Financial Amplification of Foreign Exchange Risk Premia*

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Abstract

Theories of systemic risk suggest that financial intermediaries' balance sheet constraints amplify fundamental shocks. We provide supportive evidence for such theories by decomposing the U.S. dollar risk premium into components associated with macroeconomic fundamentals, and a component associated with financial intermediary balance sheets. Relative to the benchmark model with only macroeconomic state variables, balance sheets amplify the U.S dollar risk premium. We discuss applications to systemic risk monitoring.

Keywords: Foreign Exchange Risk Premium, Systemic Risk Monitoring, Financial Intermediaries, Asset Pricing

JEL codes: G15, G01, G17, F31

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1 Introduction

Theories of systemic risk in international capital markets suggest that shocks to macroeconomic fundamentals get endogenously amplified due to the presence of funding constraints of financial intermediaries. Such theories of amplification have been proposed by Caballero and Krishnamurthy (2001) and Korinek (2010b) in the context of international capital markets, among others. Brunnermeier and Pedersen (2009) provide a theory of systemic risk based on the "margin spiral," which leads to a spillover of distress across financial market participants. The common thread to this literature on systemic risk is that the funding liquidity of intermediaries leads to limited arbitrage, which in turn gives rise to excess movements in asset prices relative to fundamentals. Within an asset pricing context, such excess volatility will generate time variation in effective risk aversion due to changes in the tightness of intermediaries' funding constraints. Balance sheet components related to the tightness of funding constraints thus enter the equilibrium pricing kernel explicitly (e.g. Adrian and Etula, 2010). From a normative point of view, the pricing of intermediary risk constraints gives rise to an externality, as individual financial institutions do not take into account the cost of excessive risk taking for the financial sector as a whole (see Korinek 2010a).

In this paper, we estimate foreign exchange risk premia associated with macroeconomic fundamentals and with funding liquidity conditions. We start by extracting the common components of expected U.S. dollar funded carry trade returns via partial least squares regressions from a large number of potential state variables. The partial least squares produces three state variables: two are associated with macroeconomic fundamentals (an inflation state variable and a real state variable), and one is associated with balance sheet components of U.S. financial institutions. Within the context

of a dynamic asset pricing model, we then estimate the cross-sectional price of foreign exchange risk as a function of the state variables. The model allows us to empirically decompose the evolution of foreign exchange risk premia into the components associated with macroeconomic fundamentals, and the component associated with funding liquidity variables.

Our main finding is that funding liquidity conditions tend to amplify the volatility of risk premia in exchange rates. Figure 1 illustrates this via estimates of the kernel density of the FX risk premium with and without balance sheet variables. The two densities indicate that the variability of risk premia is markedly larger when balance sheet variables are included in explaining the prices of risk. In addition, the skewness of risk premia becomes slightly more negative when balance sheet variables are included in the pricing kernel. These findings are in line with the theories of balance sheet amplification mentioned earlier. In a frictionless world, we would not expect such financial intermediation variables to significantly impact foreign exchange risk premia.

Our analysis demonstrates that the excess volatility of the risk premium associated with balance sheet variables (the "balance sheet premium") is tightly linked to three episodes of sharp declines in our funding liquidity indicators. The first decline within our sample started in 1988 (shortly after the signing of the Louvre Accord) and it continued until the beginning of the gulf war and the 1990 spike in the price of crude oil, which along with the collapse of the Soviet Union led much of the world into a recession in 1991. The second dramatic compression in the risk premium associated with balance sheets occurred in the run-up to the LTCM crisis, between early 1995 and 1998. The balance sheet risk premium reversed sharply in August and October 1998, around the LTCM crisis, and the well documented unwinding of carry trades. We emphasize that the risk premium associated with macroeconomic fundamentals played

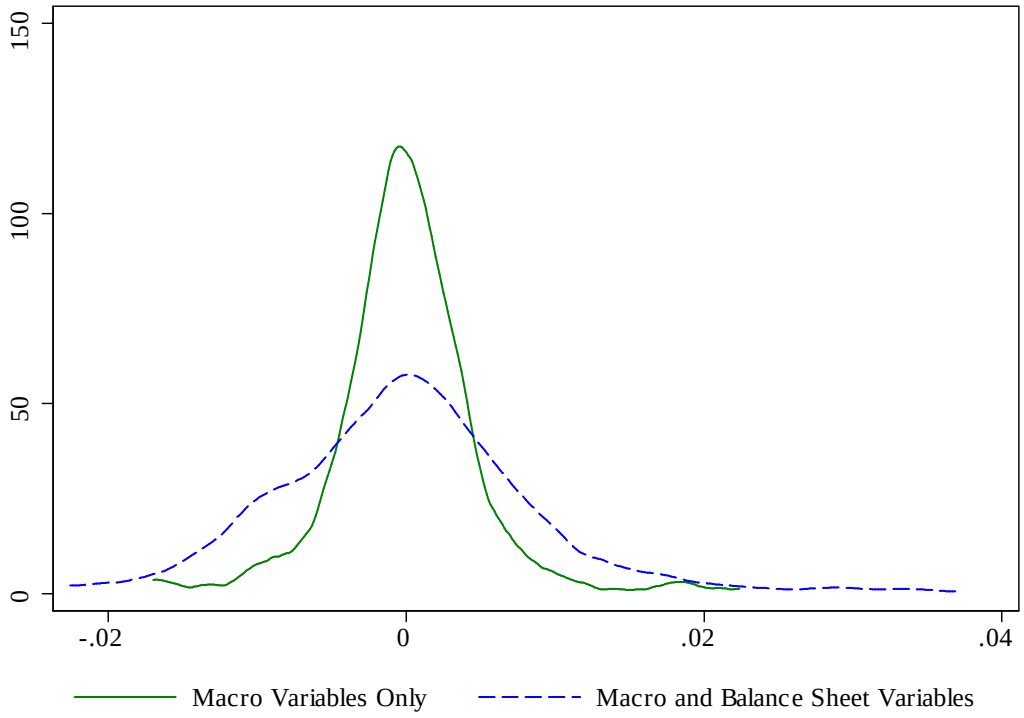

Figure 1: Risk premium kernel density estimates. We plot kernel density estimates of conditional risk premia of average carry returns for two specifications. The baseline specification uses only macroeconomic state variables (real output and inflation), while the second specification uses both macroeconomic and financial intermediary balance sheet variables.

a lesser role in these historical episodes.

