# Survey-based Exchange Rate Decomposition: New Methodology and New Facts

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**Abstract**

The nominal exchange rate, like any other asset price, is a forward looking variable. Therefore, understanding the behavior of exchange rates requires making assumptions on how agents form expectations. There has been a recent revival of the use of survey forecast data in macroeconomics and finance but international finance is lagging behind. The contribution of this paper is to provide a set of empirical stylized facts to guide theory papers aimed at modeling exchange rates and matching survey data. Using a novel VAR approach, which relies on survey data, we decompose the exchange rate change into forward looking components that capture the changes in expectations of the relative policy rate and inflation paths of both countries and also the path of expected excess returns. Based on this decomposition, we present stylized facts for a large number of bilateral exchange rate pairs of advanced economies regarding the exchange rate change and its components. Namely, we study unconditional variances and covariances, the term structure of expectations and uncertainty (conditional variances), where we consider separately the pre-ZLB and the ZLB periods.

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# 1 Introduction

Understanding the behavior of exchange rates has been one of the most important questions in international finance and asset pricing. The exchange rate is an unique variable as it is both a macroeconomic fundamental and an asset price. The asset price status makes it a forward looking variable which is a function of expectations. Therefore, a natural starting point for explaining the behavior of exchange rates is to build plausible models of expectations' formation consistent with survey-based measures of agents' expectations.

*The contribution of this paper is to provide a set of empirical stylized facts to guide theory papers aimed at modeling exchange rates and matching survey data.*

We rely on a decomposition of the nominal exchange rate change into a lagged interest rate differential and currency risk premia, changes in expectations over the relative policy rate paths, inflation rate paths and currency risk premia.[1] To calculate the components, we apply an empirical methodology, which has been previously used for the decomposition of yields (see Kim and Wright (2005), Wright (2011), Kim and Orphanides (2012), Piazzesi, Salamao, and Schneider (2015) and Crump, Eusepi, and Moench (2016)) but not for exchange rates. We estimate a VAR, augmented with additional constraints that ensure that the VAR-based expectations match the survey data well. The purpose of the VAR is to interpolate and extrapolate the expectations for exchange rates, 3-month bill rates and inflation for horizons that are not reported in the surveys.[2] We consider 10 advanced economies, which gives a total of 45 unique currency-pairs at quarterly frequency over the period 1990-2016. The survey data we use are the consensus/average forecasts of professional forecasters for a number of macroeconomic and financial variables at both short and long horizons.

Based on this methodology, the facts that we document can be grouped in the following three broad categories:

1. *Variance covariance decomposition*
   We perform a variance covariance decomposition of the exchange rate change. Our estimates indicate that the *unconditional* variance of the relative policy rate paths, relative inflation paths and currency risk premia components are about 50%, 25% and 100% of the exchange rate change volatility. The respective average numbers for the US base are 48%, 26% and 93%. When comparing the pre-ZLB period for the US with the ZLB period, we observe that the importance of the monetary policy

[1] Throughout the paper we use expected excess returns and currency risk premia as synonyms.

[2] This procedure is equivalent to estimating a data generating process for the survey forecast of the given macro variable that matches the realized survey data well and also ensures that the expectations are not too far from the realized data.

and inflation components was significantly higher prior to the ZLB (68% and 32%, respectively). While the currency risk premium is indeed the most volatile component, the macroeconomic fundamentals also contribute substantially to the exchange rate change volatility.

The covariances between the various components are such that a higher expected policy rate path in country $i$ relative to country $j$ is associated with a positive update on the path of expected excess return of being long currency $i$ and short currency $j$ which is consistent with the carry trade literature. It is also associated with higher expected inflation in country $i$ relative to country $j$ potentially due to the systematic component of monetary policy. Finally, higher inflation path in country $i$ relative to $j$ is associated with expected exchange rate depreciation of currency $i$ at some future horizon, which is consistent with purchasing power parity holding at the medium and long run.

2. *Term structure of expectations*

   We examine the term structure of expectations relevant for exchange rate changes. That is, we can further split our exchange rate change components by horizon and orthogonalize the components with respect to the proceeding horizons to decompose the variance of the monetary policy, inflation and currency risk premia components. We find that it's changes in expectations over short and medium horizons (next quarter to 10 years) orthogonal to the contemporaneous surprise that explain most of the variation of the components capturing macroeconomic fundamentals. Regarding the currency risk premia component, it's news affecting expectations over the short run (next quarter to 5 years) that matter the most, followed by the contemporaneous surprise to the currency risk premia. When one splits the sample into pre-ZLB and ZLB and considers the US base, the patterns are such that during the pre-ZLB, contemporaneous news seem to matter more for the monetary policy component relative to the ZLB, as expected. These results imply that a model which delivers a data generating process for inflation, bill rates and currency risk premia that resembles an AR(1) process will not be able to match the term structure of expectations.

3. *Exchange rate uncertainty*

   Finally, we study the behavior of the *conditional* variance of the exchange rate change and its components and the respective conditional covariances. To do so, we project model-implied squared forecast errors on the VAR variables themselves, a method akin to the one used in Campbell and Shiller (1988) and Duffie (2005). One can observe that the conditional exchange rate variance is elevated when either one of the countries is in a recession and it is quite volatile. While all of the components are quite volatile, the countercyclicality of the exchange rate uncertainty appears to be driven by the countercyclicality of the exchange rate change components which capture the relative monetary policy and inflation paths. Surprisingly, while the conditional variance of the currency risk premium component is countercyclical in a statistically significant way for the USD base specification, with respect to the US business cycle, there is no uniform pattern when one considers different base currencies. The last result can be potentially accounted for by models where the US economy is special due to its large real and financial sectors.

There has been a recent resurgence in macroeconomics and finance regarding the use of survey data expectations. More recently, in macroeconomics, inflation and real GDP growth expectations have been used to study questions related to estimating the real interest rate — a key variable in the secular stagnation debate — (Hamilton and West (2016)), monetary policy (Nakamura and Steinsson (2018)), the Phillips curve (Coibion and Gorodnichenko (2015) and Coibion, Gorodnichenko, and Kamdar (2017)) and sentiments-driven business cycles (Eusepi and Preston (2011),Angeletos and Dellas (2017)).[3] In finance, survey data have been applied to decompose yields and stock prices ( Kim and Wright (2005), Wright (2011), Kim and Orphanides (2012), Piazzesi, Salamao, and Schneider (2015), Crump, Eusepi, and Moench (2016) and De la O and Myers (2017)), to explain periods of stock market booms and busts (Adam, Marcet, and Beutel (2017)) and to revisit survey data stock price puzzles (Bordalo and Shleifer (2017)).[4]

[3]Coibion, Gorodnichenko, and Kamdar (2017) show that conditional on using survey data on inflation expectations, the New Keynesian Phillips curve can explain the data significantly better and a number of puzzles such as the missing disinflation during the Great Recession are resolved. They also provide a recent literature review on why survey data conveys meaningful information and should be used as additional variables in estimating macroeconomic models. Gertler (2017) builds an adaptive learning model and uses survey data on expectations to discipline the learning process of the agents in order to explain the failure of forward guidance in Japan. Using a similar framework, Gerko (2017) shows that deviations from rational expectations and the use of survey macroeconomic data can resolve a number of puzzles such as the missing disinflation during the Great Recession and the slow recovery in the U.S. Tang (2015), Melosi (2017) and Nakamura and Steinsson (2018) study models with a signaling effect of monetary policy and show that survey data support the models' predictions and can be used to estimate such models.

[4]In the finance literature, survey data on expectations have been used in many different ways. As mentioned above, they have been used to obtain estimates of term premia. In terms of forecasting power, Dick, Schmeling, and Schrimpf (2013) show that survey-based measures of bond term premia can predict future bond returns while Schmeling and Schrimpf (2011) show that survey-based inflation expectations predicts future stock returns in and out of sample, a result that they attribute to "money illusion". Therefore, survey-based expectations of macroeconomic variables and interest rates seem to matter for predicting asset returns.

Several papers have also shown the ability of survey forecasts to explain economic behavior. Malmendier and Nagel (2016) show that households that have higher inflation expectations tend to enter into fixed-rate rather than floating-rate contracts. Using a survey of chief financial officers (CFOs), Gennaioli, Ma, and Shleifer (2015) show that CFO expectations explain firm investment decisions well and have explanatory power above and beyond Tobin's Q or discount rates. Lastly, Greenwood and Shleifer (2014) provide one

Survey data has been also used in the past to study exchange rates (see, for example, Dominquez (1986), Frankel and Froot (1987), Frankel and Chinn (2002), Gourinchasa and Tornell (2004),Engel, Mark, and West (2008), Bacchetta and van Wincoop (2009) and the literature review in Jongen and Wolff (2008), among others). However, the use of survey data in international finance remains less common compared to macroeconomics and finance over the recent period. One of the reasons why could be the plethora of papers in the 80s and the 90s documenting that survey-based and realized exchange rate changes are often negatively and/or insignificantly correlated (see the literature review in Jongen and Wolff (2008)).

Therefore, in this paper, we present a number of exercises that examine the properties of survey-based exchange rate consensus forecasts of professional forecasters from Consensus Economics that are used in our estimation. We argue that these data have a number of appealing features. For example, we show that survey data on exchange rate expectations by professional forecasters, starting in 1990, are able to predict in-sample future exchange rate changes at various horizons and the predictive power is robust to controlling for the lagged interest rate differential measured using relative Libor rates, 3-month bill rates or the 3-month forward rate minus the spot rate. This last result implies that market participants are not simply reporting forecasts that rely on rules of thumb based on forward rates or an uncovered interest rate parity (UIRP) relationship.

Last but not least, we show that larger net cross-country inflows, denominated in the domestic currency, are associated with larger expected excess return from being long that currency over the next quarter, where the expected excess return is measured using the survey data. Stavrakeva and Tang (2018) provide further details on this relationship as we test an intermediation-based asset pricing model of the currency risk premium using survey data. The interpretation that we provide is that the higher the net exposure of the marginal trader is to a given carry trade position, the larger the expected excess return (currency risk premium) he demands from being long that position. Given that exchange rate survey data are consistent with standard asset pricing models, their use for disciplining international finance models becomes even more appealing.

Based on these evidence, we conclude that, indeed, the survey forecasts contain information relevant for explaining exchange rates and should be brought to the forefront of the

of the most exhaustive recent studies on the quality of survey data on stock return expectations. They consider six different data sources and show that the forecasts are highly positively correlated across sources. Moreover, higher expected returns based on the survey data are positively correlated with mutual fund flows and the number of initial public offerings which indicates the economic relevance of survey-based forecasts in understanding portfolio and funding decisions.

international finance research.

In addition to the literatures mentioned above, this paper is closely related to studies that decompose the exchange rate using a similar accounting identity (see Froot and Ramadorai (2005), Engel and West (2005; 2006), Engel, Mark, and West (2008), Engel and West (2010), Evans (2012), and Engel (2014; 2016)). Some of these papers also perform a variance co-variance decomposition but they usually focus on decomposing the de-trended real exchange rate level. Among them, only Engel, Mark, and West (2008) uses survey data. In particular, they use survey forecasts of inflation and output growth along with a number of calibrated parameters to approximate present discounted values of fundamentals in a Taylor-rule model of exchange rates. We contribute to this literature by disciplining the expectations that enter the exchange rate components using survey data in a model free way.

The way we use survey data is similar to methods used in the decomposition of yields into term premia and expectations hypothesis terms (see the cited papers above), but it has not been previously used to decompose exchange rates.

Finally, the paper is related to the literature in international finance that studies the various properties of the exchange rate survey data. It is a well known fact in the exchange rate literature that in order to match the survey data one needs to build a model that deviates from the full information rational expectations (FIRE) hypothesis — i.e. the forecast error is not orthogonal to period $t$ information (see the literature review in Jongen and Wolff (2008)). We also confirm the previous findings in the literature that one can reject the null that the FIRE hypothesis holds within our sample in most cases.

The paper proceeds as follows. Section 2 outlines a decomposition of exchange rate changes that relies only on a definition of the expected excess one-period currency return. Section 3 describes our survey-augmented VAR methodology while Sub-Section 3.1 discusses the survey data used and documents properties of the exchange rate change survey forecast data. Sub-Section 3.2 presents measures of how well the VAR-based expectations fit the survey data and contrasts the results to a VAR that is not disciplined with survey data. Section 4 presents our stylized facts while Section 5 concludes.

# 2 Exchange Rate Decomposition

We start by presenting an exchange rate change decomposition based on an accounting identity. We use only a definition of the expected excess return from taking a long position in one-period, risk-free bonds of currency $j$ and a simultaneous short position in one-period, risk-free bonds of currency $i$. As introduced above and using the same notation, the expected excess return from this trade is defined as

$$\sigma_t \equiv E_t \Delta s_{t+1} - \tilde{i}_t. \tag{1}$$

Using this definition, the actual change in the exchange rate can be written as

$$\Delta s_{t+1} = \tilde{i}_t + \sigma_t + \Delta s_{t+1} - E_t \Delta s_{t+1}. \tag{2}$$

Expressing equation (1) in terms of exchange rate levels and iterating forward gives

$$s_t = -E_t \sum_{k=0}^{\infty} \left[\tilde{i}_{t+k} + \sigma_{t+k}\right] + E_t \lim_{k\to\infty} s_{t+k}. \tag{3}$$

First-differencing equation (3) and combining the resulting expression with equation (1) implies that the forecast error can be expressed as

$$\begin{aligned}\Delta s_{t+1} - E_t \Delta s_{t+1} = & -\underbrace{\sum_{k=0}^{\infty} \left(E_{t+1}\tilde{i}_{t+k+1} - E_t \tilde{i}_{t+k+1}\right)}_{\varphi^{EH}_{t+1}} \\ & -\underbrace{\sum_{k=0}^{\infty} \left(E_{t+1}\sigma_{t+k+1} - E_t \sigma_{t+k+1}\right)}_{\sigma^{F}_{t+1}} + \underbrace{E_{t+1} \lim_{K\to\infty} s_{t+K} - E_t \lim_{K\to\infty} s_{t+K}}_{s^{\Delta E}_{t+1,\infty}}. \end{aligned} \tag{4}$$

Equation (4) allows us to express the realized exchange rate changes in terms of lagged interest rate differentials and expected excess returns in addition to changes in expectations in: (i) contemporaneous $(t+1)$ and future relative short-term rates, $\varphi^{EH}_{t+1}$, (ii) contemporaneous and future excess returns, $\sigma^F_{t+1}$, and (iii) long-run nominal exchange rate levels, $s^{\Delta E}_{t+1,\infty}$. This latter term can be further expressed as function of inflation expectations as follows:

$$\begin{aligned} s^{\Delta E}_{t+1,\infty} &= E_{t+1} \lim_{K\to\infty} s_{t+K} - E_t \lim_{K\to\infty} s_{t+K} \\ &= \lim_{K\to\infty} \sum_{k=0}^{K-1} \left(E_{t+1}\left[\Delta q_{t+k+1} + \tilde{\pi}_{t+k+1}\right] - E_t\left[\Delta q_{t+k+1} + \tilde{\pi}_{t+k+1}\right]\right) \\ &= E_{t+1} \lim_{K\to\infty} q_{t+K} - E_t \lim_{K\to\infty} q_{t+K} + \lim_{K\to\infty} \sum_{k=0}^{K-1} \left(E_{t+1}\tilde{\pi}_{t+k+1} - E_t \tilde{\pi}_{t+k+1}\right). \end{aligned}$$

If the real exchange rate is stationary, the change in expectations over long-run real exchange rate levels will be zero and $s^{\Delta E}_{t+1,\infty}$ will reflect changes in expectations over long-run relative price levels or the entire future path of relative inflation starting from the contemporaneous surprise. Combining equations (1) and (4) implies that

$$\Delta s_{t+1} = \tilde{i}_t - \varphi_{t+1}^{EH} + \sigma_t - \sigma_{t+1}^{F} + s_{t+1,\infty}^{\Delta E}. \tag{5}$$

# 3 VAR with Survey Data

To compute the terms in our decomposition, we need interest rate expectations at all horizons greater than zero as well as long-run exchange rate expectations. To obtain estimates of these expectations, we model exchange rates and short-term interest rates using the following reduced-form VAR($p$) process:

$$\begin{aligned} F_{t+1} &= \bar{F} + \gamma(L) F_t + \varepsilon_{F,t+1} && (6) \\ \text{where } \gamma(L) &\equiv \gamma_1 + \gamma_2 L + ... + \gamma_p L^{p-1} \\ \text{and } F_{t+1} &\equiv [q_{t+1}^{i,US}, x_{t+1}^{i}, z_{t+1}^{i}, x_{t+1}^{US}, z_{t+1}^{US}]'. && (7) \end{aligned}$$

Here, $q_{t+1}$ is the level of the real exchange rate defined as units of currency $i$ per U.S. dollar. By including the real exchange rate in levels, we are estimating a specification where a stable estimate of the VAR implies that long-run purchasing power parity holds and VAR-based expectations of the long-run real exchange rate are constant. The vector $x_{t+1}$ is a set of yield curve variables that includes the 3-month bill rate as well as the empirical term structure slope and curvature factors defined as:

$$\begin{aligned} sl_t^i &= y_t^{40,i} - i_t^i \\ c_t^i &= 2y_t^{8,i} - \left(y_t^{40,i} + i_t^i\right). \end{aligned}$$

The country-specific vector $z_{t+1}^{j}$ for $j \in \{i, US\}$ represents other variables that may be useful for forecasting either short-term interest rates or changes in the exchange rate. Importantly, we always include a quarterly inflation rate (measured using CPI inflation) in $z_{t+1}^{j}$. This allows us to compute VAR-based expectations of nominal exchange rate changes from our estimates of the real exchange rate and inflation equations. The other variables in $z_{t+1}^{j}$ include the GDP gap and the current-account-to-GDP ratio.

