shocks in all other variables: all countries.

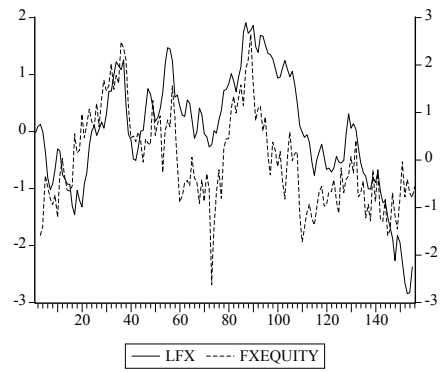


Note: For each country, impulse responses of log nominal exchange rates (LFX) to innovations in: log net accumulation of foreign equities from U.S. residents (NANORM-upper left), log net accumulation of U.S. equities from foreign residents (NANORMUS-upper right), equity return differentials defined as foreign minus U.S. (ER-lower left), interest rate differentials defined as foreign minus U.S. (RATE-lower right). Sample: 1988:1-2000:12.

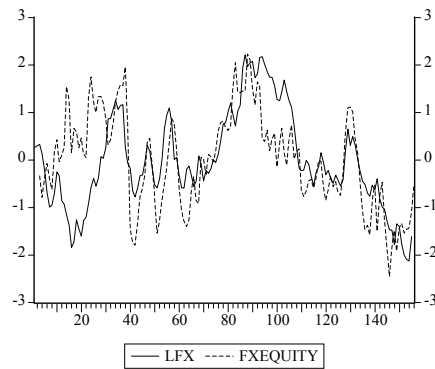
Figure 4. Counterfactual analysis: equity flows. Contemporaneous correlation in parenthesis.



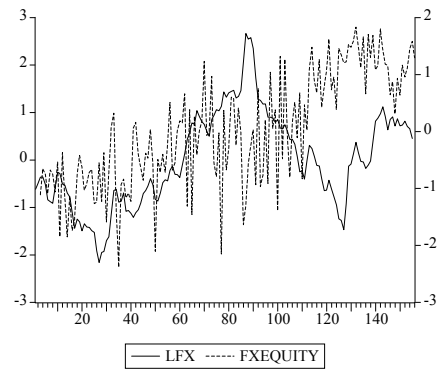
U.K. ($\rho = 0.48$)



Germany ($\rho = 0.57$)

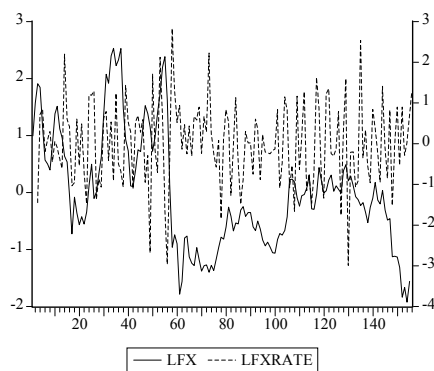


Switzerland ($\rho = 0.60$)

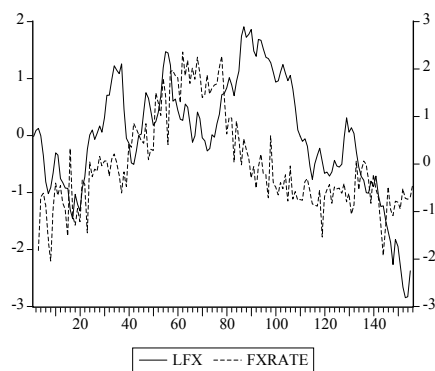


Japan ($\rho = 0.24$)

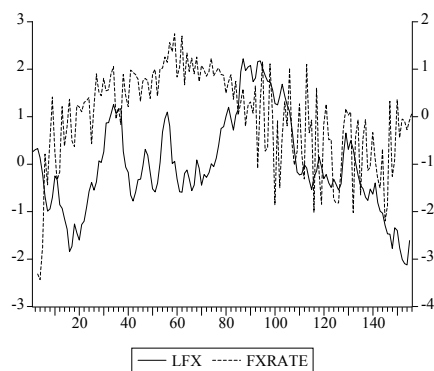
Figure 5. Counterfactual analysis: interest rate differentials. Contemporaneous correlation in parenthesis.