We contrast the behavior of the foreign exchange risk premium in the early part of our sample with the fluctuations during the global financial crisis of 2008-09, which constitutes our third episode of sharply deteriorating funding liquidity. The recent financial crisis featured unusually strong shifts in the components of the foreign risk premium associated with both macroeconomic fundamentals and balance sheets. However, the broad themes of the previous crisis episodes were featured clearly. In particular, the balance sheet risk premium exhibited a prolonged decline between July 2002 and June 2008 while the decline in the risk premium associated with macroeconomic fundamentals was substantially less pronounced. The balance sheet risk premium then increased sharply at the onset of Lehman's bankruptcy. Starting in July 2009 and continuing into early 2010, the balance sheet premium declined rapidly as funding conditions improved. The macro risk premium, however, continued to increase until September 2009. We interpret this lagged response in the macro premium as evidence for a link between funding liquidity conditions and broader macroeconomic fundamentals. Adrian, Moench and Shin (2009) provide a thorough investigation of this channel for a broad cross section of financial assets.

The remainder of the paper is organized as follows. In section 2, we provide a brief overview of the related literature. In section 3, we explain the method of extraction of state variables via partial least squares. In section 4, we present the asset pricing model, and the empirical decomposition of the price of foreign exchange risk into components linked to macroeconomic fundamentals and funding liquidity conditions. We draw implications for financial stability monitoring in section 5.

2 Related Literature

Since Fama (1984) we know that uncovered interest rate parity (UIP) is strongly violated for floating currencies. That is, a regression of subsequent relative nominal exchange rate change on the forward premium typically yields a negative parameter estimate. The most dominant explanation for this phenomenon put forward in the literature is the presence of time-varying risk premia. However, as Engel (1996) notes, many of the existing structural and reduced form models of the foreign exchange rate risk premium are not able to generate estimates of the risk premium which are sufficiently variable to explain the observed deviations from the UIP. In this paper, we use an asset pricing framework to extract a U.S. dollar risk premium from observed UIP deviations. Early studies that employed such an approach, such as Mark (1985), essentially used a consumption Euler equation. More recent studies have a used a more flexible approach in which a data generating process for the pricing kernel is assumed and estimate. Often this results in proxies for the exchange rate risk premium with realistic dynamics, such as in Groen and Balakrishnan (2006) who use a global conditional factor model, as well as Wolff (1987), Nijman *et al.* (1993), and Bams et al. (2004) who employ more agnostic time series models based on unobserved component techniques. However, none of these risk premia proxies are able to fully explain away UIP deviations and if they do, it is based on an implausibly high degree of risk aversion.

Mahieu and Schotman (1994) and Lustig *et al.* (2010) report substantial success in modeling the pattern of excess currency returns within panels of dollar-based exchange rates by assuming that the UIP deviations are driven by a small number of common components that can be interpreted as risk factors. Our paper follows this factor model approach but from a different angle: instead of trying to explain the cross-section of

foreign exchange returns by a number of risk factors, we focus on the time-varying determinants of the risk premium on a U.S. dollar funded portfolio of foreign currencies. Specifically, we allow the risk premium to vary over time with state variables linked to global real activity, inflation and U.S. balance sheet component.

3 Data and Extraction of State Variables

We use monthly data on exchange rates, macroeconomic fundamentals and aggregate balance sheet components of U.S. financial institutions. Our sample period is from January 1988 to December 2010, the beginning of which was dictated by the availability of balance sheet data.

3.1 Measuring the Foreign Exchange Risk Premium

Suppose that the foreign portfolio is invested in riskless bonds with holding period rate of return $r^i_{f,t}$, and that U.S. dollar funding is riskless at rate $r^{US}_{f,t}$. Thus, the only risk in this investment strategy stems from the movement of the spot exchange rate, ε^i_t, defined as the number of U.S. dollars that can be bought with one unit of foreign currency i.[1] The *excess* return to this strategy is given by:

$$er^i_{t+1} \equiv \left(1 + r^i_{f,t}\right) \frac{\varepsilon^i_{t+1}}{\varepsilon^i_t} - \left(1 + r^{US}_{f,t}\right). \tag{1}$$

We use monthly data on 1-month spot and forward U.S. dollar-based exchange rates for up to 35 currencies from January 1987 to March 2010. Note, however, that at the start of the sample we have have no more than 13 currencies available, a number that

[1] That is, an increase in ε^i_t corresponds to an appreciation of the foreign currency relative to the U.S. dollar.

increases to 35 in the second half of the 1990s, and then decreases again to 24 after the introduction of the euro. Therefore, at a maximum, we have data on currencies relative to the U.S. dollar for Australia, Austria, Belgium, Canada, Hong Kong, Czech Republic, Denmark, Euro area, Finland, France, Germany, Greece, Hungary, India, Indonesia, Ireland, Italy, Japan, Kuwait, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Saudi Arabia, Singapore, South Africa, South Korea, Spain, Sweden, Switzerland, Taiwan, Thailand, United Kingdom. The currency data are extracted from Datastream and we take account of transaction costs through bid-ask spreads.[2]

As Engel (1996) shows, future currency excess returns generally remain predictable based on current forward premia and we thus follow Lustig *et al.* (2010) and form six currency portfolios on the basis of the forward premium at the end of each month. More specifically, for all available currencies in a given month we sort the currencies in ascending order based on the current value of the corresponding forward premium *vis-à-vis* the U.S. dollar. We then allocate these sorted currencies to 6 portfolios and compute the average excess return (1) for each portfolio using the forward premium as a proxy for the interest rate differential.[3] Although Lustig et al. (2010) are mainly concerned with carry trade strategies, their approach is also useful in our context as (i) it provides a way to deal with the unbalanced panel nature of our currency data and (ii) it makes it more appropriate to assume constant risk factor loadings when constructing estimates of kernel-based risk premia.

[2] We are grateful to Adrian Verdelhan who made these data available through his homepage.

[3] That is, we assume that covered interest rate parity holds, i.e.,

$$\frac{\left(1+r_{f,t}^{i}\right)}{\left(1+r_{f,t}^{US}\right)}=\frac{(1+\varepsilon_{t}^{i})}{(1+F_{t}^{i})}$$

where F_t^i is 1-month ahead forward exchange rate for currency i relative to the U.S. dollar.

3.2 Macroeconomic Fundamentals

In order to proxy for U.S. and global economic activity, we construct a panel of monthly real activity data and a panel of monthly inflation data across a range of developed and developing countries. These data are extracted from the Haver Analytics database and run from January 1988 to March 2010.