In addition to these variables, we include a number of other U.S. macroeconomic variables in $z_{t+1}^{US}$. First, we capture global financial conditions using the U.S. VIX index and the spread between the 3-month U.S. Libor and Treasury bill rates (the TED spread). While the yield curve variables do capture aspects of financial conditions that affect markets for sovereign debt, the VIX and TED spread can reflect financial conditions in other markets such as equity and interbank lending markets, which may be relevant to financial market participants for forecasting interest rates, inflation, or exchange rates. Secondly, to improve our fit of long-horizon inflation forecasts, we include an exponentially weighted average of lagged U.S. inflation which is constructed as

$$\pi_{t+1}^{avg,US} = \rho\pi_t^{avg,US} + (1-\rho)\pi_{t-p+1}^{US},$$

where we choose $\rho = 0.95$. When we include $\{\pi_t^{avg,US}, ..., \pi_{t-p+1}^{avg,US}\}$ in the VAR in equation (6), this will contain information on US inflation for lags beyond $p$. Note also that the coefficients in the VAR equation for this variable can be fixed at their known values, allowing us to include information in the VAR from further lags of U.S. inflation in a way that minimizes the number of additional coefficients to be estimated.

This variable improves our fit of long-horizon inflation forecasts by capturing the declining trend in inflation expectations as most central banks in our countries of interest began targeting inflation during our sample. Since this decline is common to most countries in our sample, an alternative would've been to use an average or principal component of country-specific exponentially weighted averages rather than only the one for the U.S. The issue with such a measure is that the true data-generating process for this variable would be a function of all our countries' inflation rates. To avoid estimating a misspecified equation for this variable, we would have to estimate a large VAR with all countries' variables simultaneously, which is infeasible. Since the U.S. exponentially weighted average inflation has a correlation of .95 with the first principal component estimated from the set of analogous measures for each country, we believe that it is a sufficiently good proxy of the common declining trend in inflation across all the countries in our study.

This reduced-form VAR($p$) in equation (6) can be written in a VAR(1) companion form:

$$\underbrace{\begin{bmatrix} F_{t+1} \\ \vdots \\ F_{t-p+2} \end{bmatrix}}_{\mathbf{X}_{t+1}} = \underbrace{\begin{bmatrix} \bar{F} \\ 0 \\ 0 \end{bmatrix}}_{\bar{\mathbf{X}}} + \underbrace{\begin{bmatrix} \gamma_1 & \gamma_2 & \cdots & \gamma_p \\ & \mathbf{I} & & \mathbf{0} \end{bmatrix}}_{\mathbf{\Gamma}} \underbrace{\begin{bmatrix} F_t \\ \vdots \\ F_{t-p+1} \end{bmatrix}}_{\mathbf{X}_t} + \underbrace{\begin{bmatrix} \varepsilon_{F,t+1} \\ 0 \\ \vdots \end{bmatrix}}_{\mathbf{\Xi}_{t+1}}. \tag{8}$$

To ameliorate the problem of overparameterization in unrestricted VARs, we follow Cushman and Zha (1997) in restricting both the contemporaneous and the lagged relationships between the variables in the VAR, i.e., imposing zero restrictions on the elements of $\{\gamma_1, ..., \gamma_p\}$. More specifically, we consider a specification where each country's financial variables follow a smaller three-variable VAR.[5] This can be interpreted as a version of a three-factor affine

[5]One caveat is that we do not impose a zero lower bound (ZLB) in the VAR. However, once the estimation

term structure model where we directly measure, rather than estimate, the factors and where we do not further impose no-arbitrage restrictions. One advantage of this specification versus one that models the short-term interest rate as a function of macroeconomic variables (such as a Taylor rule) is that it uses information from long-term yields in a parsimonious way. This allows the estimates to better capture the effects of forward guidance, among other things, and is therefore more appropriate for a sample that includes zero lower bound episodes.

Our next set of restrictions concerns the macroeconomic variables. We assume that changing economic conditions in the United States affect expectations over macro variables in other countries through spillovers from the United States into the macroeconomy of these other countries. See Miranda-Agrippino and Rey (2015) for VAR-based evidence of such spillovers. At the same time, we restrict U.S. macroeconomic variables to depend only on lags of themselves and U.S. financial variables. Lastly, we allow the real exchange rate to enter as a lag only in its own equation. We impose this restriction so that information from lagged exchange rates themselves will not enter the nominal interest rate or long-term exchange rate terms. This distinction becomes important when we consider the importance of movements in these terms in driving variation exchange rate changes. As will be seen below, the model is still able to produce forecasts that closely mimic survey forecasts even with this restriction.

To summarize, if we partition each matrix $\{\gamma_1, ..., \gamma_p\}$ into five blocks corresponding to the partitioning of $F_{t+1}$ given in (7), then the above restrictions imply the following zero restrictions on the matrix of VAR coefficients:

$$\gamma_l = \begin{bmatrix} \bullet & \bullet & \bullet & \bullet & \bullet \\ 0 & \bullet & 0 & 0 & 0 \\ 0 & \bullet & \bullet & \bullet & \bullet \\ 0 & 0 & 0 & \bullet & 0 \\ 0 & 0 & 0 & \bullet & \bullet \end{bmatrix} \quad \text{for } l = 1, ..., p. \tag{9}$$

Our main innovation to the existing literature on exchange rate decompositions is that we estimate not only (8) subject to (9), but that we further discipline the estimation using survey forecasts of exchange rates, interest rates, and inflation to ensure that our model-implied estimates capture private sector expectations well.

More specifically, we add the following set of equations relating survey forecasts to VAR-

is disciplined by survey data, we estimate negative 3-month interest rate forecasts only for countries and time periods where central bank policy rates were negative.

implied forecasts:

$$\mathbf{Y}_t^S = H_t\left(\bar{\mathbf{X}}, \mathbf{\Gamma}\right)\mathbf{X}_t + H_t^Z\mathbf{Z}_t + \mathbf{\Xi}_{h,t}^S \tag{10}$$

where $\mathbf{Y}_t^S$ is a vector of survey forecasts. The right-hand-side of the above equation maps current and lagged data $\{F_{t-l}\}_{l=0}^P$ into model-implied forecasts that correspond to this vector of survey realizations. $H_t\left(\bar{\mathbf{X}}, \mathbf{\Gamma}\right)$ is the matrix of coefficients on the VAR variables $\mathbf{X}_t$, which contains up to $p$ lags of VAR variables. It's a function of the coefficient matrices in (8) as well as $t$ through the quarter of the year that period $t$ falls in. The dependence on the quarter is a result of the forecast horizons and variable definitions in our survey data. For the same reason, the mapping is also a function of additional variables $\mathbf{Z}_t$ which contains further lags of the VAR variables and data on price levels. The error $\mathbf{\Xi}_{h,t}^S$ can be interpreted as capturing measurement error due to the discrepancy between forecasters' observations of real-time macroeconomic data versus our use of current vintage data as well as small differences between the timing of the surveys and our data observations. See the Appendix for further details on this mapping.

Taken together, the system of equations given by (8) and (10) can be interpreted as a way to interpolate and extrapolate the survey data available in $\mathbf{Y}_t^S$ to other horizons in a way that's consistent with the data-generating process in (8) and the behavior of actual realized one-period ahead data. Without making any further assumptions regarding the errors, we can consistently estimate the coefficients $\bar{\mathbf{X}}$ and $\mathbf{\Gamma}$ subject to the restrictions in (9) by minimizing the sum of squared errors from all equations in (8) and (10). Since the decomposition given in equations (2) and (4) relies heavily on forecast revisions, we also include differences between model-implied and survey forecast revisions as additional errors in this estimation.[6] We estimate this system for each of our nine countries against the U.S. with a lag length of two quarters.

## 3.1 Survey Data

In the estimation, we include survey data on forecasts for exchange rates, 3-month interest rates, 10-year yields, and inflation at various horizons obtained from Blue Chip and Consensus Economics. For most variables, we have data for forecasts horizons up to 2 years ahead.

We also use data on long-horizon forecasts for 6-10 year ahead averages of inflation rates. For interest rates, we have similar long-horizon forecasts for the U.S (7-11 year ahead av-

[6] The errors in matching forecast revisions are a function of current and lagged errors in matching forecast levels.

erages). However, we do not directly observe long-horizon nominal interest rate forecasts for other countries. Instead, we impute long-horizon 3-month interest rates using a procedure akin to the one employed in Wright (2011). More specifically, Wright (2011) fits U.S. long-horizon 3-month interest rate forecasts to long-horizon inflation and GDP growth forecasts and then uses the estimated coefficients to impute long-horizon 3-month interest rate forecasts for other countries. We adopt this method but also include 5-year-ahead 5-year forward rates in the regression as we found that this greatly improved our fit of U.S. long-horizon interest rate forecasts. Table 5 shows the regression of U.S. long-horizon rates whose estimates are used to impute long-horizon interest rate forecasts for other countries. Compared to the original Wright (2011) specification, adding 5-year-ahead 5-year forward rates to the regression raises the adjusted $R^2$ from 73 to 84 percent over our sample.

### 3.1.1 Exchange Rate Survey Data

In this sub-section, we discuss the advantages of using survey data to discipline the VAR that we use to obtain expectations of future inflation, interest rates and exchange rates. While survey data on macroeconomic and interest rate forecasts have been used widely in estimating term premia, exchange rate forecasts have been less frequently used in estimation.[7] Therefore, we focus in this section on empirical exercises intended to evaluate the quality of our survey data on exchange rate forecasts. For the remainder of this paper, the time period considered is a quarter. We present the regression results only for the USD base for brevity. The results are similar for the other bases.

First, we show that survey-based forecasted exchange rate changes 3, 12 and 24 months ahead, calculated using *Consensus Economics* data, predict the exchange rate change over the corresponding horizon in sample. Table 1 presents a panel regression of the realized exchange rate change on the forecasted exchange rate change, calculated using the survey data. All the coefficients are statistically significant at 1%.

The majority of the surveyed participants work for large financial institutions. Therefore, the fact that the average exchange rate change expectation correlates in a statistically significant way with the realized exchange rate change can have a couple of interpretations. It could be that the consensus expectations are close to the expectations of professionals that are good at forecasting the exchange rate change. Alternatively, the consensus expectations

[7] Kim and Wright (2005), Kim and Orphanides (2012), Piazzesi, Salamao, and Schneider (2015), and Crump, Eusepi, and Moench (2016) use U.S. survey data to estimate U.S. term premia while Wright (2011) uses survey data to estimate term premia for a set of developed countries that largely overlaps with the ones considered in this study.

might capture well the forecasts of the large financial institutions, and, hence, the direction of the majority of the trading positions, which, in turn, would mechanically lead to the exchange rate moving in a way consistent with the consensus forecast. Both channels are potentially at play which should be taken into account when interpreting the results and when writing models matching these data.

The second exercise that we perform tests whether the in-sample predictive power of the survey exchange rate forecasts is above and beyond the predictive power of the interest rate differential. For this exercise, we separate the survey-based expected exchange rate change into a currency risk premium component and the interest rate differential. Denoting logarithms of variables with lowercase letters, we define the survey-based expected excess return (a term that we use interchangeably with currency risk premium) as:

$$\sigma_t^S \equiv E_t^S \Delta s_{t+1} - \tilde{i}_t$$

where $E_t^S$ denotes the survey-based forecast at time $t$, $s_t$ denotes the exchange rate in terms of the number of units of currency $i$ per currency $j$, and $\tilde{i}_t$ represents the relative one-period (3-month) rate differential calculated as country $i$ minus $j$.

For our empirical exercise , we consider three commonly used measures of the interest rate differential—3-month government bond rates, 3-month Libor rates and the 3-month forward premium (the 3-month forward exchange rate minus the spot rate). The forward premium is often used as a measure of the interest rate differential relevant for financial markets, conditional on covered interest rate parity (CIP) holding. For each of these measures, we calculate a corresponding survey-implied currency risk premium. Table 2 shows the regression results from a panel regression of the realized quarterly exchange rate change on $\sigma_t^S$ and $\tilde{i}_t$. $\sigma_t^S$ is highly statistically significant for all three measures while the interest rate differential is not statistically significant.[8] Therefore, the survey data has predictive content of future exchange rate movements above and beyond the interest rate differential and is a better predictor of future exchange rate changes than the forward premium or lagged interest rate differentials.

In Figure 1, we plot the expected exchange rate change using the survey data along with the lagged interest rate differential measured using forward rates, government bond rates or Libor rates. One can see that the behavior of survey-based expected exchange rate changes

[8]Note that the coefficients on both $\tilde{i}_t$ and $\sigma_t$ are way below one which implies that the perfect information rational expectations hypothesis does not hold in the data when one uses survey data—a result previously documented by Froot and Frankel (1989) among others. However, as Coibion and Gorodnichenko (2015) argues, this does not imply that the data is inconsistent with a model with imperfect information, but expectations that are still formed rationally. For the purposes of our decomposition, we do not need to take a strict stand on whether agents are rational nor on the completenesss of information.

differ greatly from the rate differentials. In addition, the survey-based expected exchange rate change also differs substantially from zero, evidence that forecasters are also not simply relying on a random walk model of exchange rates.

The difference between the expected exchange rate change and a particular interest rate differential is a period $t$ currency risk premium, $\sigma_t^S$, which is substantially more volatile than the relative interest rate differential. Table 3 reports the bilateral regression of the survey-based expected exchange rate change on the forward rate minus the spot rate and while the coefficient is statistically significant for some currency pairs, most of the variation of the survey-based expected exchange rate change (more than 80%) cannot be attributed to forward rates.

All of these results combined suggest that the surveyed practitioners do not simply use rules of thumb based on forward rates, an uncovered interest rate parity (UIRP) relationship, or a random walk model when asked to provide an exchange rate forecast. Furthermore, using survey data delivers currency risk premia which have a significant in-sample predictive power of realized exchange rate changes that is independent of the lagged interest rate differential.

Previous papers have tested the forecasting power of survey-based exchange rate expectations and have found more mixed results than the ones we document here (see, for example, Frankel and Chinn (2002).) However, these papers rely on datasets from an earlier period. It is plausible that the quality of survey data and the ability of the average/median practitioner to predict exchange rate changes have improved over time relative to the period studied by the older literature. Alternatively, over the recent period, survey data might capture better the forecasts of institutions that account for the bulk of forex trading which would mechanically generate a link between their forecasts and the exchange rate movement.

Finally, as another piece of supportive evidence that exchange rate survey data capture meaningful information, we study the link between cross country net flows and currency risk premia calculated using the survey data. In particular, in Table 4 we regress the expected excess return on the net flows from the rest of the world into country $i$, denominated in the currency of country $i$. We use the BIS data on bank and total flows from the locational statistics. The timing is such that the net flows are within the quarter $t$ while the expected excess returns are between the end of quarter $t$ and the end of quarter $t+1$. We find that higher net flows into country $i$ are associated with higher expected excess return from being long the currency of country $i$ and short the USD. As we show in Stavrakeva and Tang (2018), standard asset pricing models are consistent with this relationship. The interpretation that we provide in that paper is that the higher the net exposure of the marginal trader is to a given carry trade position, the larger the expected excess return (currency risk premium) he demands from being long that position. Therefore, survey data are consistent with standard asset pricing models which makes their use for disciplining international finance models even more appealing.

## 3.2 Properties of the VAR-Based Expectations

To assess the model's ability to fit the survey forecasts, panel A of Tables 6 through 11 present correlations as well as root-mean-square deviations between model-implied forecasts and the survey measure for 3-month interest rates, nominal exchange rates, and inflation. Panel B of these tables present the same statistics using OLS estimation of only equation (8) with the restrictions in (9). Of course, the model augmented with survey data should, by definition, produce a better fit of survey data. The measures of fit in these tables serve to illustrate that the improvement is sometimes quite substantial.

In general, the results in these tables show that a standard estimate of the VAR which only optimizes the one-period-ahead fit of each variable, by only including equation (8) subject to the restrictions in (9), does a poor job of mimicking the behavior of private sector forecasts, particularly for horizons longer than one quarter or the current year. However, panel A of these tables show that including the additional equations in the estimation given by (10) is sufficient to obtain a very good fit of the private sector forecasts without changing the data-generating process assumed in (8).[9]

Turning first to the fit of 3-month interest rate forecasts presented in Tables 6 and 7, correlations between the benchmark model-implied and survey forecasts are above 95 percent across all countries for horizons up to two years out. For our long-horizon forecasts, the correlations range from 42 to 97 percent and are a marked improvement from the case without forecast data where the correlation are even negative for Switzerland and the U.K. The RMSD reveal a similar pattern with the VAR with survey data achieving values that are smaller by a factor of close to four for many countries and horizons beyond three months. For the long-horizon forecasts, the RMSD is reduced by a factor of close to ten in some cases compared to the VAR without survey data. The results for the fit of 10-year yield survey forecasts, not shown here, are very similar to those for 3-month interest rates.

For nominal exchange rate level forecasts, Tables 8 and 9 show that the benchmark model performs similarly with correlations of 93 percent or better across all horizons and currency

[9] When evaluating these fits, it's important to keep in mind that the number of observations decreases with the forecast horizon with the longest forecast horizons suffering the most. For example, due to the timing of the survey, data for the 2Y horizon are generally only available annually and can have as few as 10-20 observations, depending on the country.

pairs in our baseline estimation. Relative to a model without forecast data, the RMSD between model-implied and survey forecasts can be lower by a factor of up to ten at longer horizons. These tables also include correlations between survey and VAR-implied measures of currency premia for a 3-month investment horizon as defined in equation (1). While the estimation that does not include survey data produces estimated currency premia that have correlations with the survey-based measures that are often negative and at most only 29 percent, our estimates produce correlations ranging from 41 to 77 percent.