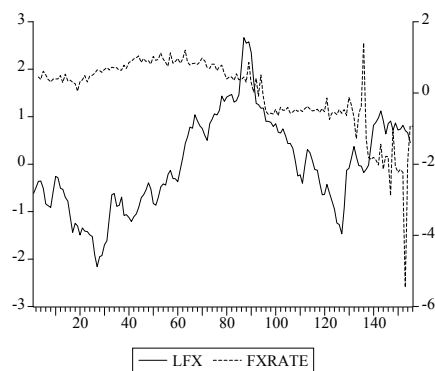
U.K. ($\rho = -0.10$)



Germany ($\rho = 0.41$)

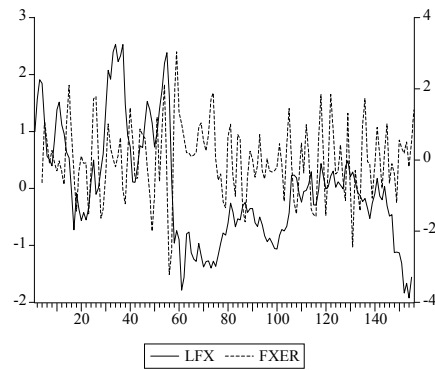


Switzerland ($\rho = 0.17$)

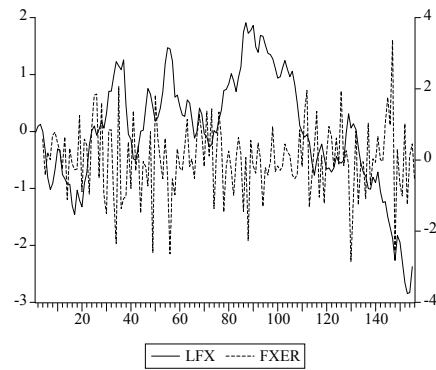


Japan ($\rho = -0.24$)

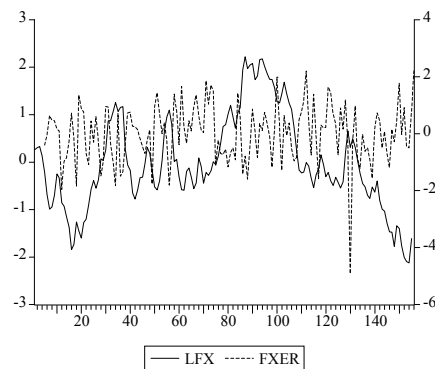
Figure 6. Counterfactual analysis: equity return differentials. Contemporaneous correlation in parenthesis.



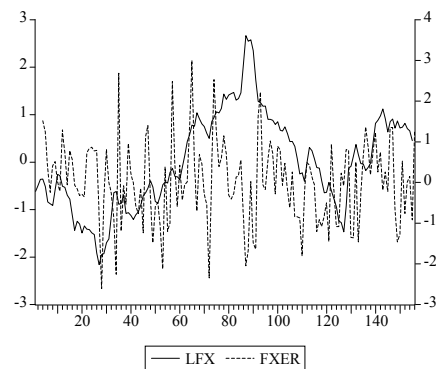
U.K. ($\rho = -0.09$)



Germany ($\rho = -0.16$)