The real activity panel consists of 44 real activity series. These include industrial production data for the United Kingdom, Denmark, France, Germany (both total and excluding construction), Spain, Austria, Belgium, Italy, Luxembourg, Norway, Ireland, Portugal, Taiwan, India, Korea, Malaysia, United States, Japan and capacity utilization rate data for the manufacturing sectors in Japan and the United States. This panel also contains consumer and business confidence indicators for the euro area, France, Italy, Netherlands, the European Union, and the United States; and business confidence indicators for the United Kingdom, Austria, Belgium, Denmark, Luxembourg, Finland, Greece, and Portugal. For Spain, the data only includes a consumer confidence indicator. We use annual growth rates of industrial production indices in order to make these series stationary. The confidence indicators are already stationary and therefore we can use the levels of these indicators in our analysis. Japanese capacity utilization rates are not stationary and thus we use annual growth rates, but the U.S. capacity utilization level is stationary.

The inflation panel consists of annual consumer price index (CPI) inflation data for 26 economies, i.e., the United States, the United Kingdom, Belgium, Denmark, France, Germany, Italy, Norway, Sweden, Switzerland, Canada, Japan, Finland, Greece, Ireland, Portugal, Spain, Taiwan, Hong Kong, Korea, Malaysia, Pakistan, Philippines, Singapore, Thailand, China. As is well known from the empirical macroeconomic literature, annual inflation rates often undergo breaks in their mean, mainly due to

monetary policy regime shifts; see, e.g., Sensier and Van Dijk (2004) and Groen and Mumtaz (2008). Therefore, we need to transform the annual inflation data such that they are guaranteed to be stationary. We do this by taking the 12-month difference in annual (year-on-year) CPI inflation rates, as this makes the dynamic properties of the series in the inflation panel comparable to those in the real activity panel as well as those in the balance sheet panel (described in the next section).

3.3 Aggregate Balance Sheet Components

We use four aggregate balance sheet series to capture time-variation in U.S. dollar funding liquidity. These data series are plotted in Figure 2. All data are obtained from Haver Analytics.

Our first series is the U.S. dollar financial commercial paper outstanding cleared at the Depository Trust and Clearing Corporation (DTCC). These data include the dollar-denominated financial commercial paper of U.S. financial institutions and foreign financial institutions with U.S. affiliates. We take year-over-year growth rates of the data to obtain a stationary series. The plot of the standardized factor in Figure 2 shows that commercial outstanding declined most in 1994, 2002 and 2009 with annualized contractions of -1, -2, and -3 standard deviations, respectively.

Second, we use data on bond issues of U.S financial corporations and non-financial corporations. We take the logarithm of the ratio of financial bonds issued relative to non-financial bonds issued each month. The series exhibits its sample maximum, a 3 standard deviation event, in 2005 and its minimum, a -4.5 standard deviation event, in the fall of 2008 following the Lehman collapse.

The third and fourth series are the free credit balances and the debit balances at U.S. broker-dealer margin accounts. We again take year-over-year growth rates of

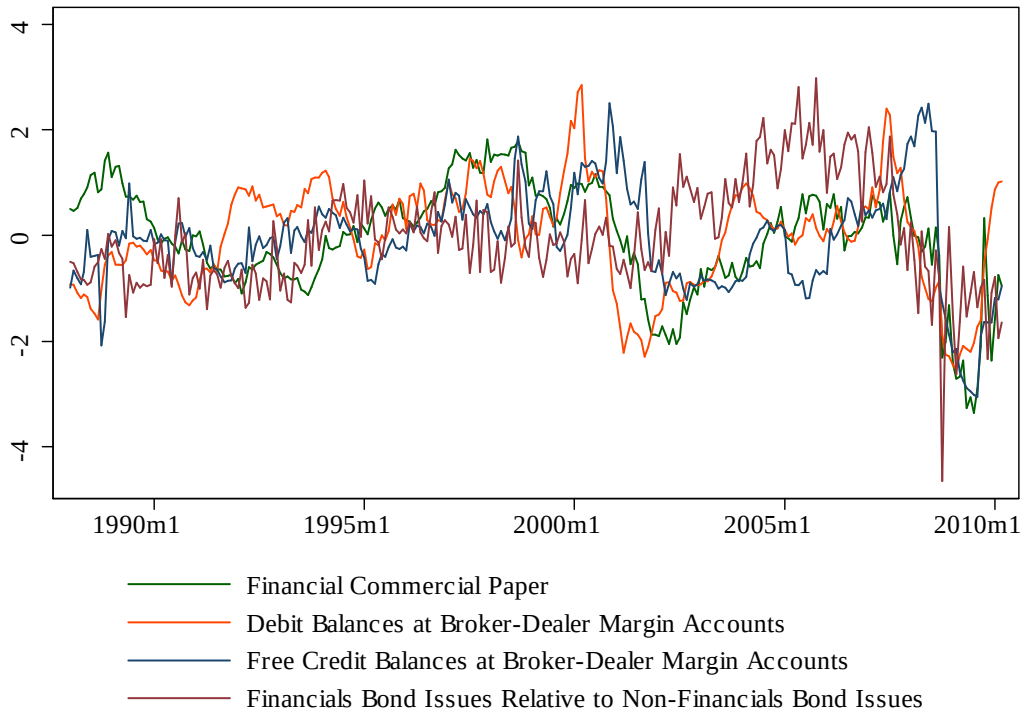

Figure 2: Balance sheet factors. We plot the standardized annual growth rates of U.S. financial commercial paper, free credit balances and debit balances at U.S. broker-dealer margin accounts, and the standardized bond issues of U.S. financial corporations relative to the bond issues of non-financial corporations.

the data to obtain stationary series. The sample maximum of free credit balances, a 3 standard deviation event, coincides with the October 1987 stock market crash. However, it is rivaled by the maxima that follow the bursting of the dot-com bubble in October 2000, and the market decline of June 2008. The credit balances bottom in the summer of 2009, following the steep decline and the April bottom of the stock market. The local extrema of debit balances tend to foreshadow the peaks and troughs of the free credit balances by a few months, indicative of possible market timing by investors.

3.4 State Variable Extraction via Partial Least Squares

We model currency risk premia in a data-rich setting, as a multitude of domestic and foreign factors can potentially affect dollar-based currencies and the risk premia embedded in them. In order to allow for this flexibility in a parsimonious way, we assume that dollar-based risk premia are driven by a limited number of common components, which are themselves unobservable but can be extracted from our data on real activity, inflation and balance sheet components.