Lastly, Tables 10 and 11 show that our benchmark model achieves a similarly large improvement in fit of inflation survey forecasts relative to an estimation that does not use this data.

Figures 2 through 7 plot survey forecasts against model-implied fits both with and without the additional forecast data equations for a few select countries. These figures illustrate the potential reasons behind some of the differences in results obtained in our exchange rate change decomposition compared to those based on estimation methods that do not use survey data. Here, one can also see how augmenting the model with survey data improves a number of qualitative aspects of the model-implied forecasts. One notable feature seen in Figure 2 is that including survey forecasts in the estimation results in no violations of the ZLB unlike the estimation without forecast data. Figure 3 shows that the model without forecast data produces long-horizon 3-month interest rate forecasts that are unrealistically smooth and low for the U.S. and Germany/Eurozone. In contrast, by using survey data in the estimation, our model is able to better mimic the variation in long-horizon survey forecasts.

The 1-year ahead inflation forecasts seen in Figure 4 are realistically less volatile when we add survey data to the estimation, particularly for the U.K. and Germany/Eurozone. Figure 5 shows that the estimation with survey data is able to match the slow-moving downward trend in long-horizon inflation forecasts over this sample. An estimation without survey data produces counterfactual long-horizon forecasts which actually trend up for Germany/Eurozone over time.

Lastly, Figures 6 and 7 shows that our VAR specification is capable of producing a very close fit of exchange rate level forecasts, even at a 24 month horizon, and currency premia based on survey data for a variety of currencies.

As an additional check of external validity, we compare our model-implied interest rate expectations with market-based measures of short-term interest rate surprises computed using futures prices by adapting the method used in Bernanke and Kuttner (2005) to a quarterly frequency. Note that this data is *not* used in the estimation. We find that the model-implied quarterly U.S. short-term interest rate surprise, $i^{US}_{t+1} - \hat{E}_t\left[i^{US}_{t+1}\right]$, has a correlation of 76 percent with the market-based federal funds rate surprise measure over the full sample. Table 12 shows these correlations for a number of additional countries. With the exception of Norway, for which we only have data on less liquid forward rate contracts rather than interest rate futures, the correlations are all 63 percent or higher and above 79 percent for a majority of the countries that we consider. These high correlations are evidence that the short-term interest rate expectations based on our survey-data-augmented VAR are also consistent with expectations of financial market participants that can be inferred from asset prices.[10]

## 3.3 Calculating the Components of the Exchange Rate Decomposition

With the estimated VARs, we can now decompose exchange rates into the five terms listed in equation (5). First, to represent the expected excess return, $\sigma_t$, in terms of VAR variables, note that the exchange rate change and lagged policy rates can be expressed as

$$\begin{aligned} \Delta s_{t+1} &\equiv \Delta q_{t+1} + \tilde{\pi}_{t+1} = \left(e_q + e^i_\pi - e^j_\pi\right)\mathbf{X}_{t+1} - e_q\mathbf{X}_t \\ \tilde{i}_t &= \left(e^i_i - e^j_i\right)\mathbf{X}_t, \end{aligned}$$

where $e_q$ is a row vector that selects $q_{t+1}$ from $\mathbf{X}_{t+1}$. That is, it has the same number of elements as $\mathbf{X}_{t+1}$ with an entry of 1 corresponding to the position of $q_{t+1}$ in $\mathbf{X}_{t+1}$ and zeros elsewhere. Likewise, $e^i_i$ and $e^j_i$ are selection vectors corresponding to the short-term interest rates of countries $i$ and the U.S., respectively, and $e^i_\pi$ and $e^j_\pi$ are the same for inflation. Thus, denoting VAR-implied expectations at time $t$ by $\hat{E}_t$, we have the following:[11]

$$\sigma_t = \hat{E}_t[\Delta s_{t+1}] - \tilde{i}_t = \left(e_q + e^i_\pi - e^j_\pi\right)\left(\bar{\mathbf{X}} + \boldsymbol{\Gamma}\mathbf{X}_t\right) - \left(e_q + e^i_i - e^j_i\right)\mathbf{X}_t.$$

Next, since our VAR includes the real exchange rate $q_t$ in levels, stationary estimates of the VAR imply constant expectations over long-run levels of the real exchange rate. Thus,

[10] Note that the futures contracts we use are typically written on interbank interest rates, while our VAR produces expectations of 3-month T-bill rates. By basing our comparisons on expected interest rate surprises, we are able to abstract from differences in the rates that do not vary at a quarterly frequency. Nonetheless, the differences in financial instruments might make it harder to detect a high correlation between our model-implied expectations and the ones implied by futures prices, even if our model accords well with financial market participants' expectations formation processes.

[11] The $\hat{E}_t$ operator denotes expectations based on the linear projections performed in the VAR estimation. Although not explicitly delineated, the operator conditions only on the set of regressors included in the estimation of each equation. Due to the restrictions set out above, this means that the relevant information set differs across variables.

the change in expectations regarding long-run nominal exchange rates, $s^{\Delta E}_{t+1,\infty}$, simply reflects changes in expectations over long-run relative price levels as follows

$$s^{\Delta E}_{t+1,\infty} = \sum_{k=0}^{\infty} \left( E_{t+1}\tilde{\pi}_{t+k+1} - E_t\tilde{\pi}_{t+k+1} \right).$$

Hence, the final three terms in equation (5) are infinite sums of changes in expectations. Note that the VAR-implied change in expectations over future $\mathbf{X}_{t+k+1}$ can be written simply as a linear combination of the time $t+1$ reduced-form residuals:

$$\hat{E}_{t+1}\mathbf{X}_{t+k+1} - \hat{E}_t\mathbf{X}_{t+k+1} = \mathbf{\Gamma}^k \mathbf{\Xi}_{t+1}.$$

Using this fact, the remaining three VAR-implied exchange rate change components can be constructed as follows, as long as estimates of the VAR are stationary, which is true for all our currency pairs:[12]

$$\begin{aligned} \varphi^{EH}_{t+1} &= \left(e^i_i - e^j_i\right) \left( \mathbf{I} - \mathbf{\Gamma}\right)^{-1} \mathbf{\Xi}_{t+1} \\ \sigma^F_{t+1} &= \left[ \left(e_q + e^i_\pi - e^j_\pi\right) \mathbf{\Gamma} - \left(e_q + e^i_i - e^j_i\right) \right] \left(\mathbf{I} - \mathbf{\Gamma}\right)^{-1} \mathbf{\Xi}_{t+1} \\ s^{\Delta E}_{t+1,\infty} &= \left(e^i_\pi - e^j_\pi\right) \left(\mathbf{I} - \mathbf{\Gamma}\right)^{-1} \mathbf{\Xi}_{t+1}. \end{aligned} \tag{11}$$

# 4 Stylized Facts

## 4.1 Variance-Covariance Decomposition of Exchange Rate Changes

In this section we present variance-covariance decompositions of the quarterly nominal exchange rate change (i.e. we examine the unconditional second moment of the exchange rate change). Note that using our decomposition, the full-sample variance of the exchange rate change is a sum of variances and the covariances of all the exchange rate components.

$$\begin{aligned} Var\left(\Delta s_{t+1}\right) &= Var\left(\tilde{\imath}_t - \varphi^{EH}_{t+1}\right) + Var\left(\sigma_t - \sigma^F_{t+1}\right) + Var\left(s^{\Delta E}_{t+1,\infty}\right) \\ &\quad +2Cov\left(\tilde{\imath}_t - \varphi^{EH}_{t+1}, \sigma_t - \sigma^F_{t+1}\right) + 2Cov\left(\tilde{\imath}_t - \varphi^{EH}_{t+1}, s^{\Delta E}_{t+1,\infty}\right) \\ &\quad +2Cov\left(s^{\Delta E}_{t+1,\infty}, \sigma_t - \sigma^F_{t+1}\right). \end{aligned} \tag{12}$$

[12] While no restrictions were imposed on the residuals when estimating the VAR, in order to derive the analytical results in (11) and also to define the VAR based expectations in equation (10) we assume that $E_t\mathbf{\Xi}_{t+k} = 0$. Given that the approach we take here is similar to estimating the parameters of a pre-specified data generating process for the consensus forecast data, as long as we are consistent and match the survey data well, it is inconsequential whether we allow for persistence in the VAR residuals. The VAR should be interpreted simply as a way to interpolate and extrapolate survey data for horizons for which it's unavailable.

The estimates of these unconditional moments are reported in Tables 13 -16. First notice that over the whole sample the average of $Var\left(\tilde{i}_t - \varphi_{t+1}^{EH}\right)/Var\left(\Delta s_{t+1}\right), Var\left(\sigma_t - \sigma_{t+1}^{F}\right)/Var\left(\Delta s_{t+1}\right)$ and $Var\left(s_{t+1,\infty}^{\Delta E}\right)/Var\left(\Delta s_{t+1}\right)$ across all currency pairs is around .50, 1, and .25 , respectively, while the average numbers for the USD base are .48, .93 and .26, respectively. When comparing the pre-ZLB period for the US with the ZLB period, we observe that the importance of the monetary policy and inflation components was significantly higher prior to the ZLB (68% and 32%, respectively). While the currency risk premium is indeed the most volatile component, the macroeconomic fundamentals also contribute substantially to the exchange rate change volatility.

Over the whole sample we observe the following patterns regarding the covariance terms. For almost all currency pairs the covariances are negative.
$Cov\left(\tilde{i}_t - \varphi_{t+1}^{EH}, \sigma_t - \sigma_{t+1}^{F}\right) < 0$ implies that higher expected future interest rate in country $i$ relative to country $j$ (higher $\varphi_{t+1}^{EH}$) is associated with higher expected future excess return from being long the 3-month government bond of country $i$ (lower $\sigma_{t+1}^{F}$), a result that is consistent with previous findings in the carry trade literature. $Cov\left(\tilde{i}_t - \varphi_{t+1}^{EH}, s_{t+1,\infty}^{\Delta E}\right) < 0$ implies that higher expected future interest rates in country $i$ relative to country $j$ (higher $\varphi_{t+1}^{EH}$) are associated with higher expected future inflation in country $i$ than in country $j$ which is consistent with short-term rates being predominantly driven by monetary policy actions that raise rates when inflation is high. Finally, $Cov\left(s_{t+1,\infty}^{\Delta E}, \sigma_t - \sigma_{t+1}^{F}\right) < 0$ implies that a higher inflation path in country $i$ relative to country $j$ will be associated with higher expected excess returns from being long currency $j$. Given that higher inflation path in country $i$ relative to country $j$ is associated with a higher interest rate path in country $i$ relative to country $j$, it must be the case that the currency of country $i$ is expected to depreciate at some point in the future which is consistent with PPP holding in the medium and long run.

When considering the patterns pre-ZLB and during ZLB, as determined by the US ZLB, not surprisingly, the exchange rate change variance appears to be higher over the ZLB as this period coincides with the financial crisis. At the same time ,the variance of the monetary policy component for most countries is lower over the ZLB, which can be explained by the binding ZLB constraints in many countries in our sample. While the higher exchange rate variance of the ZLB can be partly attributed to a more volatile currency risk premium component, it appears that the $Cov\left(\tilde{i}_t - \varphi_{t+1}^{EH}, \sigma_t - \sigma_{t+1}^{F}\right)$ has become less negative and even often positive. The structural break is the most striking for the JPY base where it goes from -12 to 9. This last result implies that during the ZLB an increase of the expected interest rate path in country $i$ relative to Japan was associated with a lower (not higher) future expected excess return of being long currency $i$ and short JPY while exactly the opposite is true prior to the ZLB. This result is consistent with the carry unravelling over the ZLB.

## 4.2 Term Structure of Expectations

In this section we examine the term structure of the components of the unconditional exchange rate change variance, equation 12. In particular we study what fraction of the variance of each of the components can be attributed to contemporaneous surprises versus news about future macrofundamentals and currency risk premia. Since each of our components can be expressed as a sum over expectations of future paths of interest rates, currency premia, or inflation, we can further split each component into lagged terms, contemporaneous surprises, and the following short, medium, and long run purely forward-looking subparts as follows:

$$
\begin{aligned}
\varphi_{t+1}^{EH} &= \underbrace{\sum_{k=1}^{20}\left(E_{t+1}-E_t\right)\tilde{\imath}_{t+k+1}}_{\varphi_{t+1}^{EH,SR}} + \underbrace{\sum_{k=21}^{40}\left(E_{t+1}-E_t\right)\tilde{\imath}_{t+k+1}}_{\varphi_{t+1}^{EH,MR}} + \underbrace{\sum_{k=41}^{\infty}\left(E_{t+1}-E_t\right)\tilde{\imath}_{t+k+1}}_{\varphi_{t+1}^{EH,LR}} \\
\sigma_{t+1}^{F} &= \underbrace{\sum_{k=1}^{20}\left(E_{t+1}-E_t\right)\sigma_{t+k+1}}_{\sigma_{t+1}^{F,SR}} + \underbrace{\sum_{k=21}^{40}\left(E_{t+1}-E_t\right)\sigma_{t+k+1}}_{\sigma_{t+1}^{F,MR}} + \underbrace{\sum_{k=41}^{\infty}\left(E_{t+1}-E_t\right)\sigma_{t+k+1}}_{\sigma_{t+1}^{F,LR}} \\
s_{t+1,\infty}^{\Delta E} &= \underbrace{\sum_{k=1}^{20}\left(E_{t+1}-E_t\right)\tilde{\pi}_{t+k+1}}_{s_{t+1,\infty}^{\Delta E,SR}} + \underbrace{\sum_{k=21}^{40}\left(E_{t+1}-E_t\right)\tilde{\pi}_{t+k+1}}_{s_{t+1,\infty}^{\Delta E,MR}} + \underbrace{\sum_{k=41}^{\infty}\left(E_{t+1}-E_t\right)\tilde{\pi}_{t+k+1}}_{s_{t+1,\infty}^{\Delta E,LR}}
\end{aligned}
$$

where $\left(E_{t+1}-E_t\right)x$ denotes a change in expectations over variable $x$. We can then consider how much each of these subcomponents contribute to the variance of each exchange rate component itself (note that the variances of the lagged terms in the decomposition are fairly small which is why we ignore them). In order to do that we perform the following orthogonalization

$$
\begin{aligned}
1 = & \frac{Cov\left(\left(\tilde{\imath}_{t+1}-E_t\tilde{\imath}_{t+1}\right)^{\perp}, \tilde{\imath}_t-\varphi_{t+1}^{EH}\right)}{Var\left(\varphi_{t+1}^{EH}\right)} + \frac{Cov\left(\varphi_{t+1}^{EH,SR,\perp}, \tilde{\imath}_t-\varphi_{t+1}^{EH}\right)}{Var\left(\varphi_{t+1}^{EH}\right)} \\
& + \frac{Cov\left(\varphi_{t+1}^{EH,MR,\perp}, \tilde{\imath}_t-\varphi_{t+1}^{EH}\right)}{Var\left(\varphi_{t+1}^{EH}\right)} + \frac{Cov\left(\varphi_{t+1}^{EH,LR.\perp}, \tilde{\imath}_t-\varphi_{t+1}^{EH}\right)}{Var\left(\varphi_{t+1}^{EH}\right)},
\end{aligned}
$$

as well as analogously defined decompositions for the currency premia and long-run exchange rate level terms. $\varphi_{t+1}^{EH,SR,\perp}$ is orthogonal to $(\tilde{\imath}_{t+1} - E_t\tilde{\imath}_{t+1})^{\perp}$, $\varphi_{t+1}^{EH,MR,\perp}$ is orthogonal to $\varphi_{t+1}^{EH,SR,\perp}$ and $(\tilde{\imath}_{t+1} - E_t\tilde{\imath}_{t+1})^{\perp}$ and so on.

Tables 19 - 22 present the results of this exercise. We find that it's changes in expectations over short and medium horizons (next quarter to 10 years) orthogonal to the contemporaneous surprise that explain most of the variation of the components capturing macroeconomic fundamentals. Regarding the currency risk premia component, it's news affecting expectations over the short run (next quarter to 5 years) that matter the most, followed by the contemporaneous surprise to the currency risk premia. When one splits the sample into pre-ZLB and ZLB and considers the US base, the patterns are such that during the pre-ZLB, contemporaneous news seem to matter more for the monetary policy component relative to the ZLB, as expected. These results imply that a model which delivers a data generating process for inflation, bill rates and currency risk premia that resembles an AR(1) process will not be able to match the term structure of expectations.

## 4.3 Exchange Rate Uncertainty

The decomposition of the exchange rate change forecast error in equation (4) allows us to also obtain estimates of the time-varying conditional variance of the exchange rate change. We can also decompose this conditional variance in a manner that parallels the unconditional case in equation (12):

$$
\begin{aligned}
E_t\left[(\Delta s_{t+1} - E_t\Delta s_{t+1})^2\right] \quad = \quad & E_t\left[\left(\varphi_{t+1}^{EH}\right)^2\right] + E_t\left[\left(\sigma_{t+1}^{F}\right)^2\right] + E_t\left[\left(s_{t+1,\infty}^{\Delta E}\right)^2\right] \\
& + 2E_t\left[\varphi_{t+1}^{EH}\sigma_{t+1}^{F}\right] - 2E_t\left[\varphi_{t+1}^{EH}s_{t+1,\infty}^{\Delta E}\right] - 2E_t\left[s_{t+1,\infty}^{\Delta E}\sigma_{t+1}^{F}\right]. \quad (13)
\end{aligned}
$$

Since the contemporaneous level of the exchange rate is known, this is equivalent to the conditional variance of the exchange rate level itself, $E_t\left[(s_{t+1} - E_t s_{t+1})^2\right] = E_t\left[(\Delta s_{t+1} - E_t\Delta s_{t+1})^2\right]$.