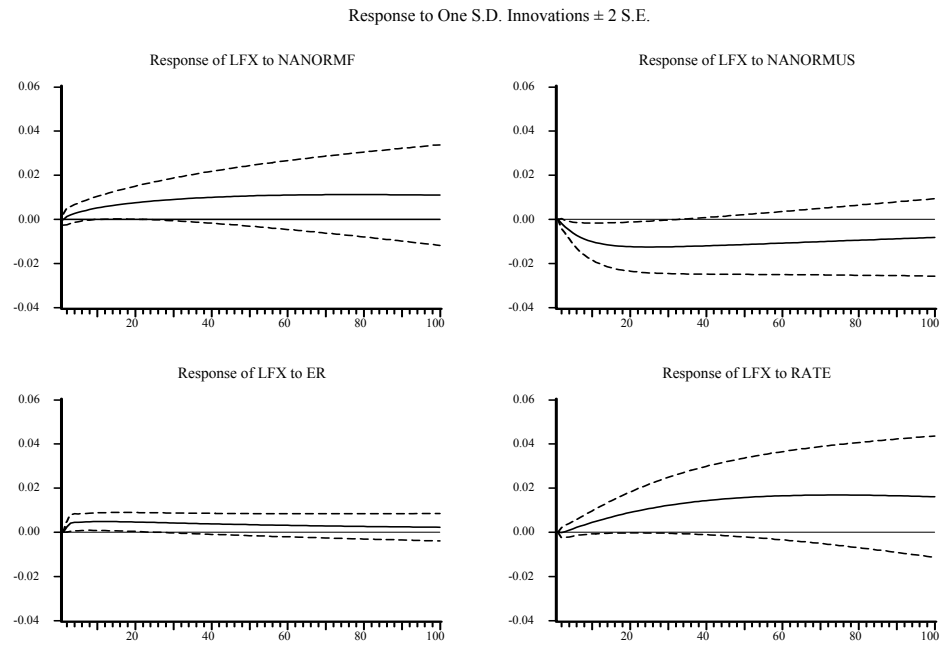


Switzerland ($\rho = -0.15$)



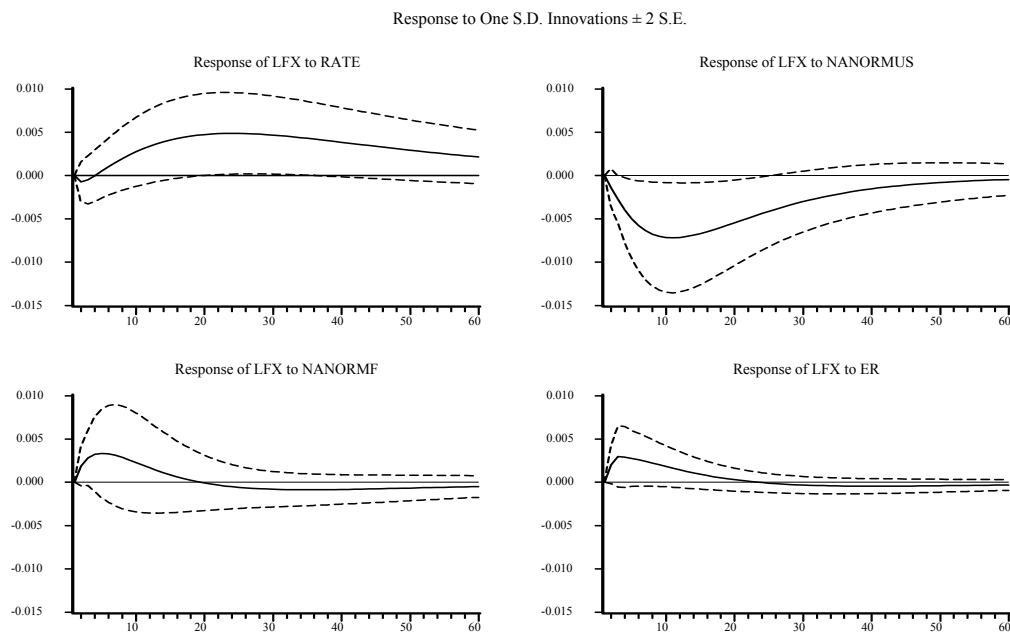
Japan ($\rho = 0.04$)

Figure 7. Impulse responses of exchange rates based on estimated VAR.



Note: Impulse responses of log nominal exchange rates (LFX) to innovations in: log net accumulation of foreign equities from U.S. residents (NANORM-upper left), log net accumulation of U.S. equities from foreign residents (NANORMUS-upper right), equity return differentials defined as foreign minus U.S. (ER-lower left), interest rate differentials defined as foreign minus U.S. (RATE-lower right). Sample: 1988:1-2000:12. The pooled data excludes Japan. Fixed effects included.