Stock and Watson (2002) propose to extract a limited number of principal components from such a large panel data set to proxy these common factors. The authors, along with Bai (2003), show that under certain assumptions principal components can provide consistent estimates of unobserved common factors in large data sets. The drawback of the use of principal components is that it does not always guarantee that the information extracted from a large number of predictors is particularly useful in the context of a modeling exercise. Boivin and Ng (2006) make it clear that if the explanatory power for a certain target variable comes from a certain factor, this factor can be dominated by other factors in a large data set, as the principal components solely provide the best fit for the large data set and not for the target variable of inter-

est. We therefore consider an alternative to principal components in which only factors relevant for modeling the target variables, in our case a panel of dollar-based currency excess returns, are extracted from the set of predictor variables.

One such possible alternative approach is the partial least squares (PLS) regression. As Groen and Kapetanios (2008) show, the PLS regression outperforms the usual principal components-based approach both in simulations and empirically, and especially when the underlying factor structure is weak. One condition under which principal components provide consistent estimates of the unobserved factor structure in large data sets is when these factors strongly dominate the dynamics of the data series relative to the non-factor components of the data (see, e.g., Bai, 2003). However, in an international context common factors might not dominate the non-structural dynamics as strongly as assumed in the underlying asymptotic theory because real activity and inflation cycles might not be synchronized between the U.S. and other economies. Under such circumstances, the accuracy of the factors estimated through principal components will be compromised. The PLS regression, on the other hand, will always result in consistent estimates of the unobserved common factors relevant for dollar-based currency returns, even when the factor structure in the combined data on real activity, inflation and balance sheet components is relatively weak — see Groen and Kapetanios (2008, Theorem 2).

Following Stock and Watson (2002) we can take our $T \times N$ matrix of N indicator variables $Z = (z_1' \cdots z_T')'$ (consisting of real activity, inflation and balance sheet data) and standardize this such that the variables are in the zero mean and unit variance space, resulting in the $T \times N$ matrix $\tilde{Z} = (\tilde{z}_1' \cdots \tilde{z}_T')'$. Like Groen and Kapetanios (2010), we implement the PLS regression in a multivariate context by constructing the factors as linear, orthogonal combinations of the standardized predictor variables

assembled in matrix $\tilde{Z}$ such that the linear combinations maximize the covariance between the demeaned 1-month ahead dollar-based currency returns (1), and each of the common components constructed from the predictor variables.[4] Specifically, we assume one common component in the dollar-based currency returns, and therefore the PLS is implemented by constructing the dominant eigenvector v of what is essentially the squared covariance between the vector of demeaned dollar-based currency returns and the panel of combined predictor variables:

$$\tilde{Z}'\bar{er}\bar{er}'\tilde{Z}, \tag{2}$$

where $\bar{er} = (\bar{er}^{1'} \cdots \bar{er}^{6'})'$ with $\bar{er}^i = (\bar{er}_1^i \cdots \bar{er}_T^i)'$ where $\bar{er}_t^i$ is the demeaned excess return on currency i relative to the U.S. dollar. The common factor from $\tilde{Z}$ relevant for the dollar-based excess returns (1) is:

$$X_t = (\bar{v}\tilde{z}_t)', \tag{3}$$

where $\bar{v}$ is a transformation of the $N \times 1$ dominant eigenvector v of (2) such that $||v|| = 1$. This common factor X_t has mean of zero and variance of one.

This common factor X_t is a convolution of developments in global real activity, global inflation and U.S. balance sheet component data. In order to be able to interpret the movements in X_t and its effect on dollar-based currency returns, we decompose X_t into subfactors relevant for the common component in dollar-based currency returns: a global real activity subfactor X_t^{real}, a global inflation subfactor X_t^{infl} and an aggregate U.S. balance sheet subfactor X_t^{BS}. To do that, we impose a hierarchical factor structure,

[4] Demeaning of the dollar-based excess returns is necessary in order to avoid scale effects that can bias the factor estimates.

which essentially means that X_t is a linear combination of the aforementioned real activity, inflation and balance sheet subfactors. Each of the subfactors is extracted as the common component from the corresponding (real activity, inflation or balance sheet) subpanel so as to have the highest covariance with the dollar-based currency returns. We implement this through an iterative procedure where we first use an initial value of the common component in the excess currency returns and apply the PLS on each subpanel relative to this common component to get initial estimates of X_t^{real}, X_t^{infl} and X_t^{BS}. We then apply the PLS again relative to the panel of excess returns to get an initial X_t that implies a new estimate of the common component in these excess returns. These steps are iterated until convergence. Groen and Kapetanios (2010) provide more detail about this procedure and show that it yields a simultaneous estimate of X_t^{real}, X_t^{infl} and X_t^{BS}. The authors prove that a linear combination of X_t^{real}, X_t^{infl} and X_t^{BS} is asymptotically equivalent to X_t.

3.5 Estimated State Variables

Figure 3 plots the evolution in the three PLS-based subfactors (henceforth referred to as state variables) as well as the cumulative average excess carry portfolio return. The real activity state variable exhibits a plausible pattern: when it increases, meaning that global activity is expanding, the dollar funded carry returns decrease as U.S. investors become more inclined to pursue overseas investments. The converse holds for decreases in the real activity state variable. For example, between 2000 and 2001 the real activity factor turned negative, coinciding with the recession in the U.S. As an immediate result, the dollar appreciated and realized carry returns decreased, reflecting the higher risk premia dollar based investors demanded on their investments in foreign currencies going forward.