In order to estimate these conditional moments, we project each of the squared components and products of components in the expression above on the variables used in the VAR defined in equation (7) as these are considered to be in the time $t$ information set of market participants.[13] A similar procedure is used in Campbell and Shiller (1988) and Duffie (2005) to estimate conditional variances of stock and bond returns.

[13] We can use the same procedure to estimate conditional variances of the exchange rate change directly from the 3-month ahead exchange rate forecast survey data discussed in Section 3.1.1. Comparing these to the conditional variances estimated using our VAR-implied 3-month ahead forecasts gives correlations ranging from 86 to 97 percent.

The results from these projections are reported in Table 23. The main variables that appear to be correlated with the conditional variance of the exchange rate change across our different currency pairs are the U.S. GDP gap, inflation, and TED spread. Macroeconomic conditions in the other country in the pair are occasionally also significant in this regression.

The estimated conditional variances are plotted along with the squared forecast errors in Figure 8.[14] There are several features of note. One is that the squared forecast errors and the estimated conditional variances are highly volatile. Second, our procedure for estimating conditional variances is able to capture much of the variation in the squared forecast errors for most currencies. Lastly, by smoothing our conditional variance estimates, one can see that there is some low frequency movement with conditional variances being elevated for many currencies during U.S. recessions.

Figure 9 plots the estimated one-period-ahead conditional variances against within-quarter realized variances of daily exchange rate changes. The plots exhibit some common low frequency variation in these two variables. The correlation between these two series at a quarterly frequency ranges from 25 to 66 percent across our nine currency pairs.

Figures 10 through 15 plot estimates of the conditional variances and covariances of the exchange rate change components on the right-hand-side of equation (13). These conditional moments were estimated using the same projection on VAR variables. Thus, the equality in equation (13) holds for all the estimated conditional moments.

Tables 26 - **??** estimate a regression of the conditional variance of the exchange rate change and its components on recession indicators. The conditional exchange rate variance is higher when either the base currency country or the other country has a recession in a statistically significant way. The countercyclicality of the exchange rate uncertainty appears to be driven by the countercyclicality of the components which capture the relative monetary policy and inflation paths. Surprisingly, while the conditional variance of the currency risk premium component is countercyclical in a statistically significant way for the USD base specification, with respect to the US business cycle, there is no uniform pattern when one considers different base currencies. The last result can be potentially accounted for by models where the US economy is special due to its large real and financial sectors.

[14]Note that, as in Campbell and Shiller (1988), we use a linear projection without imposing nonnegativity in the estimation of conditional variances. This is to ensure that the estimated conditional second moments continue to follow equation (13).

# 5 Conclusion

[TO BE COMPLETED]

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# Tables and Figures

Table 1: Predictive Power of Survey Forecasted Exchange Rate Changes

| Months ahead: | 3 | 12 | 24 |
|---|---|---|---|
| $E_t^S[s_{t+h} - s_t]$ | 0.24*** | 0.49* | 0.85** |
| | (0.05) | (0.29) | (0.37) |
| Constant | −0.10*** | 0.09 | 1.04 |
| | (0.02) | (1.39) | (3.10) |
| Adj. $R^2$ | 0.01 | 0.05 | 0.13 |
| # of Observations | 954 | 927 | 729 |

Note: The dependent variable is the realized exchange rate change over the respective horizon. Standard errors are reported in parentheses. The 3-month ahead regression uses heteroskedasticity-robust standard errors clustered by currency pair. The 12- and 24-month ahead regressions use Driscoll-Kraay standard errors with a lag length of 3 and 7 quarters, respectively, to account for the overlapping observations at these horizons.

Table 2: Predictive Power of Survey Forecasted Excess Returns vs Interest Rate Differentials

| Rate differential Measure: | Bill rates | Libor rates | Forward premium |
|---|---|---|---|
| $\sigma_t^S$ | 0.25*** | 0.26*** | 0.23*** |
| | (0.06) | (0.06) | (0.06) |
| $\tilde{i}_t$ | 0.22 | 0.15 | 0.41 |
| | (0.43) | (0.45) | (0.29) |
| Constant | −0.09 | −0.14** | −0.13** |
| | (0.11) | (0.06) | (0.05) |
| Adj. $R^2$ | 0.01 | 0.01 | 0.01 |
| # of Observations | 954 | 863 | 918 |

Note: The dependent variable is the realized exchange rate change. Heteroskedasticity-robust standard errors clustered by currency pair are reported in parentheses.

Figure 1: Survey Forecasted Exchange Rate Changes vs Interest Rate Differentials

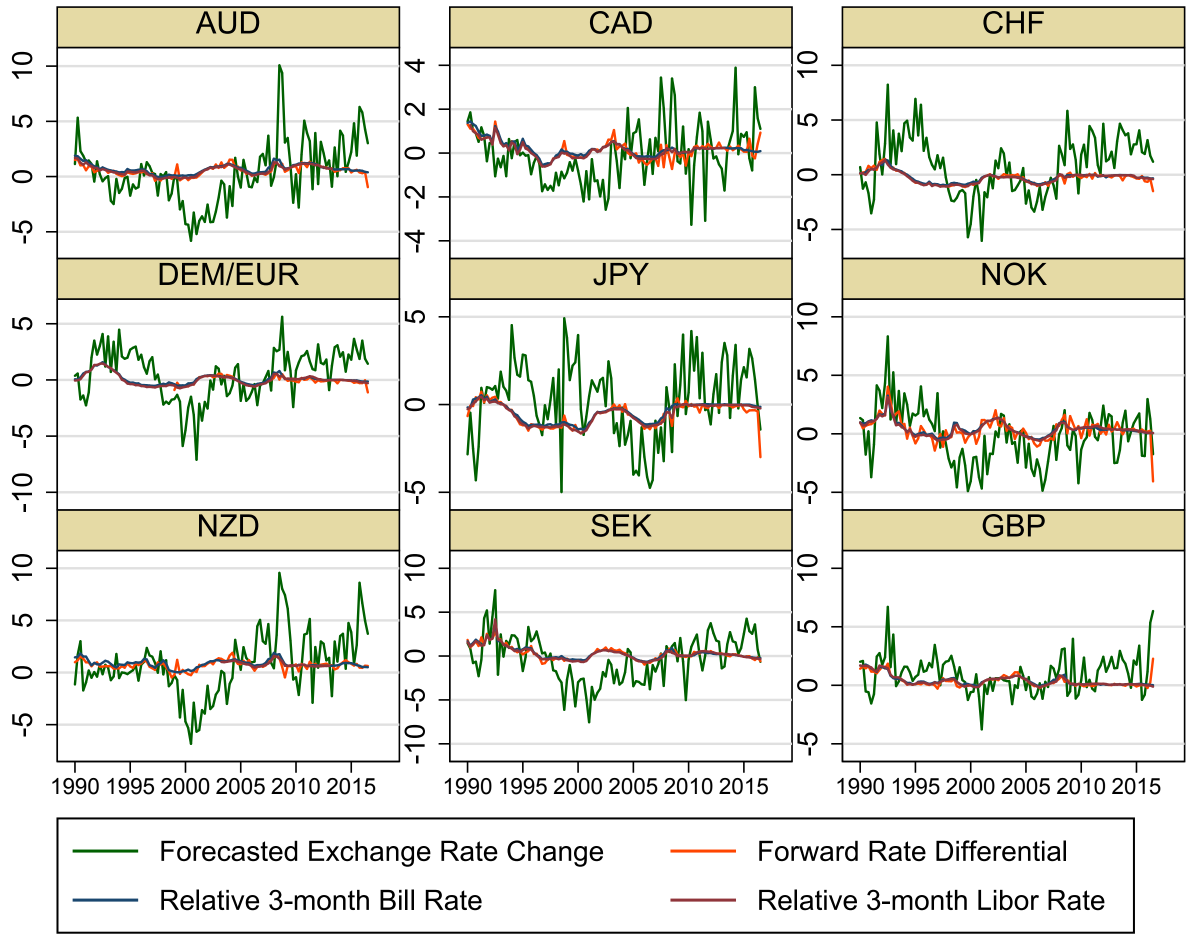



Table 3: Relationship Between Survey Forecasted Exchange Rate Changes and the Forward Premium

| | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| Forward Premium | 1.69*** | 0.48 | 1.35*** | 1.56* | 0.70** | 1.02*** | 1.19 | 1.47*** | 0.79* |
| | (0.63) | (0.31) | (0.49) | (0.84) | (0.31) | (0.30) | (0.87) | (0.33) | (0.46) |
| Constant | −0.59 | −0.13 | 1.24*** | 0.37 | 0.68*** | −0.55** | −0.07 | −0.72*** | 0.68*** |
| | (0.40) | (0.15) | (0.29) | (0.28) | (0.26) | (0.23) | (0.76) | (0.25) | (0.19) |
| Adj. $R^2$ | 0.07 | 0.02 | 0.07 | 0.04 | 0.03 | 0.15 | 0.02 | 0.17 | 0.05 |
| # of Observations | 107 | 107 | 107 | 71 | 107 | 107 | 107 | 107 | 107 |

Note: The dependent variable is the expected exchange rate change using the survey data. Heteroskedasticity-robust standard errors clustered by currency pair are reported in parentheses.

Table 4: Relationship Between Currency Risk Premia and Cross Country Net Flows

| | All Counterparties | Interbank |
|---|---|---|
| Net Flows | $-1.05^{**}$ | $-1.76^{**}$ |
| | (0.44) | (0.71) |
| Constant | 0.04 | $0.06^{*}$ |
| | (0.03) | (0.02) |
| Adj. $R^2$ | 0.01 | 0.01 |
| # of Observations | 932 | 928 |

Note: The dependent variable is the expected excess return defined as being long the dollar and short the currency of country $i$ between the end of period t and the end of period t+1. The independent variable is the net flows into country $i$ in period t in domestic currency calculated using BIS data. Heteroskedasticity-robust standard errors clustered by currency pair are reported in parentheses.

Table 5: Relationship Between U.S. Long-Horizon Interest Rate Forecasts, Macroeconomic Forecasts, and Forward Rates

| | Baseline | Wright (2011) |
|---|---|---|
| 6Y-10Y Ahead Inflation Forecast | $0.93^{***}$ | $1.60^{***}$ |
| | (0.23) | (0.22) |
| 6Y-10Y Ahead GDP Growth Forecast | $0.42^{***}$ | $0.86^{***}$ |
| | (0.13) | (0.13) |
| 5Y Ahead 5Y Forward Rate | $0.23^{***}$ | |
| | (0.04) | |
| Constant | $-0.17$ | $-1.86^{***}$ |
| | (0.57) | (0.60) |
| Adj. $R^2$ | 0.84 | 0.73 |
| # of Observations | 41 | 41 |

Note: The dependent variable is the 6Y-10Y ahead 3-month interest rate forecast. All dependent and independent variables in this regression are specific to the U.S. and are contemporaneous in timing. All forecast data used is from *Consensus Economics*. The sample is semi-annual observations over 1997:Q3–2013:Q4 and quarterly observations thereafter until 2015:Q4. Heteroskedasticity-robust standard errors are reported in parentheses.

Table 6: Correlations Between Survey and Model-Implied Forecasts: 3-month Interest Rates

**Panel A: With Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.990 | 0.990 | 0.972 | 0.991 | 0.991 | | | | 0.994 | 0.991 |
| 3M | CF | 0.996 | 0.992 | 0.990 | 0.996 | 0.997 | 0.991 | 0.994 | 0.995 | 0.996 | 0.998 |
| 6M | BC | 0.987 | 0.990 | 0.963 | 0.993 | 0.990 | | | | 0.995 | 0.993 |
| 12M | BC | 0.981 | 0.984 | 0.966 | 0.989 | 0.987 | | | | 0.995 | 0.988 |
| 12M | CF | 0.992 | 0.978 | 0.989 | 0.992 | 0.996 | 0.970 | 0.975 | 0.989 | 0.993 | 0.991 |
| 0Y | BC | 0.985 | 0.987 | | 0.994 | 0.980 | | | | 0.997 | |
| 1Y | BC | 0.963 | 0.979 | | 0.982 | 0.960 | | | | 0.992 | |
| 2Y | BC | 0.972 | 0.977 | | 0.972 | 0.945 | | | | 0.987 | |
| LR | BC/Imp. | 0.956 | 0.928 | 0.586 | 0.917 | 0.948 | 0.835 | 0.525 | 0.969 | 0.423 | 0.926 |

**Panel B: Without Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.974 | 0.983 | 0.955 | 0.984 | 0.990 | | | | 0.988 | 0.989 |
| 3M | CF | 0.994 | 0.991 | 0.989 | 0.994 | 0.998 | 0.988 | 0.991 | 0.986 | 0.994 | 0.997 |
| 6M | BC | 0.948 | 0.982 | 0.940 | 0.982 | 0.983 | | | | 0.988 | 0.985 |
| 12M | BC | 0.901 | 0.975 | 0.918 | 0.974 | 0.952 | | | | 0.987 | 0.969 |
| 12M | CF | 0.952 | 0.973 | 0.975 | 0.985 | 0.990 | 0.958 | 0.933 | 0.978 | 0.990 | 0.974 |
| 0Y | BC | 0.934 | 0.973 | | 0.978 | 0.945 | | | | 0.988 | |
| 1Y | BC | 0.819 | 0.961 | | 0.952 | 0.808 | | | | 0.980 | |
| 2Y | BC | 0.899 | 0.976 | | 0.955 | 0.628 | | | | 0.987 | |
| LR | BC/Imp. | 0.946 | 0.924 | -0.031 | 0.879 | 0.326 | 0.802 | 0.323 | 0.945 | -0.101 | 0.851 |

Note: The horizons 0Y-2Y in this table represent current year up to two years ahead. The "LR" horizon represents the average over years 7 to 11 ahead for the U.S. For other countries, this horizon represents imputed forecasts for the average of years 6 to 10 ahead. See the main text for details on the imputation method.

Table 7: RMSD Between Survey and Model-Implied Forecasts: 3-month Interest Rates

**Panel A: With Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.054 | 0.068 | 0.085 | 0.061 | 0.026 | | | | 0.067 | 0.074 |
| 3M | CF | 0.048 | 0.062 | 0.086 | 0.051 | 0.035 | 0.068 | 0.065 | 0.091 | 0.052 | 0.039 |
| 6M | BC | 0.064 | 0.066 | 0.094 | 0.053 | 0.027 | | | | 0.058 | 0.066 |
| 12M | BC | 0.076 | 0.078 | 0.083 | 0.062 | 0.033 | | | | 0.060 | 0.081 |
| 12M | CF | 0.077 | 0.094 | 0.081 | 0.060 | 0.038 | 0.114 | 0.103 | 0.114 | 0.065 | 0.070 |
| 0Y | BC | 0.064 | 0.075 | | 0.049 | 0.035 | | | | 0.048 | |
| 1Y | BC | 0.094 | 0.086 | | 0.078 | 0.058 | | | | 0.069 | |
| 2Y | BC | 0.089 | 0.082 | | 0.104 | 0.070 | | | | 0.086 | |
| LR | BC/Imp. | 0.075 | 0.064 | 0.062 | 0.089 | 0.088 | 0.071 | 0.071 | 0.054 | 0.072 | 0.072 |

**Panel B: Without Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.087 | 0.124 | 0.133 | 0.102 | 0.049 | | | | 0.134 | 0.150 |
| 3M | CF | 0.078 | 0.073 | 0.136 | 0.087 | 0.063 | 0.132 | 0.081 | 0.169 | 0.114 | 0.077 |
| 6M | BC | 0.130 | 0.152 | 0.164 | 0.113 | 0.070 | | | | 0.143 | 0.177 |
| 12M | BC | 0.194 | 0.224 | 0.216 | 0.162 | 0.128 | | | | 0.187 | 0.249 |
| 12M | CF | 0.288 | 0.196 | 0.255 | 0.172 | 0.152 | 0.232 | 0.181 | 0.260 | 0.194 | 0.230 |
| 0Y | BC | 0.129 | 0.155 | | 0.122 | 0.087 | | | | 0.134 | |
| 1Y | BC | 0.212 | 0.275 | | 0.241 | 0.192 | | | | 0.231 | |
| 2Y | BC | 0.229 | 0.360 | | 0.327 | 0.250 | | | | 0.310 | |
| LR | BC/Imp. | 0.290 | 0.569 | 0.456 | 0.573 | 0.654 | 0.477 | 0.236 | 0.562 | 0.678 | 0.663 |

Note: The horizons 0Y-2Y in this table represent current year up to two years ahead. The "LR" horizon represents the average over years 7 to 11 ahead for the U.S. For other countries, this horizon represents imputed forecasts for the average of years 6 to 10 ahead. See the main text for details on the imputation method.