Figure 8. Impulse responses of exchange rates based on estimated VAR with reversed ordering.



Note: Impulse responses of log nominal exchange rates (LFX) to innovations in: log net accumulation of foreign equities from U.S. residents (NANORM-lower left), log net accumulation of U.S. equities from foreign residents (NANORMUS-upper right), equity return differentials defined as foreign minus U.S. (ER-lower right), interest rate differentials defined as foreign minus U.S. (RATE-upper left). Sample: 1988:1-2000:12. The pooled data excludes Japan. Fixed effects included.

Figure 9. Impulses response of exchange rates from shocks to net equity flows in U.S. assets using the Canova-DeNicolò method of sign restrictions. Pooled data. Fixed effects included.

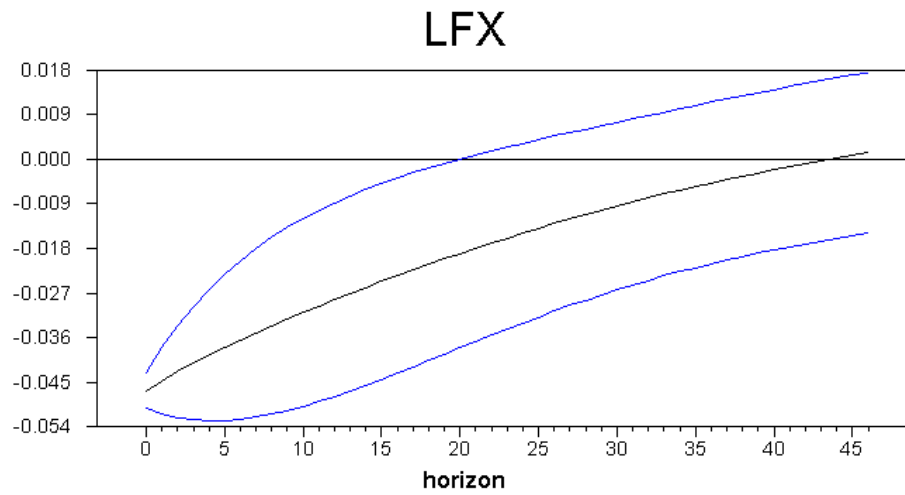


Figure 10. Gross cross border portfolio flows (right scale) v.s. gross cross border FDI's (left scale) between US and UK, Germany, Switzerland and Japan (in million \$). Sample: 1988-2000. (Correlations in parenthesis).