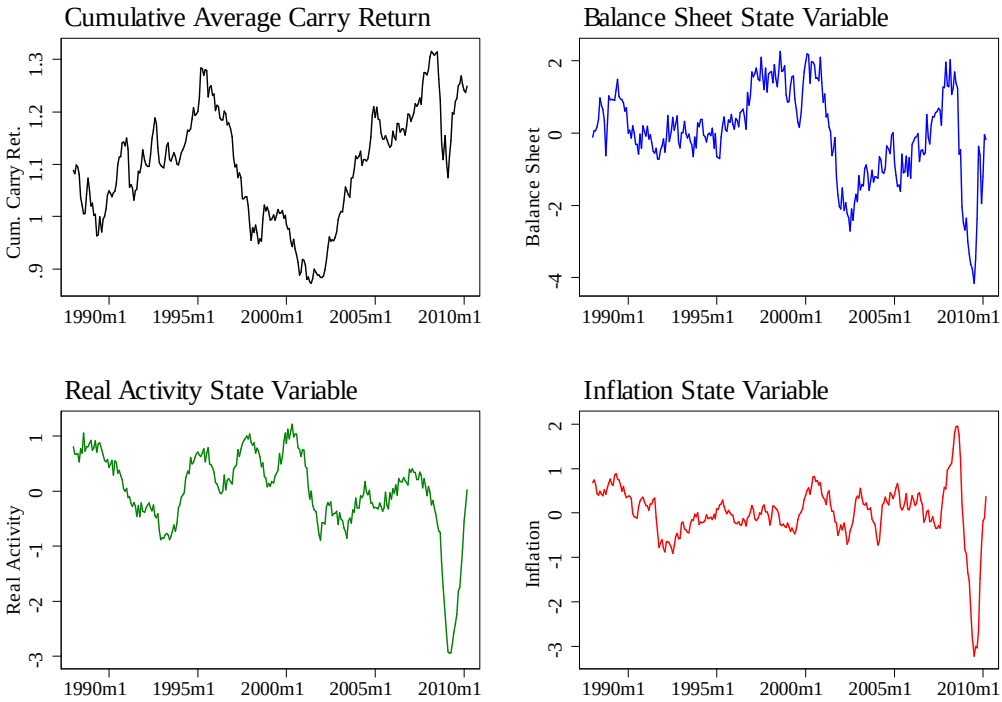

Figure 3: The four panels contain the cumulative excess return to the average carry portfolio, the balance sheet state variable, and the two macroeconomic state variables (real activity and inflation).

For the inflation state variable, we observe sharp increases before the 2000-01 recession and particularly before the 2008-09 crisis, which signal heightened global inflation pressures. These peaks are followed by sharp disinflationary movements at the onset of the respective recessions. Finally, for the balance sheet state variable, we observe a pattern that is similar to that observed in the real activity state variable: more ample U.S. liquidity increases U.S. investors' appetite for foreign investments. Note, however, that the amplitude of the swings in the aggregate balance sheet factor are larger than those observed for the real activity factor.

4 Estimating the Foreign Exchange Risk Premium

4.1 Asset Pricing Approach

Following the construction of carry-portfolios in section 3 we suppose that the foreign portfolio is invested in riskless bonds with holding period rate of return $r^i_{f,t}$, and that U.S. dollar funding is riskless at rate $r^{US}_{f,t}$ (see equation (1)). Under the risk neutral measure, the payoff to this strategy is zero. Denoting the pricing kernel by M_{t+1}/M_t, the expected payoff is:

$$E_t\left[\frac{M_{t+1}}{M_t}\left(\left(1+r^i_{f,t}\right)\frac{\varepsilon^i_{t+1}}{\varepsilon^i_t}-\left(1+r^{US}_{f,t}\right)\right)\right]=0 \tag{4}$$

Using the definition of covariance, we find the uncovered interest rate parity:

$$\frac{\varepsilon^i_{t+1}}{\varepsilon^i_t}=\frac{1+r^{US}_{f,t}}{1+r^i_{f,t}}+\mu_t+\xi^i_{t+1} \tag{5}$$

where u_{t+1}^i denotes exchange rate risk with $E_t\left[u_{t+1}^i\right]=0$ and

$$\mu_t = -Cov_t\left[\frac{M_{t+1}/M_t}{E_t\left[M_{t+1}/M_t\right]}, \frac{\varepsilon_{t+1}^i}{\varepsilon_t^i}\right] \tag{6}$$

is the foreign exchange risk premium. It follows that exchange rate appreciation is due to three components:

$$\underbrace{\frac{\varepsilon_{t+1}^i}{\varepsilon_t^i}}_{\substack{\text{Exchange Rate}\\ \text{Appreciation}}} = \underbrace{\frac{1+r_{f,t}^{US}}{1+r_{f,t}^i}}_{\substack{\text{Interest Rate}\\ \text{Carry}}} + \underbrace{\mu_t}_{\substack{\text{FX Risk}\\ \text{Premium}}} + \underbrace{\xi_{t+1}^i}_{\substack{\text{FX}\\ \text{Risk}}}. \tag{7}$$

4.2 Empirical Implementation

In order to estimate (7) in the data, we assume that the pricing kernel M_{t+1}/M_t is exponentially affine in the state variables X_t:

$$\frac{M_{t+1}}{M_t} = \exp\left(-r_t^f - \frac{1}{2}\lambda_t'\lambda_t - \lambda_t' v_{t+1}\right) \tag{8}$$

$$\Sigma_t\lambda_t = \lambda_0 + \lambda_1 X_t \tag{9}$$

where

$$X_{t+1} = \mu + \phi X_t + v_{t+1}. \tag{10}$$

We further assume that the innovations to state variables are normally distributed with $v_{t+1} \sim N\left(0, \Sigma_t\right)$.

With this notation, we use Stein's lemma to express the FX risk premium (6) as:

$$\mu_t = -Cov_t\left[\frac{M_{t+1}/M_t}{E_t\left[M_{t+1}/M_t\right]}, \frac{\varepsilon_{t+1}^i}{\varepsilon_t^i}\right] = Cov_t\left[v_{t+1}, \frac{\varepsilon_{t+1}^i}{\varepsilon_t^i}\right]\Sigma_t^{-1}\left(\lambda_0 + \lambda_1 X_t\right). \tag{11}$$

It follows that the pricing equation reduces to:

$$\frac{\varepsilon_{t+1}^{i}}{\varepsilon_{t}^{i}} = \frac{1+r_{f,t}^{US}}{1+r_{f,t}^{i}} + \beta_{t}^{i\prime}\left(\lambda_{0}+\lambda_{1}X_{t}\right) + \xi_{t+1}^{i}, \tag{12}$$

where $\beta_{t}^{i\prime} = Cov_{t}\left[v_{t+1}, \frac{1/\varepsilon_{t+1}^{i}}{1/\varepsilon_{t}^{i}}\right]\Sigma_{t}^{-1}$. The exchange rate risk ξ_{t+1}^{i} can further be decomposed into a systematic component $\beta_{t}^{i\prime}v_{t+1}$, and an idiosyncratic component e_{t+1}^{i}, such that:

$$\underbrace{\frac{\varepsilon_{t+1}^{i}}{\varepsilon_{t}^{i}}}_{\substack{\text{FX}\\ \text{Appreciation}}} - \underbrace{\frac{1+r_{f,t}^{US}}{1+r_{f,t}^{i}}}_{\text{Carry}} = \underbrace{\beta_{t}^{i\prime}\left(\lambda_{0}+\lambda_{1}X_{t}\right)}_{\substack{\text{FX Risk}\\ \text{Premia}}} + \underbrace{\beta_{t}^{i\prime}v_{t+1}}_{\substack{\text{Systematic}\\ \text{FX Risk}}} + \underbrace{e_{t+1}^{i}}_{\substack{\text{Idiosyncratic}\\ \text{FX Risk}}}. \tag{13}$$