Table 8: Correlations Between Survey and Model-Implied Forecasts: Nominal Exchange Rate

**Panel A: With Forecast Data**

| Horizon | Source | AUD | CAD | CHF | DEM | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.993 | 0.994 | 0.988 | 0.988 | 0.985 | | | | 0.982 |
| 3M | CF | 0.993 | 0.998 | 0.993 | 0.993 | 0.992 | 0.988 | 0.993 | 0.989 | 0.991 |
| 6M | BC | 0.985 | 0.993 | 0.986 | 0.985 | 0.985 | | | | 0.983 |
| 12M | BC | 0.982 | 0.985 | 0.984 | 0.978 | 0.973 | | | | 0.971 |
| 12M | CF | 0.987 | 0.996 | 0.986 | 0.989 | 0.984 | 0.974 | 0.985 | 0.974 | 0.986 |
| 24M | CF | 0.977 | 0.995 | 0.981 | 0.981 | 0.963 | 0.969 | 0.980 | 0.966 | 0.977 |
| 0Y | BC | 0.966 | 0.978 | | 0.973 | 0.980 | | | | 0.974 |
| 1Y | BC | 0.962 | 0.977 | | 0.958 | 0.960 | | | | 0.957 |
| 2Y | BC | 0.967 | 0.982 | | 0.929 | 0.956 | | | | 0.964 |
| 3M CP | BC | 0.770 | 0.410 | 0.746 | 0.724 | 0.539 | | | | 0.505 |
| 3M CP | CF | 0.637 | 0.648 | 0.748 | 0.738 | 0.597 | 0.478 | 0.670 | 0.595 | 0.561 |

**Panel B: Without Forecast Data**

| Horizon | Source | AUD | CAD | CHF | DEM | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.955 | 0.970 | 0.950 | 0.936 | 0.928 | | | | 0.904 |
| 3M | CF | 0.968 | 0.982 | 0.949 | 0.950 | 0.950 | 0.950 | 0.973 | 0.938 | 0.936 |
| 6M | BC | 0.884 | 0.935 | 0.901 | 0.857 | 0.841 | | | | 0.820 |
| 12M | BC | 0.807 | 0.851 | 0.804 | 0.706 | 0.577 | | | | 0.764 |
| 12M | CF | 0.841 | 0.884 | 0.811 | 0.706 | 0.648 | 0.707 | 0.845 | 0.656 | 0.775 |
| 24M | CF | 0.671 | 0.707 | 0.838 | 0.466 | 0.242 | 0.585 | 0.581 | 0.465 | 0.637 |
| 0Y | BC | 0.913 | 0.928 | | 0.869 | 0.836 | | | | 0.820 |
| 1Y | BC | 0.804 | 0.768 | | 0.605 | 0.513 | | | | 0.720 |
| 2Y | BC | 0.612 | 0.691 | | 0.383 | 0.327 | | | | 0.718 |
| 3M CP | BC | -0.011 | -0.133 | 0.095 | -0.056 | 0.005 | | | | -0.163 |
| 3M CP | CF | 0.201 | 0.293 | 0.027 | 0.035 | 0.155 | -0.003 | 0.148 | 0.072 | 0.187 |

Note: The horizons 0Y, 1Y, and 2Y in this table represent current year, next year, and two years ahead. The remaining horizons are months out from the forecast month. Exchange rate forecasts are for end-of-period values. The “3M CP” rows correspond to fits of survey-implied 3-month currency premia, for both sources of survey data, computed using the 3-month bill rate data used in our VAR. The units for currency premia are in unannualized percents.

Table 9: RMSD Between Survey and Model-Implied Forecasts: Nominal Exchange Rate

**Panel A: With Forecast Data**

| Horizon | Source | AUD | CAD | CHF | DEM | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.023 | 0.017 | 0.025 | 0.022 | 0.024 | | | | 0.019 |
| 3M | CF | 0.021 | 0.010 | 0.018 | 0.015 | 0.018 | 0.021 | 0.021 | 0.020 | 0.012 |
| 6M | BC | 0.030 | 0.018 | 0.027 | 0.023 | 0.024 | | | | 0.020 |
| 12M | BC | 0.033 | 0.024 | 0.029 | 0.026 | 0.031 | | | | 0.023 |
| 12M | CF | 0.024 | 0.013 | 0.023 | 0.017 | 0.024 | 0.028 | 0.026 | 0.025 | 0.014 |
| 24M | CF | 0.030 | 0.013 | 0.023 | 0.019 | 0.028 | 0.028 | 0.025 | 0.023 | 0.016 |
| 0Y | BC | 0.048 | 0.032 | | 0.030 | 0.026 | | | | 0.021 |
| 1Y | BC | 0.048 | 0.030 | | 0.032 | 0.032 | | | | 0.024 |
| 2Y | BC | 0.049 | 0.025 | | 0.039 | 0.035 | | | | 0.023 |
| 3M CP | BC | 2.259 | 1.720 | 2.453 | 2.156 | 2.417 | | | | 1.915 |
| 3M CP | CF | 2.094 | 1.021 | 1.780 | 1.491 | 1.791 | 2.059 | 2.134 | 2.029 | 1.224 |

**Panel B: Without Forecast Data**

| Horizon | Source | AUD | CAD | CHF | DEM | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|---|
| 3M | BC | 0.055 | 0.037 | 0.054 | 0.048 | 0.052 | | | | 0.041 |
| 3M | CF | 0.044 | 0.028 | 0.051 | 0.041 | 0.046 | 0.043 | 0.044 | 0.050 | 0.032 |
| 6M | BC | 0.087 | 0.054 | 0.077 | 0.069 | 0.075 | | | | 0.055 |
| 12M | BC | 0.110 | 0.087 | 0.117 | 0.092 | 0.113 | | | | 0.060 |
| 12M | CF | 0.093 | 0.078 | 0.111 | 0.088 | 0.107 | 0.103 | 0.101 | 0.116 | 0.055 |
| 24M | CF | 0.132 | 0.157 | 0.125 | 0.115 | 0.131 | 0.144 | 0.178 | 0.162 | 0.067 |
| 0Y | BC | 0.079 | 0.057 | | 0.067 | 0.075 | | | | 0.052 |
| 1Y | BC | 0.110 | 0.115 | | 0.104 | 0.111 | | | | 0.060 |
| 2Y | BC | 0.149 | 0.176 | | 0.127 | 0.126 | | | | 0.063 |
| 3M CP | BC | 5.505 | 3.665 | 5.404 | 4.836 | 5.186 | | | | 4.085 |
| 3M CP | CF | 4.434 | 2.827 | 5.133 | 4.137 | 4.584 | 4.283 | 4.381 | 4.973 | 3.170 |

Note: The horizons 0Y, 1Y, and 2Y in this table represent current year, next year, and two years ahead. The remaining horizons are months out from the forecast month. Exchange rate forecasts are for end-of-period values. The "3M CP" rows correspond to fits of survey-implied 3-month currency premia, for both sources of survey data, computed using the 3-month bill rate data used in our VAR. The units for currency premia are in unannualized percents.

Table 10: Correlations Between Survey and Model-Implied Forecasts: Inflation

**Panel A: With Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0Y | BC | 0.907 | 0.905 | | 0.907 | 0.962 | | | | 0.972 | |
| 0Y | CF | 0.940 | 0.973 | 0.991 | 0.934 | 0.985 | 0.973 | 0.909 | 0.992 | 0.993 | 0.990 |
| 1Y | BC | 0.794 | 0.788 | | 0.904 | 0.921 | | | | 0.893 | |
| 1Y | CF | 0.896 | 0.738 | 0.979 | 0.930 | 0.949 | 0.921 | 0.779 | 0.979 | 0.927 | 0.971 |
| 2Y | BC | 0.905 | 0.807 | | 0.937 | 0.821 | | | | 0.613 | |
| 2Y | CF | 0.908 | 0.655 | 0.975 | 0.923 | 0.916 | 0.902 | 0.851 | 0.978 | 0.618 | 0.965 |
| LR | CF | 0.895 | 0.577 | 0.214 | 0.906 | 0.773 | -0.226 | 0.728 | 0.689 | 0.877 | 0.942 |

**Panel B: Without Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0Y | BC | 0.861 | 0.841 | | 0.834 | 0.935 | | | | 0.925 | |
| 0Y | CF | 0.865 | 0.947 | 0.974 | 0.883 | 0.977 | 0.944 | 0.863 | 0.983 | 0.966 | 0.978 |
| 1Y | BC | 0.175 | 0.233 | | 0.268 | 0.712 | | | | 0.510 | |
| 1Y | CF | 0.202 | 0.294 | 0.728 | 0.449 | 0.868 | 0.537 | 0.457 | 0.879 | 0.578 | 0.772 |
| 2Y | BC | -0.514 | -0.103 | | -0.043 | 0.357 | | | | 0.008 | |
| 2Y | CF | -0.515 | 0.063 | 0.284 | 0.155 | 0.640 | 0.283 | 0.246 | 0.737 | -0.141 | 0.650 |
| LR | CF | -0.696 | 0.505 | 0.112 | -0.457 | 0.158 | 0.464 | 0.506 | 0.051 | 0.028 | 0.137 |

Note: The horizons 0Y, 1Y, and 2Y in this table represent current year, next year, and two years ahead. Inflation forecasts are on an annual-average over annual-average basis. The "LR" horizon represents the average over years 6 to 10 ahead.

Table 11: RMSD Between Survey and Model-Implied Forecasts: Inflation

**Panel A: With Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0Y | BC | 0.403 | 0.286 | | 0.365 | 0.232 | | | | 0.231 | |
| 0Y | CF | 0.358 | 0.156 | 0.182 | 0.343 | 0.196 | 0.205 | 0.450 | 0.287 | 0.120 | 0.148 |
| 1Y | BC | 0.282 | 0.184 | | 0.232 | 0.304 | | | | 0.181 | |
| 1Y | CF | 0.414 | 0.209 | 0.194 | 0.233 | 0.322 | 0.301 | 0.487 | 0.304 | 0.189 | 0.190 |
| 2Y | BC | 0.168 | 0.190 | | 0.176 | 0.426 | | | | 0.144 | |
| 2Y | CF | 0.313 | 0.133 | 0.214 | 0.215 | 0.400 | 0.306 | 0.255 | 0.265 | 0.158 | 0.157 |
| LR | CF | 0.281 | 0.193 | 0.190 | 0.189 | 0.351 | 0.336 | 0.211 | 0.229 | 0.167 | 0.199 |

**Panel B: Without Forecast Data**

| Horizon | Source | AU | CA | CH | DE | JP | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0Y | BC | 0.535 | 0.400 | | 0.524 | 0.320 | | | | 0.410 | |
| 0Y | CF | 0.577 | 0.228 | 0.339 | 0.484 | 0.236 | 0.316 | 0.591 | 0.449 | 0.282 | 0.226 |
| 1Y | BC | 0.806 | 0.587 | | 0.739 | 0.653 | | | | 0.750 | |
| 1Y | CF | 1.270 | 0.528 | 1.050 | 0.721 | 0.512 | 0.749 | 0.902 | 1.019 | 0.732 | 0.536 |
| 2Y | BC | 0.960 | 0.688 | | 0.795 | 0.969 | | | | 0.755 | |
| 2Y | CF | 1.420 | 0.590 | 1.685 | 0.805 | 0.840 | 0.816 | 0.832 | 1.352 | 0.791 | 0.597 |
| LR | CF | 1.169 | 0.498 | 6.927 | 0.723 | 1.179 | 0.579 | 0.380 | 0.873 | 0.381 | 0.872 |

Note: The horizons 0Y, 1Y, and 2Y in this table represent current year, next year, and two years ahead. Inflation forecasts are on an annual-average over annual-average basis. The "LR" horizon represents the average over years 6 to 10 ahead.

Figure 2: Model-Implied and Survey Forecasts: 3-Month Interest Rate (12 Months Ahead)

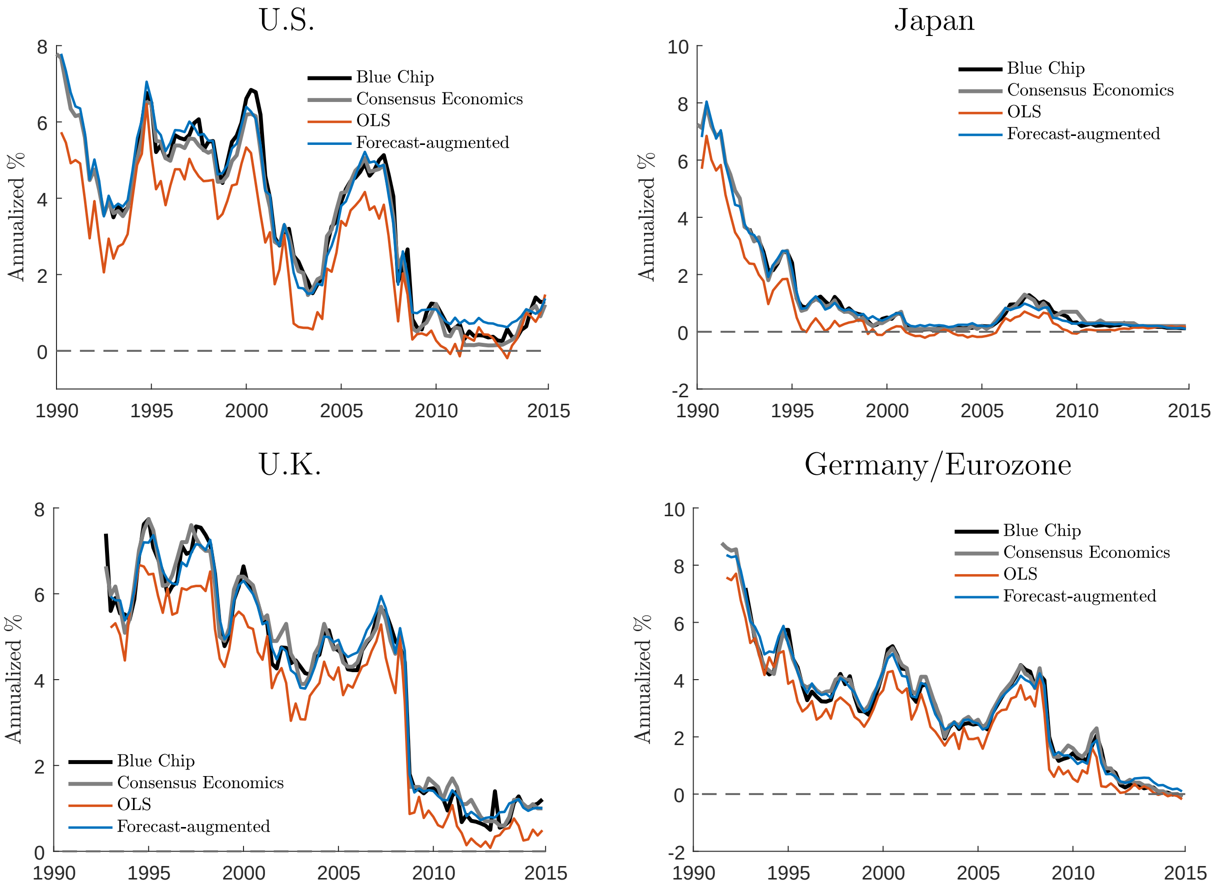
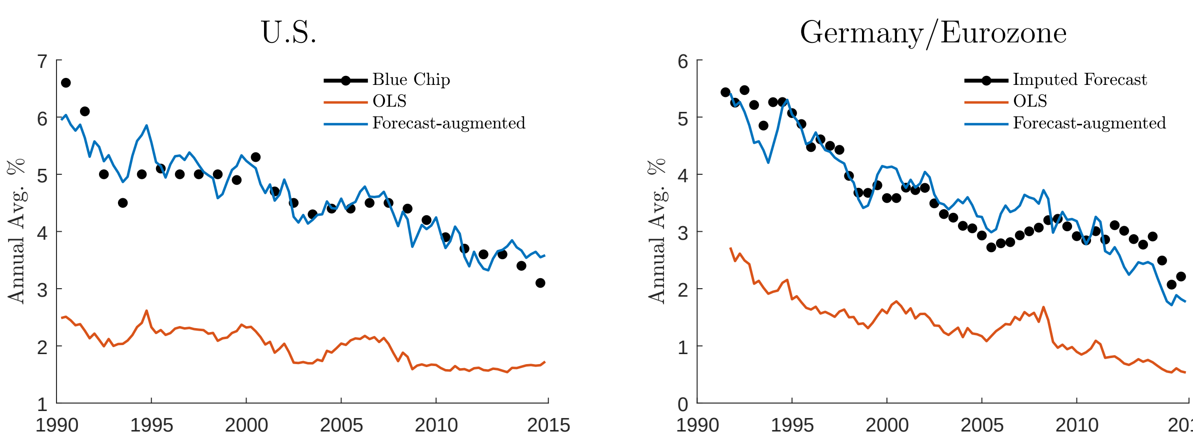



Figure 3: Model-Implied and Survey Forecasts: 3-Month Interest Rate (Long Horizon)




Note: The long horizon for the U.S. is the 7-11 year ahead average while it is the 6-10 year ahead for all other countries.