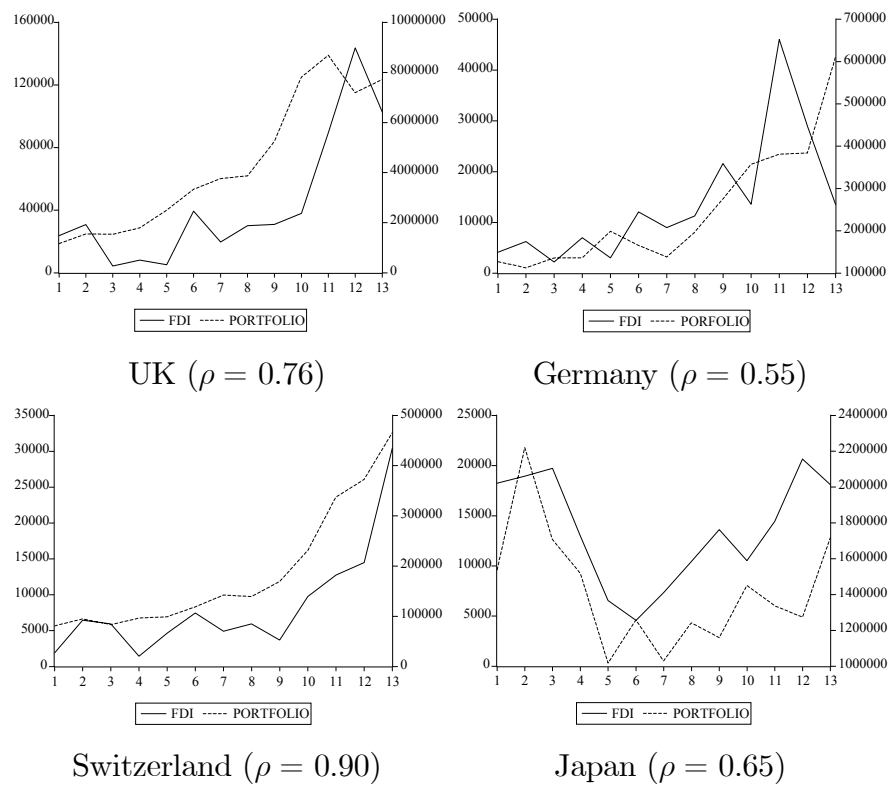
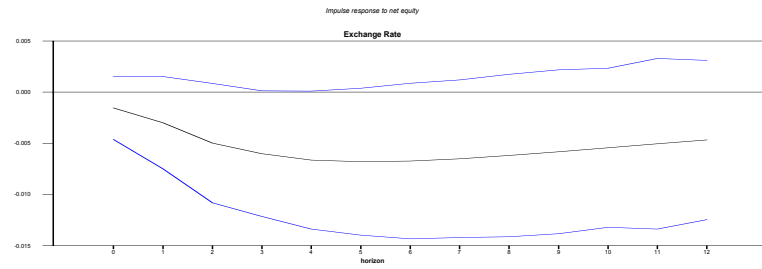
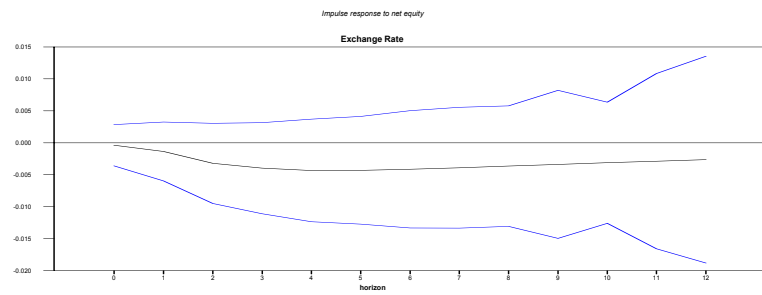


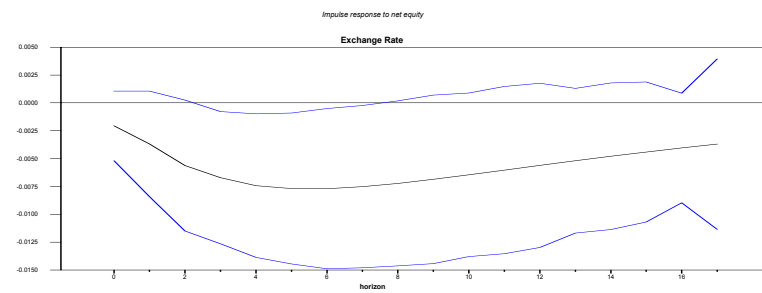
Figure 11. Impulses responses of exchange rates from shocks to net equity flows in U.S. assets with three different iid measurement errors. Pooled data. Fixed effects included. "Sigma" is the standard deviation of the measurement error.



$\sigma = 0.25$



$\sigma = 0.4$



$\sigma = 0.2$

Table 1. Percentage of daily foreign exchange market turnover by exchange rate.

Year	1992	1995	1998	2001
Exchange Rate				
Dollar/pound	10	7	8	11
Dollar/euro	-	-	-	30
Dollar/mark	25	22	20	-
Dollar/yen	20	21	18	20
Dollar/Swiss F	6	5	5	5
Total	61	55	51	66

Note: Daily averages. Adjusted for local and cross border double counting. Source: Bank of International Settlements.