Equipped with the cross-sectional no-arbitrage model of (13), we next investigate the extent to which the forecasting variables identified in section 3 determine the FX risk premium. We define systematic FX risk as the unforecastable part of the return to an equal-weighted carry portfolio. More formally, we let the vector of forecasting varibles to be given by the three variables from our PLS factor extraction:

$$X_{t} = \begin{pmatrix} X_{t}^{\text{real}} \\ X_{t}^{\text{infl}} \\ X_{t}^{\text{BS}} \end{pmatrix}, \tag{14}$$

and consider a single risk factor:

$$v_{t+1} = \tilde{r}_{t+1}^{EW},$$

where $\tilde{r}_{t+1}^{EW} = r_{t+1}^{EW} - E_t\left[\tilde{r}_{t+1}^{EW}|1, r_t^{EW}, X_t\right]$ is the unforecastable part of the equal-weighted carry return. We estimate cross-sectional model in (13) by way of three-step OLS regressions applied to the cross-section of 6 carry portfolios (see Adrian and Moench (2008) for details of the estimation methodology). For simplicity, we assume that betas are constant for each portfolio i.

4.3 Empirical Results

We begin by estimating the model (13) for the specification where the price of FX risk is allowed to vary with all three state variables specified in (14). The resulting risk premium is plotted in Figure 4 along with the realized returns on the single risk factor (equal-weighted carry return r_{t+1}^{EW}, with $\beta^{EW} = 1$). The figure shows that our cross-sectional no-arbitrage model is picking up the low frequency component of exchange rate returns. The risk premium rises sharply in late 1989-90, in 2000-01, and again in late 2008, correctly forecasting the succeeding U.S. dollar depreciations.

Intertemporal Decomposition of the Foreign Exchange Risk Premium. In order to understand the sources of variation in the compensation for FX risk, we decompose the risk premium of Figure 4 into two components. The first component captures the time variation in the risk premium due to the macroeconomic state variables X_t^{real} and X_t^{infl}. We refer to the resulting series as the risk premium associated with macro fundamentals, or simply the "macro risk premium." The second component captures the time variation in the risk premium due to the balance sheet state variable X_t^{BS}, which we refer to as the "balance sheet risk premium." The sum of the macro an balance sheet components of the risk premium captures the time variation in the total FX risk premium.

Figure 5 plots the macro risk premium along with the total FX risk premium.

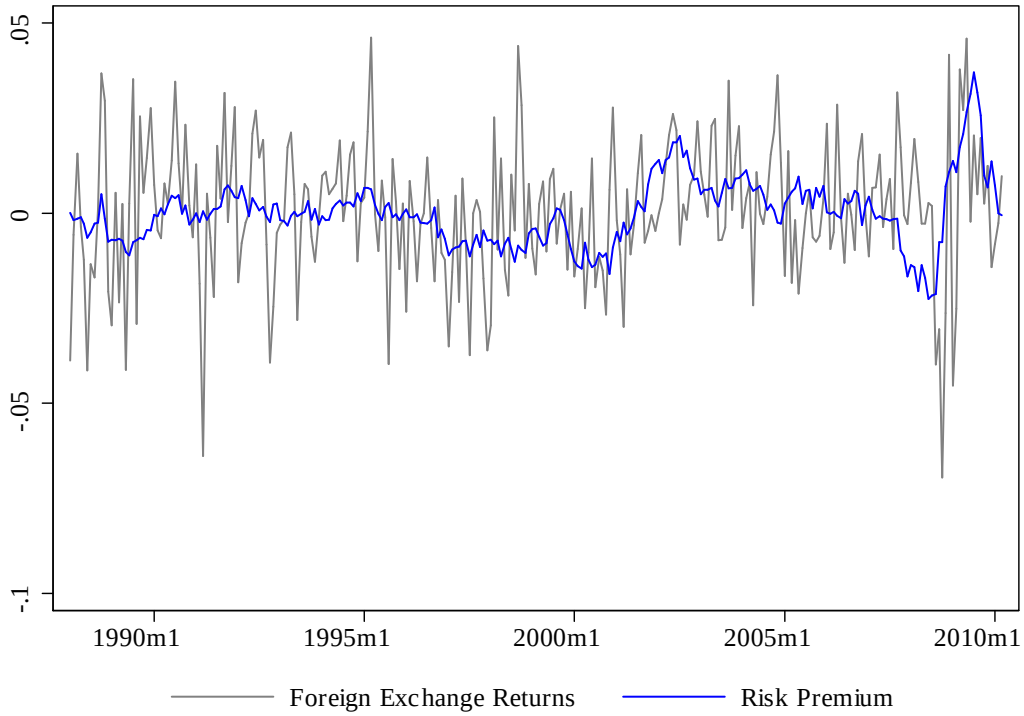

Figure 4: The risk-premium of an equal-weighted U.S. dollar funded carry portfolio and the realized returns on the portfolio.