Figure 4: Model-Implied and Survey Forecasts: Inflation (1 Year Ahead)

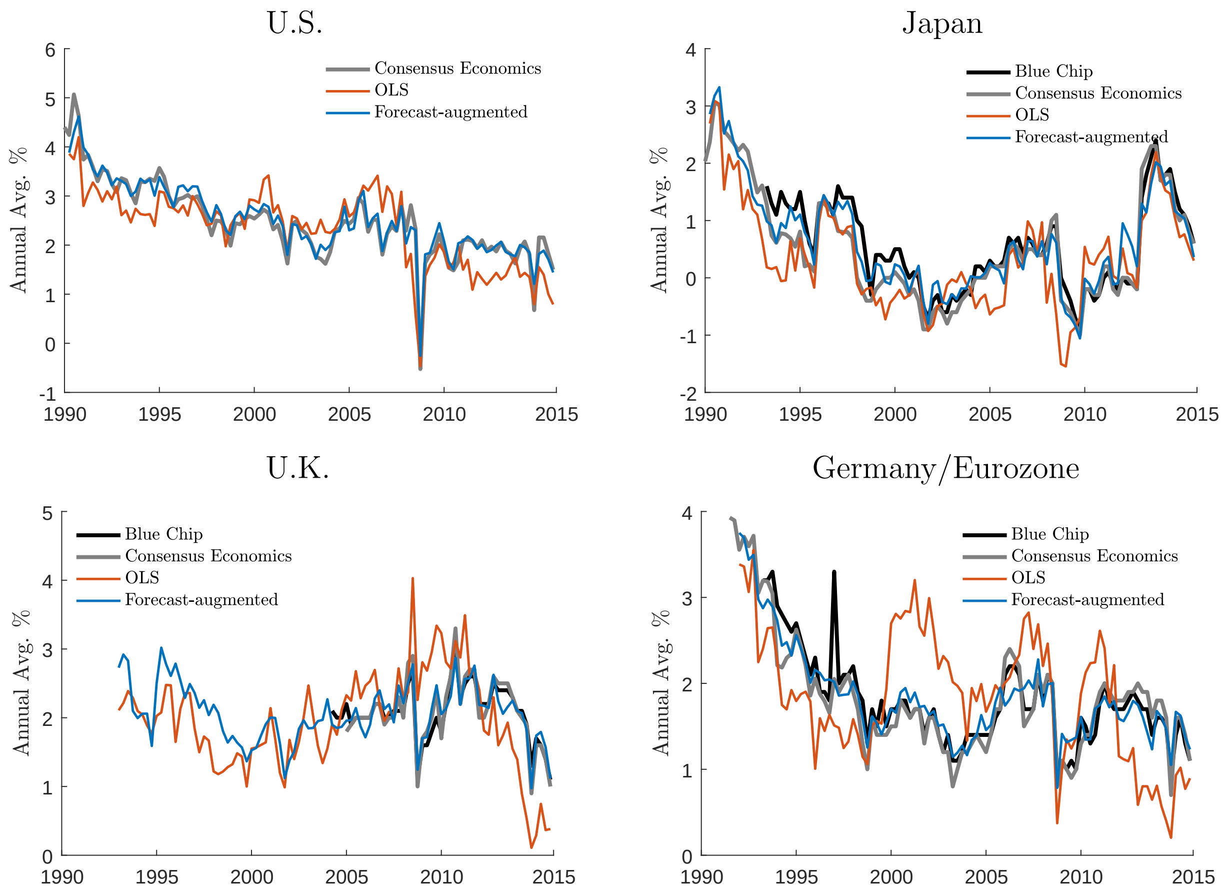



Figure 5: Model-Implied and Survey Forecasts: Inflation (6-10 Years Ahead)

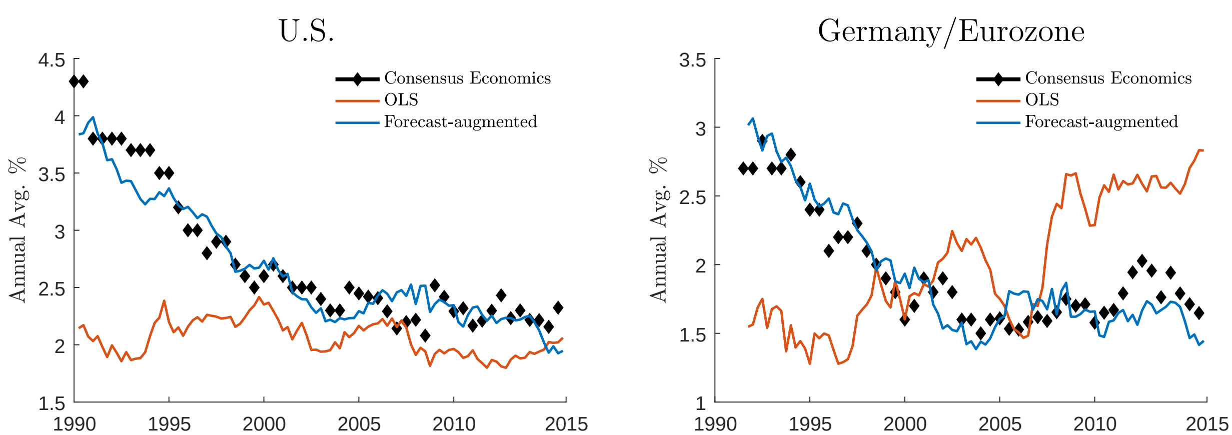


Figure 6: Model-Implied and Survey Forecasts: Exchange Rates (24 Months Ahead)

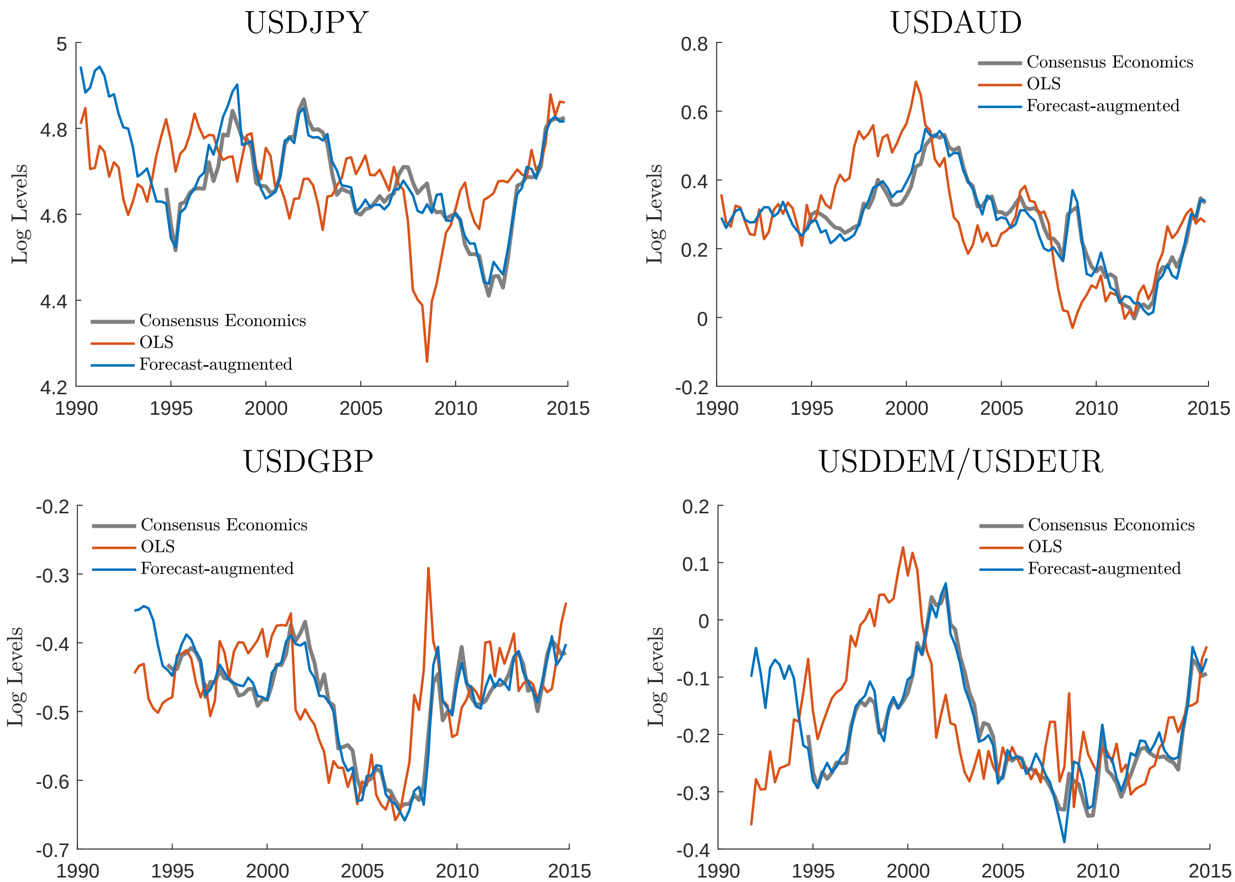



Figure 7: Model-Implied and Survey Currency Premia (3-Month Horizon)

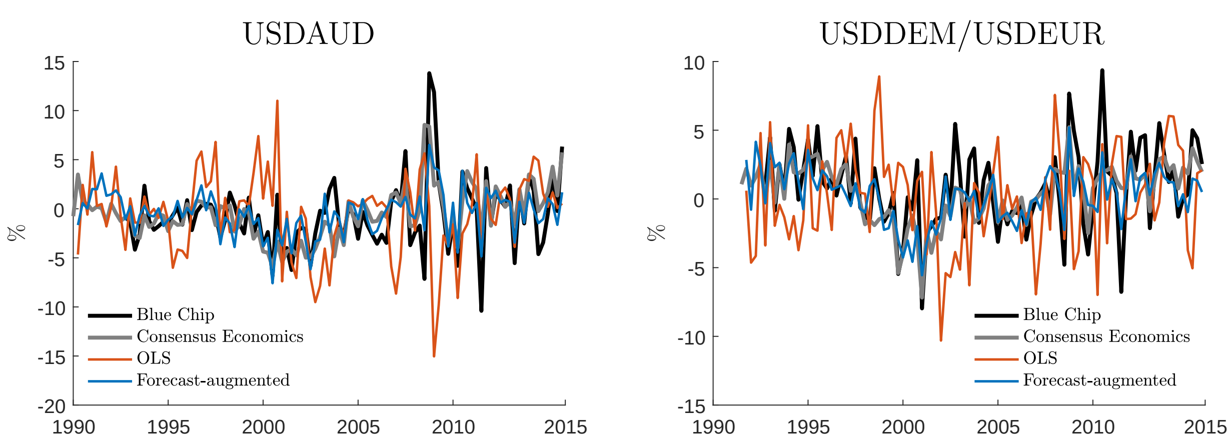


Table 12: Correlation between Model-Implied and Market-Based 3-Month Interest Rate Surprises

| | AU | CA | CH | DE | NO | NZ | SE | UK | US |
|---|---|---|---|---|---|---|---|---|---|
| | 0.83 | 0.68 | 0.63 | 0.84 | 0.12 | 0.86 | 0.79 | 0.81 | 0.76 |
| # Observations | 105 | 100 | 102 | 96 | 102 | 102 | 102 | 110 | 115 |

Note: These correlations are between errors in 3-month ahead forecasts, based on our VAR and futures/forwards prices, of 3-month interest rates.

Table 13: Component Variances and Covariances

| Bases (avg across pairs) | AUD | CAD | CHF | DEM/EUR | GBP | JPY | NOK | NZD | SEK | USD |
|---|---|---|---|---|---|---|---|---|---|---|
| $Var(\Delta s_{t+1})$ | 35.54 | 27.28 | 31.40 | 24.28 | 24.80 | 48.25 | 27.46 | 33.64 | 28.42 | 30.52 |
| $Var(\tilde{i}_t - \varphi^{EH}_{t+1})$ | 21.32 | 9.60 | 15.22 | 12.32 | 7.92 | 25.66 | 21.47 | 12.27 | 17.62 | 15.18 |
| $Var(s^{\Delta E}_{t+1,\infty})$ | 5.23 | 6.06 | 5.82 | 9.42 | 9.09 | 8.41 | 6.95 | 13.19 | 6.17 | 6.41 |
| $Var(\sigma_t - \sigma^F_{t+1})$ | 31.63 | 28.24 | 33.40 | 31.57 | 27.01 | 51.78 | 40.05 | 34.95 | 30.73 | 28.37 |
| $Cov(\tilde{i}_t - \varphi^{EH}_{t+1}, s^{\Delta E}_{t+1,\infty})$ | −6.08 | −2.91 | −3.22 | −2.86 | −3.49 | −9.93 | −1.98 | −5.08 | −5.75 | −4.75 |
| $Cov(\tilde{i}_t - \varphi^{EH}_{t+1}, \sigma_t - \sigma^F_{t+1})$ | −4.91 | −3.81 | −7.65 | −7.15 | −1.96 | −7.70 | −13.00 | −2.40 | −7.81 | −3.81 |
| $Cov(s^{\Delta E}_{t+1,\infty}, \sigma_t - \sigma^F_{t+1})$ | −0.33 | −1.59 | −0.64 | −4.51 | −4.16 | −1.18 | −5.52 | −5.90 | 0.50 | −1.17 |

Note: Variance-covariance decomposition of the exchange rate change components based on the survey-data augmented VAR.

Table 14: Component Variances and Covariances

| USD Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $Var(\Delta s_{t+1})$ | 34.52 | 15.04 | 36.60 | 28.92 | 35.86 | 35.43 | 31.63 | 38.30 | 18.36 |
| $Var(\tilde{i}_t - \varphi^{EH}_{t+1})$ | 15.21 | 6.05 | 14.17 | 10.45 | 22.07 | 29.05 | 9.49 | 23.92 | 6.24 |
| $Var(s^{\Delta E}_{t+1,\infty})$ | 2.20 | 7.76 | 1.18 | 1.19 | 9.07 | 0.86 | 18.50 | 3.74 | 13.23 |
| $Var(\sigma_t - \sigma^F_{t+1})$ | 30.53 | 13.62 | 29.29 | 27.48 | 38.92 | 35.85 | 34.87 | 28.64 | 16.16 |
| $Cov(\tilde{i}_t - \varphi^{EH}_{t+1}, s^{\Delta E}_{t+1,\infty})$ | −3.41 | −3.83 | −3.18 | 1.81 | −10.33 | −1.97 | −8.62 | −7.09 | −6.11 |
| $Cov(\tilde{i}_t - \varphi^{EH}_{t+1}, \sigma_t - \sigma^F_{t+1})$ | −5.11 | −3.15 | −0.19 | −4.94 | −2.89 | −14.16 | −0.86 | −4.31 | 1.34 |
| $Cov(s^{\Delta E}_{t+1,\infty}, \sigma_t - \sigma^F_{t+1})$ | 1.81 | 0.79 | −0.65 | −1.97 | −3.88 | 0.97 | −6.13 | 2.40 | −3.87 |

Note: Variance-covariance decomposition of the exchange rate change components based on the survey-data augmented VAR.

Table 15: Component Variances and Covariances

| Pre-ZLB | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bases (avg across pairs) | AUD | CAD | CHF | DEM/EUR | GBP | JPY | NOK | NZD | SEK | USD |
| $Var(\Delta s_{t+1})$ | 35.69 | 27.63 | 28.99 | 22.76 | 19.69 | 42.23 | 24.41 | 31.96 | 29.19 | 28.11 |
| $Var(\tilde{i}_t - \varphi_{t+1}^{EH})$ | 23.23 | 11.31 | 16.04 | 12.78 | 9.01 | 32.14 | 24.64 | 14.53 | 21.56 | 18.93 |
| $Var(s_{t+1,\infty}^{\Delta E})$ | 5.37 | 5.99 | 5.35 | 9.44 | 8.63 | 8.99 | 7.03 | 13.00 | 6.48 | 6.09 |
| $Var(\sigma_t - \sigma_{t+1}^F)$ | 31.49 | 29.71 | 33.20 | 30.93 | 25.21 | 47.28 | 34.83 | 35.05 | 31.38 | 28.51 |
| $Cov(\tilde{i}_t - \varphi_{t+1}^{EH}, s_{t+1,\infty}^{\Delta E})$ | −6.47 | −2.92 | −3.72 | −1.95 | −3.57 | −11.97 | −1.97 | −5.13 | −6.59 | −5.79 |
| $Cov(\tilde{i}_t - \varphi_{t+1}^{EH}, \sigma_t - \sigma_{t+1}^F)$ | −5.85 | −5.40 | −8.71 | −8.87 | −2.78 | −13.63 | −14.94 | −4.39 | −10.54 | −5.69 |
| $Cov(s_{t+1,\infty}^{\Delta E}, \sigma_t - \sigma_{t+1}^F)$ | 0.12 | −1.37 | −0.37 | −4.37 | −5.23 | 2.50 | −4.13 | −5.79 | 2.02 | −1.23 |

Note: Variance-covariance decomposition of the exchange rate change components based on the survey-data augmented VAR.

Table 16: Component Variances and Covariances

| ZLB | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Bases (avg across pairs) | AUD | CAD | DEM/EUR | GBP | JPY | NOK | NZD | SEK | USD |
| $Var(\Delta s_{t+1})$ | 33.92 | 25.05 | 30.53 | 34.83 | 68.53 | 34.68 | 37.56 | 26.90 | 37.18 |
| $Var(\tilde{i}_t - \varphi_{t+1}^{EH})$ | 15.25 | 6.09 | 11.12 | 5.98 | 8.69 | 14.10 | 6.90 | 7.11 | 5.49 |
| $Var(s_{t+1,\infty}^{\Delta E})$ | 5.30 | 6.24 | 10.39 | 9.63 | 6.90 | 7.55 | 13.48 | 5.78 | 8.01 |
| $Var(\sigma_t - \sigma_{t+1}^F)$ | 32.92 | 24.77 | 36.10 | 31.74 | 66.12 | 54.21 | 36.36 | 29.33 | 29.19 |
| $Cov(\tilde{i}_t - \varphi_{t+1}^{EH}, s_{t+1,\infty}^{\Delta E})$ | −5.35 | −3.42 | −5.24 | −4.04 | −4.83 | −2.13 | −5.71 | −3.76 | −2.30 |
| $Cov(\tilde{i}_t - \varphi_{t+1}^{EH}, \sigma_t - \sigma_{t+1}^F)$ | −2.51 | 0.06 | −2.86 | −0.22 | 9.11 | −8.47 | 2.86 | 0.24 | 0.97 |
| $Cov(s_{t+1,\infty}^{\Delta E}, \sigma_t - \sigma_{t+1}^F)$ | −1.91 | −2.67 | −5.43 | −2.00 | −10.87 | −9.99 | −6.73 | −4.14 | −1.43 |

Note: Variance-covariance decomposition of the exchange rate change components based on the survey-data augmented VAR.