Table 2. Capital flows elasticities of nominal exchange rates. Dependent variable: Log of nominal exchange rate (FX), relative to the U.S. dollar. Independent variables: net flows in foreign equities (FE), net flows in U.S. equities (USE), net flows in foreign bonds (FB), Net flows in U.S. bonds (USB). *P-values* in parenthesis.

FX		\$ /pound		\$ /mark		\$ /swiss franc		\$ /yen	
		$ln(FX)_t = \alpha + \beta_i(\ln(Capital\ Flow_i))_t + \varepsilon_t$							
Flow		$\widehat{\beta}_i$	R^2	$\widehat{\beta}_i$	R^2	$\widehat{\beta}_i$	R^2	$\widehat{\beta}_i$	R^2
FE	88-00	-0.08(0.000)	0.10	0.02(0.033)	0.01	-0.08(0.002)	0.07	0.03(0.018)	0.03
	88-94	-0.10(0.072)	0.04	0.09(0.000)	0.14	-0.03(0.299)	0.01	-0.09(0.000)	0.13
	95-00	-0.05(0.015)	0.05	-0.14(0.016)	0.09	-0.15(0.000)	0.21	-0.09(0.000)	0.21
USE	88-00	-0.14(0.000)	0.27	-0.18(0.000)	0.29	-0.23(0.000)	0.26	0.05(0.000)	0.06
	88-94	-0.26(0.000)	0.33	-0.13(0.000)	0.25	-0.18(0.000)	0.16	0.18(0.000)	0.22
	95-00	-0.10(0.025)	0.11	-0.26(0.000)	0.17	-0.34(0.000)	0.42	-0.08(0.000)	0.14
FB	88-00	-0.12(0.000)	0.15	-0.03(0.246)	0.02	-0.08(0.002)	0.07	0.05(0.230)	0.06
	88-94	-0.02(0.000)	0.12	-0.07(0.002)	0.12	-0.03(0.299)	0.01	0.18(0.020)	0.21
	95-00	-0.09(0.030)	0.10	-0.01(0.897)	0.00	-0.15(0.000)	0.21	-0.08(0.050)	0.12
USB	88-00	-0.16(0.000)	0.22	-0.05(0.028)	0.02	-0.07(0.002)	0.05	0.05(0.001)	0.02
	88-94	-0.31(0.000)	0.22	-0.02(0.367)	0.01	-0.06(0.034)	0.04	0.18(0.020)	0.22
	95-00	-0.19(0.000)	0.28	-0.05(0.315)	0.01	-0.07(0.08)	0.05	-0.08(0.001)	0.10

Table 3: Likelihood ratio tests to identify which flows matter for exchange rates.

	(1)	(2)	(3)	(4)	(5)	(6)
<i>\$/DEM</i>	114.6 (0.000)	0.296 (0.862)	30.00 (0.000)	22.57 (0.000)	3.351 (0.067)	0.160 (0.899)
<i>\$/GBP</i>	46.06 (0.000)	1.34 (0.260)	25.15 (0.000)	43.53 (0.000)	14.75 (0.000)	10.04 (0.002)
<i>\$/CHF</i>	53.99 (0.000)	0.161 (0.688)	2.47 (0.105)	31.64 (0.000)	7.14 (0.008)	0.203 (0.652)
<i>\$/JPY</i>	29.61 (0.000)	0.723 (0.391)	0.006 (0.933)	13.48 (0.000)	0.026 (0.871)	0.010 (0.917)

Note: All tests are based on estimated bilateral VAR's including capital flows, exchange rates, equity return differentials and interest rate differentials. Sample is 1988:01-200:12.

(1) Test for H_0 : Net total accumulation of bonds plus net total accumulation of equities (from U.S. residents) equals zero.

(2) Test for H_0 : Net total accumulation of bonds (from U.S. residents) equals zero.

(3) Test for H_0 : Net total accumulation of equities (from U.S. residents) equals zero.

(4) Test for H_0 : Net accumulation of foreign equities (from U.S. residents) minus net accumulation of U.S. equities (from foreign residents) equals zero.