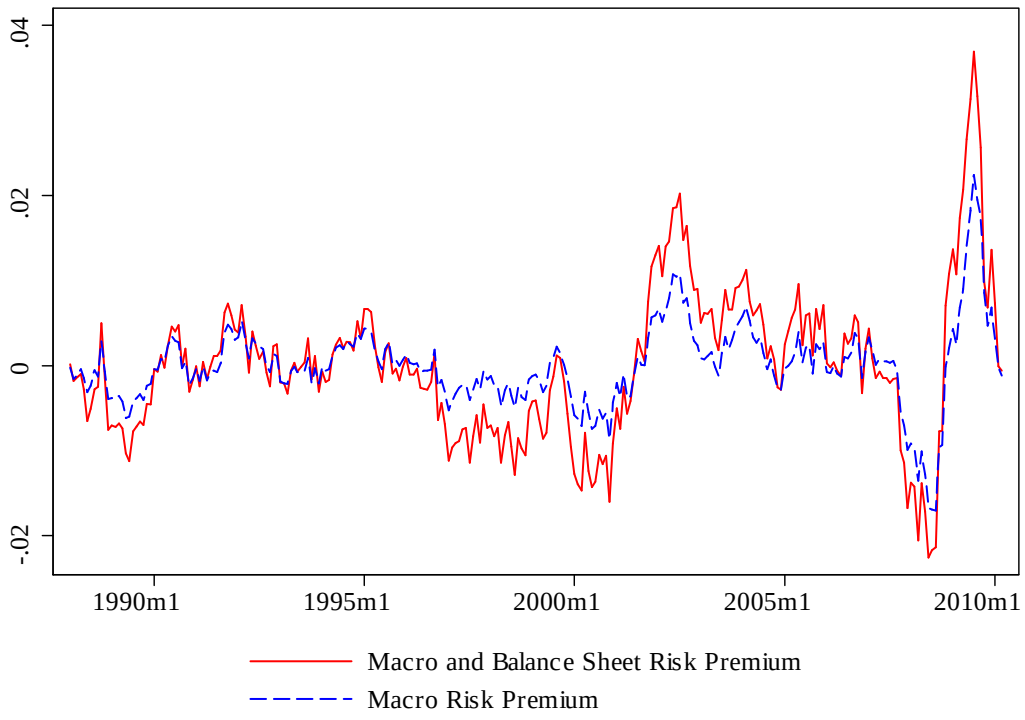

Figure 5: Risk Premia of the Macro Variables and the Balance Sheet Variables

The wedge between the two series is due to the balance sheet component of the risk premium. Overall, we notice that the total FX risk premium is substantially more volatile than the component attributable to macro variables alone, speaking to the amplification mechanism that was depicted in the kernel density plot of Figure 1. The wedge between the two series gets particularly wide during times that preceed crises and during early parts of crises episodes. We will now walk through these episodes.

At the start of our sample we observe a substantial decrease in the balance sheet premium in 1989, corresponding to the period before the 1990-91 recession. The wedge between the macro component of the risk premium and the total risk premium may be considered as a warning of the amplification mechnism at work; in particular, the low level of the total risk premium is not fully justifiable by macroeconomic fundamentals but is in part driven by ample funding liquidity in the economy. Indeed, both components of the risk premium exhibit sharp reversals in the 1990-91 global turmoil. Prior to the Mexican peso crisis of 1994-95 both macro and balance sheet premia again decline but we observe little balance sheet amplification over this period.

Beginning in late 1996, the risk premium associated with balance sheets again dives sharply, driving a large wedge between the total risk premium and the macro risk premium, which persists until the LTCM crisis of 1998. This period is often characterized as that of "irrational exuberance," borrowing the words of the Federal Reserve Chairman Alan Greenspan. Indeed, as Figure 5 shows, hardly any of the decline in the total risk premium can be substantiated by macroeconomic fundamentals.

Following the LTCM collapse, both macro and balance sheet risk premia increase sharply such that in 1999, all of the FX risk premium is attributable to macroeconomic fundamentals. However, in late 1999, the component associated with balance sheets decreases again rapidly, fuelling the race to the peak of the dot-com bubble in mid-

2000. Note that at this point, the total FX risk premium is as low as -1.5% per month while the macro premium is only -0.5%. The risk premium reverses sharply as the corporate scandals of 2001-02 hit America. The reversal receives strong amplification from the balance sheet component of the risk premium, which increases to its highest level to date in 2002.

Finally, the figure illustrates how the financial crisis of 2007-09 was preceeded by a longlasting decline in the balance sheet risk premium. The long downward trend in the balance sheet risk premium begins in late 2002 and drives a large negative wedge between the total risk premium and the macro risk premium by middle of 2008. This decline in the balance sheet risk premium is followed by a sharp reversal in the fall of 2008. The macro risk premium follows the dynamics of the balance sheet premium, albeit with a 1-2 month lag. In this sense, our analysis of the FX risk premium thereby lends support to the view that the recent financial turmoil was driven largely by balance sheet components. However, we emphasize that macroeconomic fundamentals nevertheless accounted for most of the level of the total risk premium. Thus, the balance sheets again served to amplify the fluctuations of macroeconomic fundamentals.

Another way to understand the mechanism of balance sheet amplification is via a scatter akin to a Q-Q plot. We do this in Figure 6, which plots the total FX risk premium against the component associated with macroeconomic fundamentals. The figure shows that both positive and negative macro risk premia get amplified by balance sheets, resulting in a curved scatter around the 45-degree line.

To sum up, our analysis of the FX risk premium reflects an overarching theme of balance sheet amplification: Most of the crisis episodes within our sample feature substantial declines in the component of the risk premium associated with balance sheets during the run-up to a crisis. These declines are followed by sharp increases