Table 17: Regressing The Exchange Rate Change on Fundamental

| USD Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $\tilde{i}_t - \varphi^{EH}_{t+1} + s^{\Delta E}_{t+1,\infty}$ | $0.69^{***}$ | $0.62^{***}$ | $0.91^{***}$ | $0.55^{***}$ | $0.35^{**}$ | $0.49^{***}$ | $0.35^{*}$ | $0.86^{***}$ | $0.65^{**}$ |
| Adj. $R^2$ | 0.14 | 0.15 | 0.19 | 0.15 | 0.03 | 0.17 | 0.03 | 0.25 | 0.16 |
| # of Observations | 102 | 93 | 84 | 96 | 102 | 102 | 102 | 102 | 91 |

| GBP Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | USD |
|---|---|---|---|---|---|---|---|---|---|
| $\tilde{i}_t - \varphi^{EH}_{t+1} + s^{\Delta E}_{t+1,\infty}$ | $0.42^{*}$ | 0.15 | $0.63^{**}$ | $0.23^{*}$ | $1.03^{**}$ | 0.12 | $0.69^{**}$ | 0.26 | $0.65^{**}$ |
| Adj. $R^2$ | 0.03 | -0.00 | 0.18 | 0.04 | 0.13 | 0.01 | 0.04 | 0.02 | 0.16 |
| # of Observations | 91 | 91 | 73 | 91 | 91 | 91 | 91 | 91 | 91 |

| DEM/EUR Base | AUD | CAD | CHF | JPY | NOK | NZD | SEK | GBP | USD |
|---|---|---|---|---|---|---|---|---|---|
| $\tilde{i}_t - \varphi^{EH}_{t+1} + s^{\Delta E}_{t+1,\infty}$ | $0.65^{***}$ | $0.34^{**}$ | $-0.03$ | 0.21 | $-0.08$ | $0.45^{***}$ | $-0.19$ | $0.23^{*}$ | $0.55^{***}$ |
| Adj. $R^2$ | 0.18 | 0.06 | -0.01 | 0.01 | -0.00 | 0.13 | 0.02 | 0.04 | 0.15 |
| # of Observations | 96 | 93 | 78 | 96 | 96 | 96 | 96 | 91 | 96 |

Table 18: Regressing The Exchange Rate Change on Currency Premia Component

| USD Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{t+1} - E_t[\sigma_{t+1}]$ | 0.89*** | 0.83*** | 0.97*** | 0.75*** | 0.83*** | 0.63*** | 0.80*** | 0.93*** | 0.84*** |
| Adj. $R^2$ | 0.70 | 0.61 | 0.75 | 0.53 | 0.74 | 0.40 | 0.70 | 0.65 | 0.62 |
| # of Observations | 102 | 93 | 84 | 96 | 102 | 102 | 102 | 102 | 91 |

| GBP Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | USD |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{t+1} - E_t[\sigma_{t+1}]$ | 0.86*** | 0.79*** | 0.79*** | 0.52*** | 1.01*** | 0.41*** | 0.96*** | 0.75*** | 0.84*** |
| Adj. $R^2$ | 0.77 | 0.75 | 0.54 | 0.40 | 0.87 | 0.34 | 0.89 | 0.67 | 0.62 |
| # of Observations | 91 | 91 | 73 | 91 | 91 | 91 | 91 | 91 | 91 |

| DEM/EUR Base | AUD | CAD | CHF | JPY | NOK | NZD | SEK | GBP | USD |
|---|---|---|---|---|---|---|---|---|---|
| $\sigma_{t+1} - E_t[\sigma_{t+1}]$ | 0.82*** | 0.67*** | 0.38*** | 0.72*** | 0.43*** | 0.64*** | 0.56*** | 0.52*** | 0.75*** |
| Adj. $R^2$ | 0.58 | 0.53 | 0.39 | 0.65 | 0.48 | 0.43 | 0.64 | 0.40 | 0.53 |
| # of Observations | 96 | 93 | 78 | 96 | 96 | 96 | 96 | 91 | 96 |

Table 19: Variance Ratios of Subcomponents Orthogonalized Across Horizons

| Bases (avg across pairs) | AUD | CAD | CHF | DEM/EUR | GBP | JPY | NOK | NZD | SEK | USD |
|---|---|---|---|---|---|---|---|---|---|---|
| $\frac{Var\left(\left(\tilde{i}_{t+1}-E_t[\tilde{i}_{t+1}]\right)^{\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.46 | 0.42 | 0.48 | 0.34 | 0.32 | 0.35 | 0.56 | 0.41 | 0.41 | 0.44 |
| $\frac{Var\left(\varphi_{t+1}^{EH,SR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.33 | 0.41 | 0.37 | 0.35 | 0.35 | 0.33 | 0.32 | 0.35 | 0.37 | 0.39 |
| $\frac{Var\left(\varphi_{t+1}^{EH,MR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.18 | 0.14 | 0.12 | 0.23 | 0.25 | 0.27 | 0.10 | 0.22 | 0.19 | 0.14 |
| $\frac{Var\left(\varphi_{t+1}^{EH,LR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.02 | 0.03 | 0.02 | 0.08 | 0.08 | 0.05 | 0.02 | 0.02 | 0.03 | 0.03 |
| $\frac{Var\left((\sigma_{t+1}-E_t[\sigma_{t+1}])^{\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.42 | 0.44 | 0.34 | 0.33 | 0.38 | 0.22 | 0.06 | 0.11 | 0.11 | 0.38 |
| $\frac{Var\left(\sigma_{t+1}^{F,SR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.24 | 0.32 | 0.44 | 0.44 | 0.26 | 0.62 | 0.44 | 0.61 | 0.57 | 0.43 |
| $\frac{Var\left(\sigma_{t+1}^{F,MR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.07 | 0.12 | 0.10 | 0.10 | 0.03 | 0.07 | 0.26 | 0.21 | 0.10 | 0.09 |
| $\frac{Var\left(\sigma_{t+1}^{F,LR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.28 | 0.12 | 0.11 | 0.13 | 0.33 | 0.09 | 0.24 | 0.07 | 0.22 | 0.10 |
| $\frac{Var\left((\tilde{\pi}_{t+1}-E_t[\tilde{\pi}_{t+1}])^{\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.13 | 0.07 | 0.14 | 0.03 | 0.08 | 0.15 | 0.05 | 0.03 | 0.15 | 0.17 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,SR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.46 | 0.54 | 0.53 | 0.55 | 0.55 | 0.38 | 0.32 | 0.54 | 0.46 | 0.50 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,MR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.29 | 0.23 | 0.22 | 0.25 | 0.22 | 0.35 | 0.49 | 0.33 | 0.24 | 0.22 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,LR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.12 | 0.16 | 0.10 | 0.17 | 0.15 | 0.12 | 0.14 | 0.10 | 0.16 | 0.11 |

Note: Variance ratios of components at different horizons based on the survey-data augmented VAR. Subcomponents at each horizon are orthogonalized with respect to subcomponents of preceding horizons.

Table 20: Variance Ratios of Subcomponents Orthogonalized Across Horizons

| USD Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $\frac{Var\left(\left(\tilde{i}_{t+1}-E_t[\tilde{i}_{t+1}]\right)^{\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.50 | 0.37 | 0.55 | 0.41 | 0.34 | 0.66 | 0.28 | 0.56 | 0.29 |
| $\frac{Var\left(\varphi_{t+1}^{EH,SR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.31 | 0.53 | 0.40 | 0.37 | 0.30 | 0.30 | 0.54 | 0.32 | 0.42 |
| $\frac{Var\left(\varphi_{t+1}^{EH,MR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.17 | 0.09 | 0.05 | 0.13 | 0.30 | 0.04 | 0.16 | 0.12 | 0.20 |
| $\frac{Var\left(\varphi_{t+1}^{EH,LR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.02 | 0.01 | 0.00 | 0.09 | 0.06 | 0.00 | 0.01 | 0.00 | 0.09 |
| $\frac{Var\left((\sigma_{t+1}-E_t[\sigma_{t+1}])^{\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.55 | 0.45 | 0.69 | 0.63 | 0.45 | 0.01 | 0.06 | 0.02 | 0.55 |
| $\frac{Var\left(\sigma_{t+1}^{F,SR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.20 | 0.30 | 0.23 | 0.31 | 0.44 | 0.63 | 0.76 | 0.88 | 0.12 |
| $\frac{Var\left(\sigma_{t+1}^{F,MR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.01 | 0.13 | 0.07 | 0.05 | 0.03 | 0.30 | 0.18 | 0.04 | 0.00 |
| $\frac{Var\left(\sigma_{t+1}^{F,LR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.24 | 0.12 | 0.01 | 0.01 | 0.08 | 0.07 | 0.01 | 0.07 | 0.33 |
| $\frac{Var\left((\tilde{\pi}_{t+1}-E_t[\tilde{\pi}_{t+1}])^{\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.23 | 0.15 | 0.30 | 0.03 | 0.26 | 0.07 | 0.05 | 0.18 | 0.23 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,SR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.65 | 0.70 | 0.45 | 0.23 | 0.39 | 0.43 | 0.65 | 0.51 | 0.51 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,MR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.11 | 0.12 | 0.15 | 0.29 | 0.30 | 0.29 | 0.25 | 0.29 | 0.15 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,LR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.01 | 0.03 | 0.10 | 0.45 | 0.04 | 0.20 | 0.04 | 0.01 | 0.11 |

Note: Variance ratios of components at different horizons based on the survey-data augmented VAR. Subcomponents at each horizon are orthogonalized with respect to subcomponents of preceding horizons.

Table 21: Variance Ratios of Subcomponents Orthogonalized Across Horizons

| Pre-ZLB | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bases (avg across pairs) | AUD | CAD | CHF | DEM/EUR | GBP | JPY | NOK | NZD | SEK | USD |
| $\frac{Var\left(\left(\tilde{i}_{t+1}-E_t[\tilde{i}_{t+1}]\right)^{\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.49 | 0.46 | 0.50 | 0.36 | 0.43 | 0.35 | 0.66 | 0.44 | 0.47 | 0.50 |
| $\frac{Var\left(\varphi_{t+1}^{EH,SR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.30 | 0.38 | 0.36 | 0.33 | 0.30 | 0.33 | 0.23 | 0.34 | 0.33 | 0.36 |
| $\frac{Var\left(\varphi_{t+1}^{EH,MR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.19 | 0.14 | 0.12 | 0.23 | 0.20 | 0.27 | 0.09 | 0.21 | 0.17 | 0.12 |
| $\frac{Var\left(\varphi_{t+1}^{EH,LR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.02 | 0.03 | 0.02 | 0.08 | 0.07 | 0.04 | 0.02 | 0.01 | 0.03 | 0.02 |
| $\frac{Var\left((\tilde{\pi}_{t+1}-E_t[\tilde{\pi}_{t+1}])^{\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.16 | 0.08 | 0.14 | 0.05 | 0.10 | 0.16 | 0.05 | 0.05 | 0.17 | 0.14 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,SR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.47 | 0.56 | 0.53 | 0.55 | 0.56 | 0.37 | 0.38 | 0.55 | 0.44 | 0.52 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,MR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.26 | 0.21 | 0.23 | 0.24 | 0.16 | 0.35 | 0.45 | 0.31 | 0.22 | 0.23 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,LR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.12 | 0.15 | 0.10 | 0.16 | 0.17 | 0.11 | 0.12 | 0.09 | 0.16 | 0.11 |
| $\frac{Var\left((\sigma_{t+1}-E_t[\sigma_{t+1}])^{\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.42 | 0.46 | 0.37 | 0.32 | 0.35 | 0.22 | 0.07 | 0.10 | 0.10 | 0.39 |
| $\frac{Var\left(\sigma_{t+1}^{F,SR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.23 | 0.30 | 0.42 | 0.45 | 0.26 | 0.59 | 0.41 | 0.62 | 0.59 | 0.42 |
| $\frac{Var\left(\sigma_{t+1}^{F,MR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.10 | 0.14 | 0.10 | 0.11 | 0.05 | 0.09 | 0.30 | 0.20 | 0.09 | 0.09 |
| $\frac{Var\left(\sigma_{t+1}^{F,LR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.25 | 0.10 | 0.11 | 0.13 | 0.33 | 0.10 | 0.22 | 0.08 | 0.22 | 0.10 |

Table 22: Variance Ratios of Subcomponents Orthogonalized Across Horizons

| | | | | ZLB | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Bases (avg across pairs) | AUD | CAD | CHF | DEM/EUR | GBP | JPY | NOK | NZD | SEK | USD |
| $\frac{Var\left(\left(\tilde{i}_{t+1}-E_t[\tilde{i}_{t+1}]\right)^{\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.42 | 0.25 | 0.27 | 0.32 | 0.14 | 0.32 | 0.15 | 0.30 | 0.07 | 0.17 |
| $\frac{Var\left(\varphi_{t+1}^{EH,SR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.44 | 0.53 | 0.62 | 0.40 | 0.50 | 0.44 | 0.73 | 0.41 | 0.63 | 0.51 |
| $\frac{Var\left(\varphi_{t+1}^{EH,MR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.11 | 0.18 | 0.08 | 0.20 | 0.30 | 0.15 | 0.10 | 0.24 | 0.24 | 0.29 |
| $\frac{Var\left(\varphi_{t+1}^{EH,LR,\perp}\right)}{Var\left(\varphi_{t+1}^{EH}\right)}$ | 0.03 | 0.04 | 0.03 | 0.08 | 0.07 | 0.10 | 0.02 | 0.05 | 0.06 | 0.04 |
| $\frac{Var\left((\tilde{\pi}_{t+1}-E_t[\tilde{\pi}_{t+1}])^{\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.07 | 0.06 | 0.17 | 0.03 | 0.10 | 0.12 | 0.04 | 0.04 | 0.07 | 0.25 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,SR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.47 | 0.53 | 0.51 | 0.53 | 0.50 | 0.43 | 0.20 | 0.50 | 0.52 | 0.45 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,MR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.34 | 0.26 | 0.16 | 0.25 | 0.29 | 0.33 | 0.54 | 0.34 | 0.28 | 0.17 |
| $\frac{Var\left(s_{t+1,\infty}^{\Delta E,LR,\perp}\right)}{Var\left(s_{t+1,\infty}^{\Delta E}\right)}$ | 0.13 | 0.15 | 0.16 | 0.20 | 0.11 | 0.12 | 0.22 | 0.12 | 0.13 | 0.13 |
| $\frac{Var\left((\sigma_{t+1}-E_t[\sigma_{t+1}])^{\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.43 | 0.36 | 0.20 | 0.37 | 0.43 | 0.23 | 0.06 | 0.14 | 0.20 | 0.32 |
| $\frac{Var\left(\sigma_{t+1}^{F,SR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.25 | 0.42 | 0.57 | 0.44 | 0.28 | 0.69 | 0.49 | 0.59 | 0.49 | 0.49 |
| $\frac{Var\left(\sigma_{t+1}^{F,MR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.01 | 0.08 | 0.14 | 0.07 | 0.05 | 0.03 | 0.20 | 0.22 | 0.12 | 0.09 |
| $\frac{Var\left(\sigma_{t+1}^{F,LR,\perp}\right)}{Var\left(\sigma_{t+1}^{F}\right)}$ | 0.31 | 0.15 | 0.10 | 0.12 | 0.23 | 0.05 | 0.24 | 0.05 | 0.19 | 0.10 |