(5) Test for H_0 : Net accumulation of foreign equities (from U.S. equities) equal zero.

(6) Test for H_0 : Net accumulation of U.S. (from foreign residents) equities equal zero. Under the null hypothesis the test statistic is distributed as a χ^2 with degrees of freedom equal to the number of the restrictions. *P-values* in parenthesis.

Table 4. Percentage of the in-sample forecast error variance of nominal exchange rates explained by capital flows (CF), equity return differentials (ER), and interest rate differentials (RATE).

Currency/Variable	CF	ER	RATE
Sample 1988:1-2000:12			
\$/GBP			
1-month horizon	16	0.4	0
3-months horizon	23	0.2	0
6-months horizon	25	0.2	0
9-months horizon	26	0.1	0.2
12-months horizon	27	0.1	0.4
24-months horizon	28	0.1	2
\$/DEM			
1-month horizon	7	0.4	0
3-months horizon	14	0.2	0
6-months horizon	22	0.1	0.1
9-months horizon	27	0.1	0.3
12-months horizon	30	0.1	0.5
24-months horizon	38	0.1	2
\$/CHF			
1-month horizon	13	1	0
3-months horizon	23	1	0.1
6-months horizon	30	1	0.6
9-months horizon	33	1	2
12-months horizon	34	1	3
24-months horizon	33	1	10
\$/YEN			
1-month horizon	0.3	0	0
3-months horizon	1	0.2	0.1
6-months horizon	1	0.1	0.3
9-months horizon	2	0.1	1
12-months horizon	4	0.1	1
24-months horizon	7	0.1	3

Table 5. Percentage of the in-sample forecast error variance of nominal exchange rates explained by equity flows (CF: foreign plus U.S.), equity return differentials (ER), and interest rate differentials (RATE). The pooled data excludes Japan. Fixed effects included.

Variable	CF	ER	RATE
Pooled-Sample 1988:1-2000:12/Observations:468			
Horizon			
1-month	7	1	0
3-months	10	1	0
6-months	13	1	0.1
9-months	17	1	0.4
12-months	19	1	1
24-months	23	2	4
36-months	23	2	7

Table 6. Root mean square forecast error in percentages.

Exchange Rate	Model:	Random Walk	Equity-augmented VAR
	Horizon		
\$ / pound	1 month	1.18	0.61
	3 months	0.88	1.61
	6 months	1.81	3.47
	12 months	1.53	3.88
	18 months	1.62	4.28
\$ / mark	1 month	4.67	5.01
	3 months	3.35	3.71
	6 months	2.94	2.88
	12 months	2.64	2.85
	18 months	3.33	3.30
\$ / swiss franc	1 month	3.62	3.32
	3 months	2.24	2.03
	6 months	2.29	2.27
	12 months	3.24	2.80
	18 months	4.45	2.91
\$ / yen	1 month	4.12	4.51
	3 months	5.77	6.19
	6 months	7.79	8.27
	12 months	8.99	9.49
	18 months	11.83	12.29

Table 7. Diebold-Mariano statistics for the best forecast of exchange rates among a capital-augmented VAR (F), a standard VAR (VRW) and a univariate random walk (RW). *P-values* in parenthesis. The test indicates which forecast is the best according to the mean square error criterion and tests the null hypothesis that there exists a significant difference between two tested forecasts.