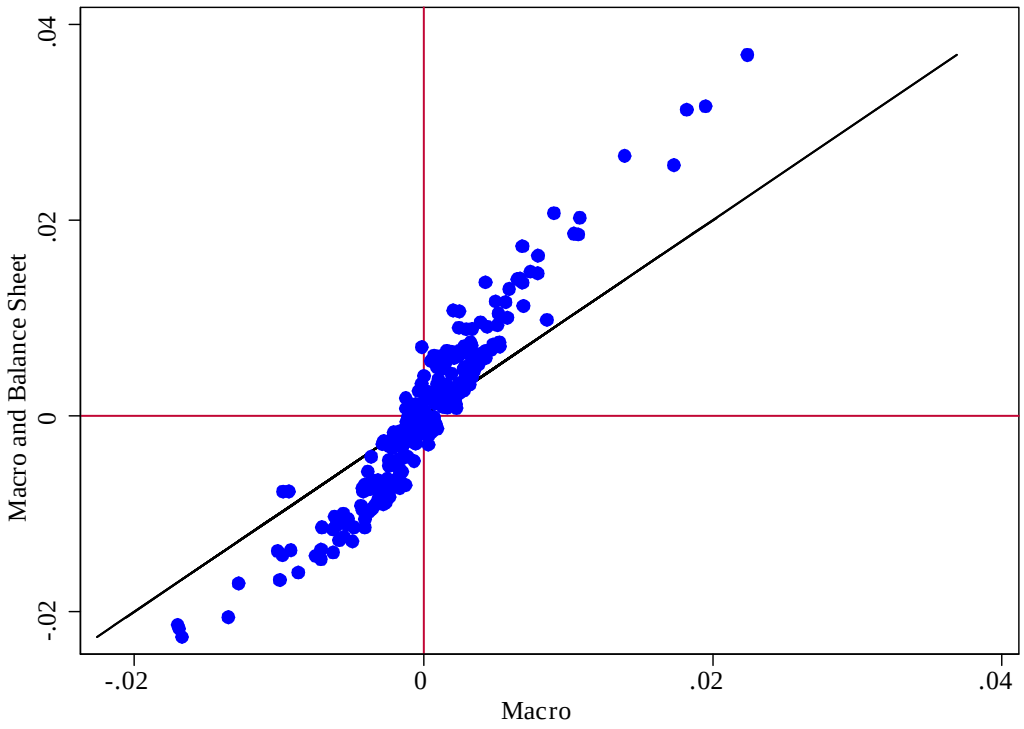

Figure 6: The figure plots the FX risk premium estimated from macro and balance sheet variables (y-axis) against the FX risk premium associated with only macro variables (x-axis). The scatter illustrates the amplification of the risk premium when balance sheet variables are included in the estimation of the pricing kernel.

in both macro and balance sheet components of the risk premium at the onset of the crisis. Thus, balance sheets seem to amplify both positive and negative shocks to the macro risk premium. During calmer periods, the relative contribution of balance sheets to the FX risk premium is smaller. Our results therefore suggest that the mechanism of balance sheet amplification is particularly important during crises.

5 Implications for Financial Stability Monitoring

Systemic risk regulators monitor the evolution of risk in the financial system, develop early warning systems to detect the buildup of potential vulnerabilities, and formulate appropriate policies. This paper presents a methodology to measure the risk premium associated with the dynamics of intermediary balance sheets, which in turn is an indicator for the buildup of systemic risk. In line with theories of systemic risk, Figures 1, 5, and 6 show that the financial intermediary balance sheet variables amplify the volatility of the U.S. dollar risk premium relative to the macro fundamentals.

FX volatility is an indicator of risk. Episodes of systemic financial instability are usually accompanied with high FX volatility. In order to gain insight into how the balance sheet risk premium relates to FX volatility, Figure 7 plots the standardized balance sheet risk premium together with standardized log FX volatility. The standardization is done so that each of the variables has mean zero and standard deviation of one.

Figure 7 shows that the relationship between FX volatility and the balance sheet risk premium is a complex one. There are some episodes in which the volatility measure and the balance sheet risk premium correlate strongly. In particular, the deleveraging in the fall of 2008 was associated with a sharp increase in both FX volatility and the

balance sheet risk premium. Log volatility shot up nearly four standard deviations, and the balance sheet risk premium increased by over three standard deviations. Fall 2008 can thus be interpreted as a systemic risk event where increased FX volatility was associated with an increase in the balance sheet component of the risk premium.

However, many periods of sharp increases in FX volatility do not correspond to changes in the balance sheet risk premium, and likewise, many periods of sharp increases in the balance sheet risk premium do not correspond to any changes in FX volatility. For example, in November 1997, FX volatility peaked corresponding to the Asian currency crisis. Not surprisingly, this spike in volatility was not associated with any particular change in the balance sheet risk premium, as captured by our U.S. dollar balance sheet aggregates. Thus, from the perspective of U.S. financial stability, the Asian currency crisis did not represent a systemic risk event. The converse was true around the 2001 recession. The balance sheet risk premium was at a historical low in spring 2000, just prior to the bursting of the dot-com bubble. Between mid-2000 and the end of 2001, the balance sheet risk premium increased sharply, but this increase was not associated with a change in FX volatility. Figure 4, on the other hand, shows that dollar funded carry returns changed dramatically over the 2000–01 period, which is the development picked up by the balance sheet state variable.

The method developed in this paper can be used in real time policy analysis. While the application here is to one particular assets class—foreign currencies—the method is applicable more generally. Additional research should consider the linkage between the compression of the balance sheet risk premium and the buildup of systemic risk more explicitly. That is, the extent to which sharp declines in the balance sheet risk premium cause an increase in the level of systemic risk.

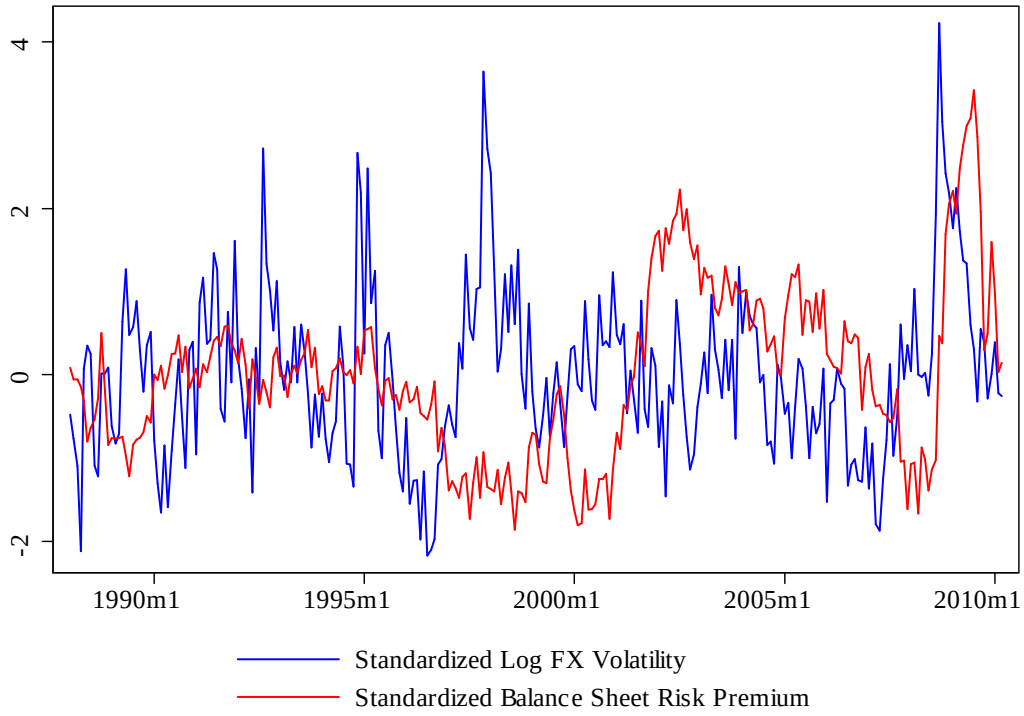

Figure 7: This plots the standardized log FX volatility and the standardized balance sheet risk premium.

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