	Test:	F vs. RW	F vs. VRW	RW vs. VRW
FX	<i>k</i>			
\$/GBP	3	1.618 (0.105) : <i>RW</i>	-1.526 (0.127) : <i>F</i>	-2.394 (0.017) : <i>RW</i>
	6	2.068 (0.038) : <i>RW</i>	-2.397 (0.017) : <i>F</i>	-2.657 (0.001) : <i>RW</i>
	12	4.183 (0.000) : <i>RW</i>	-4.933 (0.000) : <i>F</i>	-5.519 (0.000) : <i>RW</i>
	18	4.759 (0.000) : <i>RW</i>	-6.39 (0.000) : <i>F</i>	-6.615 (0.000) : <i>RW</i>
	24	-4.163 (0.000) : <i>F</i>	-4.584 (0.000) : <i>F</i>	-1.010 (0.312) : <i>RW</i>
\$/DEM	3	-7.547 (0.000) : <i>F</i>	-0.203 (0.839) : <i>F</i>	0.357 (0.720) : <i>RW</i>
	6	0.913 (0.360) : <i>RW</i>	-1.336 (0.182) : <i>F</i>	-1.304 (0.192) : <i>RW</i>
	12	2.085 (0.037) : <i>RW</i>	2.932 (0.003) : <i>F</i>	-3.059 (0.002) : <i>RW</i>
	16	3.037 (0.002) : <i>RW</i>	-4.210 (0.000) : <i>F</i>	-4.124 (0.000) : <i>RW</i>
	24	-0.133 (0.895) : <i>F</i>	-5.536 (0.000) : <i>F</i>	-2.856 (0.004) : <i>RW</i>
\$/CHF	3	-0.4677 (0.640) : <i>F</i>	-2.796 (0.006) : <i>F</i>	-1.064 (0.287) : <i>RW</i>
	6	1.509 (0.131) : <i>RW</i>	-2.206 (0.027) : <i>F</i>	-1.844 (0.065) : <i>RW</i>
	12	1.456 (0.145) : <i>RW</i>	-4.64 (0.000) : <i>F</i>	-2.963 (0.003) : <i>RW</i>
	18	2.489 (0.012) : <i>F</i>	-5.907 (0.000) : <i>F</i>	1.456 (0.145) : <i>RW</i>
	24	-1.681 (0.092) : <i>F</i>	-3.655 (0.000) : <i>F</i>	0.7865 (0.432) : <i>VRW</i>
\$/JPY	3	-0.467 (0.640) : <i>F</i>	-573 (0.000) : <i>F</i>	-577 (0.000) : <i>RW</i>
	6	1.509 (0.131) : <i>RW</i>	-178 (0.00) : <i>0F</i>	-180 (0.000) : <i>RW</i>
	12	1.456 (0.145) : <i>RW</i>	-177 (0.000) : <i>F</i>	179 (0.000) : <i>RW</i>
	18	2.489 (0.012) : <i>RW</i>	226 (0.000) : <i>F</i>	228 (0.000) : <i>RW</i>
	24	-1.681 (0.092) : <i>F</i>	-113 (0.000) : <i>F</i>	-115 (0.000) : <i>RW</i>

:

Table 8. Estimated residual cross correlations. Sample 1988:1-2000:12. The pooled data excludes Japan. Fixed effects included.

	CFF	CFUS	ER	FX	RATE
ρ_{ij}					
CFF	1				
CFUS	0.073	1			
ER	0.137	0.063	1		
FX	-0.005	-0.254	-0.031	1	
RATE	0.062	0.127	-0.045	-0.066	1

Note: CFF denotes net accumulation of foreign equities, CFUS denotes net accumulation of U.S. equities, ER denotes equity return differentials (foreign minus U.S.), FX denotes foreign exchange rate, and RATE denotes interest rate differentials (foreign minus U.S.).

Table 9. Percentage of the forecast error variance of nominal exchange rates explained by net equity flows in U.S. assets (NANORMUS), net equity flows in foreign assets (NANORMF), equity return differentials (ER) and interest rate differentials (RATE). The pooled data excludes Japan. Fixed effects included.

Variable	NANORMF	NANORMUS	ER	RATE
Pooled-Sample 1988:1-1994:12/Observations:282				
Horizon				
1 month	0.2	6	0.2	0
3 months	1	7	0.2	0.2
9 months	4	13	0.3	0.1
12 months	5	14	0.3	0.2
24 months	6	15	0.3	0.4
36 months	6	15	0.3	0.5
Pooled-Sample 1995:1-2000:12/Observations:186				
Horizon				
1 month	0	9	0	0
3 months	0.1	15	2	0.2
9 months	1	20	1	4
12 months	3	21	1	6
24 months	6	20	1	14
36 months	6	20	1	16