Table 23: Estimation of Conditional Variance of Exchange Rate Change

| | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $q_t^{i,US}$ | −0.46 | 1.07 | −0.48 | 0.46 | 0.04 | −0.23 | 0.67 | 2.56*** | 1.44 |
| $q_{t-1}^{i,US}$ | 0.20 | −0.34 | 0.76 | −0.44 | −0.76 | −1.25 | 0.57 | −1.90* | −0.64 |
| $i_t^i$ | 27.32 | 13.06 | 48.34 | 175.69 | −503.79 | 220.23* | 108.82 | 50.45 | 78.35 |
| $i_{t-1}^i$ | −65.99 | −58.63 | −139.75 | −166.68 | 140.12 | −117.35 | −5.44 | −25.54 | −2.70 |
| $sl_t^i$ | −59.74 | −2.73 | −171.79 | 35.90 | −276.11 | 123.21 | 49.02 | −28.58 | −16.62 |
| $sl_{t-1}^i$ | −41.38 | −59.72 | 81.84 | −73.25 | −6.90 | −74.59 | 58.37 | 11.72 | 16.14 |
| $c_t^i$ | −9.34 | −4.81 | 2.59 | 10.13 | 46.56 | −16.76 | −11.79 | −6.06 | −3.76 |
| $c_{t-1}^i$ | 6.04 | 2.66 | 16.44 | −5.08 | 4.63 | 12.22 | 1.03 | −1.26 | −4.86 |
| $GDPGAP_t^i$ | −21.76** | 7.32 | −8.66 | −11.26 | −4.43 | −1.55 | −6.93 | 0.91 | −24.04** |
| $GDPGAP_{t-1}^i$ | 22.96** | −5.09 | 10.41 | 9.64 | −4.69 | 4.17 | 10.25 | 6.49 | 28.99*** |
| $\pi_t^i$ | −11.25 | 11.15* | −28.61 | −24.50 | −14.51 | 9.56 | −4.45 | −5.01 | 9.59 |
| $\pi_{t-1}^i$ | 35.92* | 9.55 | −5.48 | −3.23 | −17.01 | 12.51 | 36.21** | −3.06 | 17.88 |
| $CAtoGDP_t^i$ | 14.64* | −4.24 | −2.60 | −11.00 | −5.46 | 3.40* | 2.84 | −0.07 | −4.75 |
| $CAtoGDP_{t-1}^i$ | −5.08 | 5.41 | 1.44 | 6.26 | 1.07 | 3.85 | −10.20** | −2.93 | −6.53 |
| $i_t^{US}$ | 178.49 | −30.09 | −227.99 | −163.91 | 31.28 | −205.99 | 151.79 | 100.99 | 133.12 |
| $i_{t-1}^{US}$ | 56.05 | 100.15 | 281.65 | 150.02 | 38.66 | 65.99 | −47.16 | 161.88 | −179.66** |
| $sl_t^{US}$ | 27.64 | −22.40 | −127.49 | −34.22 | −37.70 | −101.16 | −91.29 | −1.89 | 85.43* |
| $sl_{t-1}^{US}$ | 149.08 | 79.28 | 218.71 | 81.39 | 82.86 | 92.79 | 49.97 | 158.97 | −60.35 |
| $c_t^{US}$ | −1.24 | 6.66 | 31.88 | 8.43 | −6.44 | 40.48** | −13.64 | −6.75 | 1.45 |
| $c_{t-1}^{US}$ | −21.01 | −11.19** | −34.82 | −2.68 | −0.41 | −21.96 | −10.98 | −21.99 | 6.86 |
| $GDPGAP_t^{US}$ | 11.39 | −7.26* | 12.13 | 22.46** | 21.00 | 21.85 | 12.25 | 28.37** | −4.88 |
| $GDPGAP_{t-1}^{US}$ | −16.13 | −3.27 | −17.21 | −30.41*** | −16.95 | −15.78 | −7.64 | −39.54** | −2.71 |
| $\pi_t^{US}$ | 22.79 | 8.90 | 32.84 | −0.81 | 1.03 | −5.72 | 0.41 | 11.01 | 4.93 |
| $\pi_{t-1}^{US}$ | −85.66*** | −19.81** | −8.31 | −16.67 | 3.22 | −29.04* | −33.96*** | −11.03 | −14.43** |
| $CAtoGDP_t^{US}$ | 10.16 | −2.20 | 31.45* | −7.76 | −9.67 | −3.96 | 15.44 | 0.46 | 4.86 |
| $CAtoGDP_{t-1}^{US}$ | −22.08 | −7.58 | −29.99* | 0.03 | 20.31 | 19.50 | −3.93 | −11.89 | −12.10 |
| $VIX_t^{US}$ | −0.01 | −0.94 | 0.67 | 0.54 | −0.05 | 0.54 | −0.96 | −0.46 | 1.47** |
| $VIX_{t-1}^{US}$ | 0.76 | −0.02 | −1.23 | −0.10 | −2.23 | −0.01 | 0.73 | −0.63 | 0.01 |
| $TED_t^{US}$ | 46.40** | 38.43*** | 11.57 | −10.12 | 47.25* | 29.98 | 28.26 | 26.93 | 59.55*** |
| $TED_{t-1}^{US}$ | 28.79 | −6.51 | 29.56 | 29.80 | −6.45 | −3.29 | 0.44 | 40.61 | −44.84*** |
| $\pi_t^{avg,US}$ | −174.72 | −221.96 | −310.79 | 223.43 | −86.82 | −476.15 | −393.02 | −159.54 | 265.34* |
| $\pi_{t-1}^{avg,US}$ | 291.20 | 331.99** | 66.58 | −432.31* | 426.20* | 351.75 | 390.69 | 123.42 | −247.42* |
| Constant | −116.90 | −98.52* | 135.72 | 91.07 | 259.83 | 284.64* | −17.40 | −209.84 | −86.97 |
| $R^2$ | 0.64 | 0.56 | 0.50 | 0.40 | 0.36 | 0.45 | 0.48 | 0.38 | 0.81 |
| # of Observations | 102 | 93 | 84 | 96 | 102 | 102 | 102 | 102 | 91 |

Note: The dependent variable is the model-implied squared exchange rate change forecast error, $(\Delta s_{t+1} - E_t[\Delta s_{t+1}])^2$. The significance stars are based on heteroskedasticity-consistent standard errors. Standard errors are omitted from this table for brevity.

Table 24: Is exchange rate uncertainty driven by fundamental uncertainty?

| USD Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $E_t[(s^{\Delta E}_{t+1,\infty} - \varphi^{EH}_{t+1})^2]$ | 1.04*** | 0.91** | 1.76*** | 0.40* | 0.35* | 0.27** | −0.15 | 0.37** | 1.95*** |
| Adj. $R^2$ | 0.09 | 0.20 | 0.14 | 0.04 | 0.02 | 0.11 | -0.00 | 0.18 | 0.63 |
| # of Observations | 102 | 93 | 84 | 96 | 102 | 102 | 102 | 102 | 91 |

| GBP Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | USD |
|---|---|---|---|---|---|---|---|---|---|
| $E_t[(s^{\Delta E}_{t+1,\infty} - \varphi^{EH}_{t+1})^2]$ | −0.21 | 0.43** | 1.81*** | 0.39 | 5.05* | −0.09 | 1.69** | 0.41 | 1.95*** |
| Adj. $R^2$ | -0.01 | 0.04 | 0.55 | 0.05 | 0.27 | 0.01 | 0.02 | 0.03 | 0.63 |
| # of Observations | 91 | 91 | 73 | 91 | 91 | 91 | 91 | 91 | 91 |

| DEM/EUR Base | AUD | CAD | CHF | JPY | NOK | NZD | SEK | GBP | USD |
|---|---|---|---|---|---|---|---|---|---|
| $E_t[(s^{\Delta E}_{t+1,\infty} - \varphi^{EH}_{t+1})^2]$ | 0.38*** | 0.03 | 0.00 | 0.59** | 0.06* | 0.20 | 0.42*** | 0.39 | 0.40* |
| Adj. $R^2$ | 0.03 | -0.01 | -0.01 | 0.07 | 0.00 | 0.02 | 0.13 | 0.05 | 0.04 |
| # of Observations | 96 | 93 | 78 | 96 | 96 | 96 | 96 | 91 | 96 |

Table 25: Is exchange rate uncertainty driven by currency risk premia uncertainty?

| USD Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | GBP |
|---|---|---|---|---|---|---|---|---|---|
| $E_t[(\sigma_{t+1} - E_t[\sigma_{t+1}])^2]$ | 1.42*** | 0.58*** | 0.80*** | 0.68*** | 0.66*** | 0.76*** | 0.86*** | 0.50*** | 1.24*** |
| Adj. $R^2$ | 0.76 | 0.24 | 0.66 | 0.28 | 0.68 | 0.46 | 0.79 | 0.25 | 0.34 |
| # of Observations | 102 | 93 | 84 | 96 | 102 | 102 | 102 | 102 | 91 |

| GBP Base | AUD | CAD | CHF | DEM/EUR | JPY | NOK | NZD | SEK | USD |
|---|---|---|---|---|---|---|---|---|---|
| $E_t[(\sigma_{t+1} - E_t[\sigma_{t+1}])^2]$ | 0.69*** | 0.34*** | 0.63*** | 0.44** | 1.54*** | 0.14** | 1.04*** | 0.55*** | 1.24*** |
| Adj. $R^2$ | 0.51 | 0.31 | 0.11 | 0.12 | 0.88 | 0.04 | 0.88 | 0.27 | 0.34 |
| # of Observations | 91 | 91 | 73 | 91 | 91 | 91 | 91 | 91 | 91 |

| DEM/EUR Base | AUD | CAD | CHF | JPY | NOK | NZD | SEK | GBP | USD |
|---|---|---|---|---|---|---|---|---|---|
| $E_t[(\sigma_{t+1} - E_t[\sigma_{t+1}])^2]$ | 0.92*** | 0.37*** | 0.31*** | 0.39*** | 0.11*** | 0.25** | 0.28*** | 0.44** | 0.68*** |
| Adj. $R^2$ | 0.52 | 0.21 | 0.23 | 0.41 | 0.17 | 0.09 | 0.60 | 0.12 | 0.28 |
| # of Observations | 96 | 93 | 78 | 96 | 96 | 96 | 96 | 91 | 96 |

Table 26: Cyclicality of the exchange rate change

| Bases: | CHF | DEM/EUR | JPY | GBP | USD | All |
|---|---|---|---|---|---|---|
| Country $j$ recession | 5.02* | 0.87 | 24.30*** | 9.79** | 5.57* | 7.26*** |
| Base country recession | 14.31** | 5.48* | 0.43 | 6.25** | 15.12** | 6.37*** |
| Constant (normal times) | 23.13*** | 23.02*** | 35.31*** | 19.54*** | 25.92*** | 25.31*** |
| Adj. $R^2$ | 0.04 | 0.01 | 0.03 | 0.02 | 0.03 | 0.02 |
| # of Observations | 730 | 838 | 874 | 801 | 874 | 4215 |

Table 27: Cyclicality of the monetary policy component

| Bases: | CHF | DEM/EUR | JPY | GBP | USD | All |
|---|---|---|---|---|---|---|
| Country $j$ recession | 4.59* | 2.14 | 11.99** | 1.91 | 7.15* | 5.20*** |
| Base country recession | 10.87** | 6.85*** | 5.66 | 1.59 | 1.80 | 5.97*** |
| Constant (normal times) | 8.74*** | 8.77*** | 18.89*** | 6.93*** | 11.85*** | 11.78*** |
| Adj. $R^2$ | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.02 |
| # of Observations | 730 | 838 | 874 | 801 | 874 | 4215 |

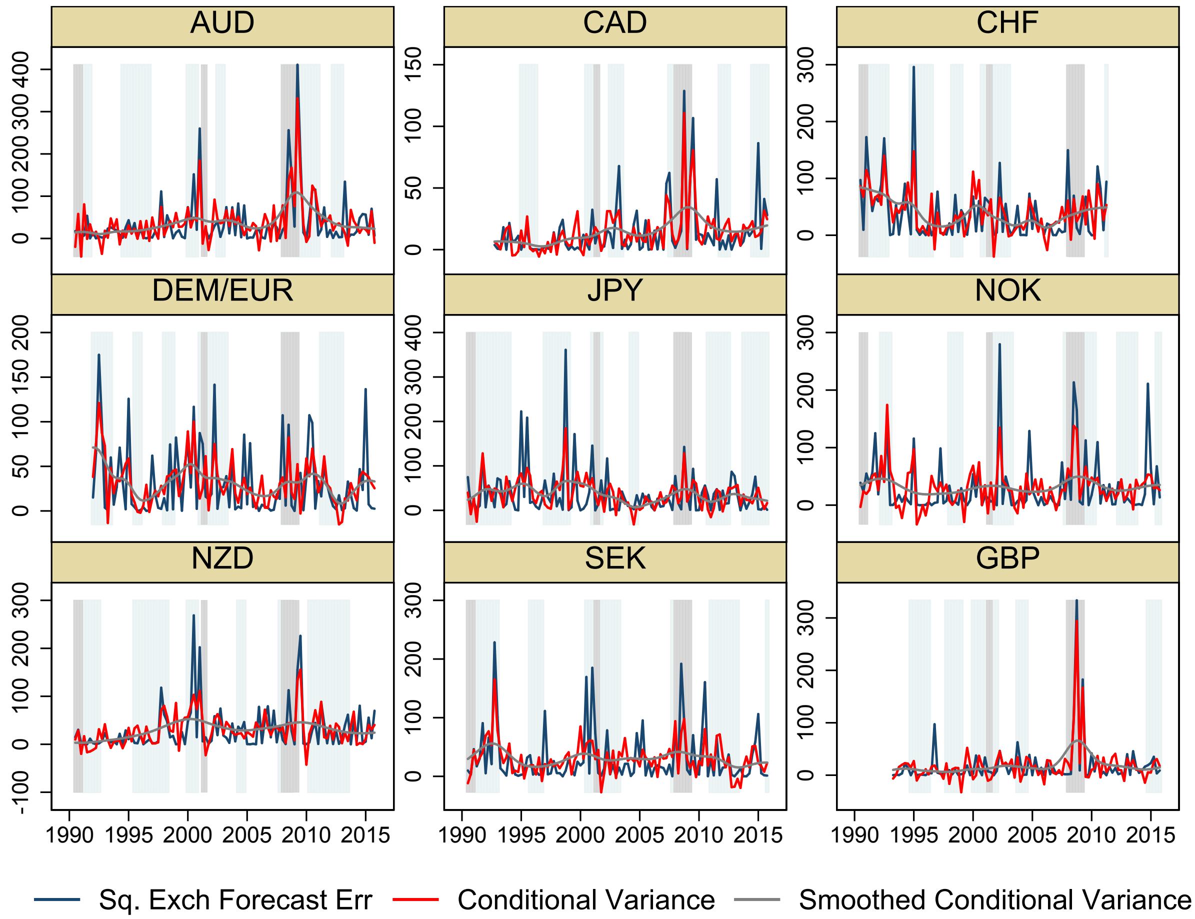
Table 28: Cyclication of the relative inflation component

| Bases: | CHF | DEM/EUR | JPY | GBP | USD | All |
|---|---|---|---|---|---|---|
| Country $j$ recession | 1.97** | 2.88** | 4.59*** | 5.44* | 0.43 | 3.55*** |
| Base country recession | 2.84** | 6.00** | 1.52 | 2.37** | 11.97** | 3.35*** |
| Constant (normal times) | 4.11*** | 6.44*** | 6.31*** | 6.77*** | 5.33*** | 5.60*** |
| Adj. $R^2$ | 0.03 | 0.04 | 0.03 | 0.03 | 0.08 | 0.03 |
| # of Observations | 730 | 838 | 874 | 801 | 874 | 4215 |

Table 29: Cyclicality of the currency risk premium component

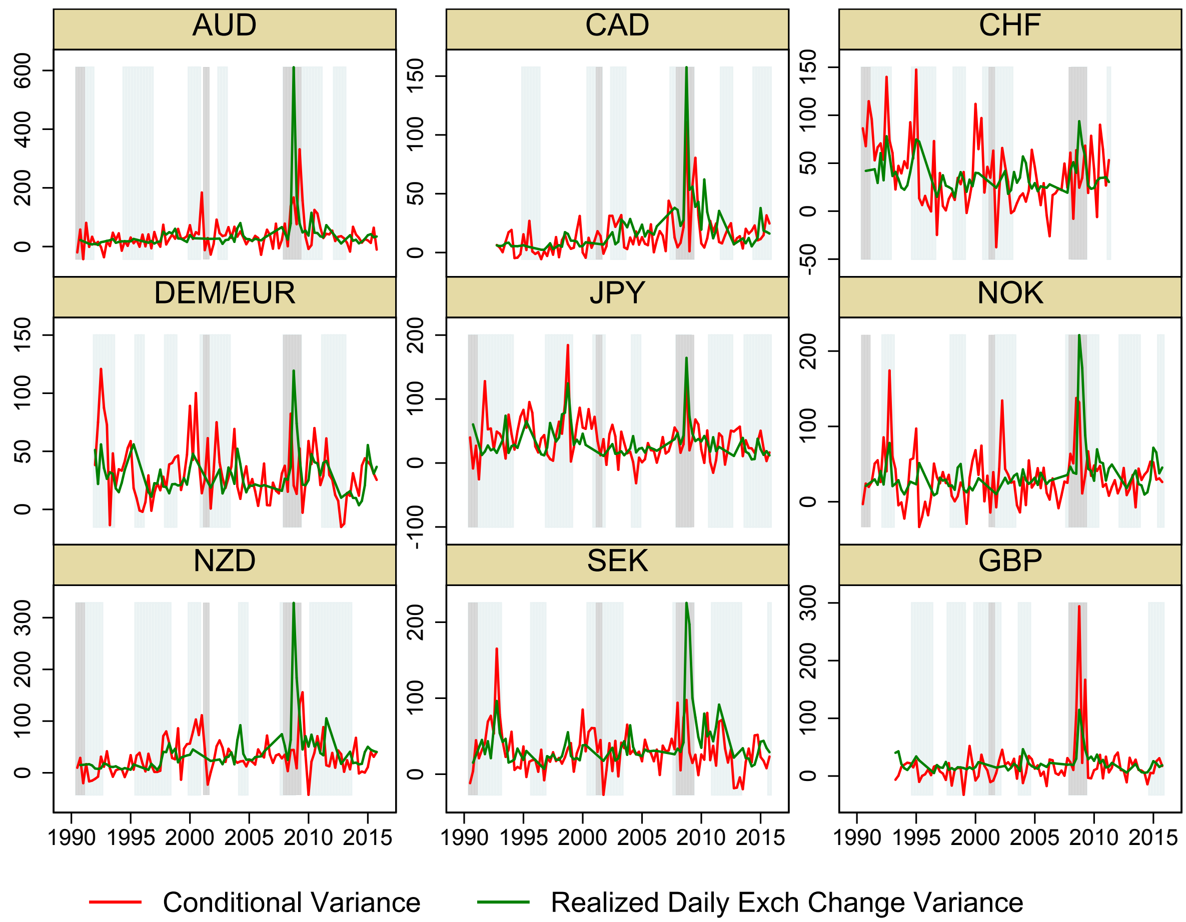
| Bases: | CHF | DEM/EUR | JPY | GBP | USD | All |
|---|---|---|---|---|---|---|
| Country $j$ recession | 4.37 | 0.17 | 25.94*** | 3.05 | 0.64 | 5.27** |
| Base country recession | 8.55 | 4.60 | −10.39** | 3.23 | 10.14** | 4.01 |
| Constant (normal times) | 30.59*** | 31.73*** | 46.08*** | 25.09*** | 28.44*** | 31.21*** |
| Adj. $R^2$ | 0.01 | 0.00 | 0.03 | 0.00 | 0.01 | 0.01 |
| # of Observations | 730 | 838 | 874 | 801 | 874 | 4215 |

Figure 8: Conditional Variance of the Nominal Exchange Rate Change



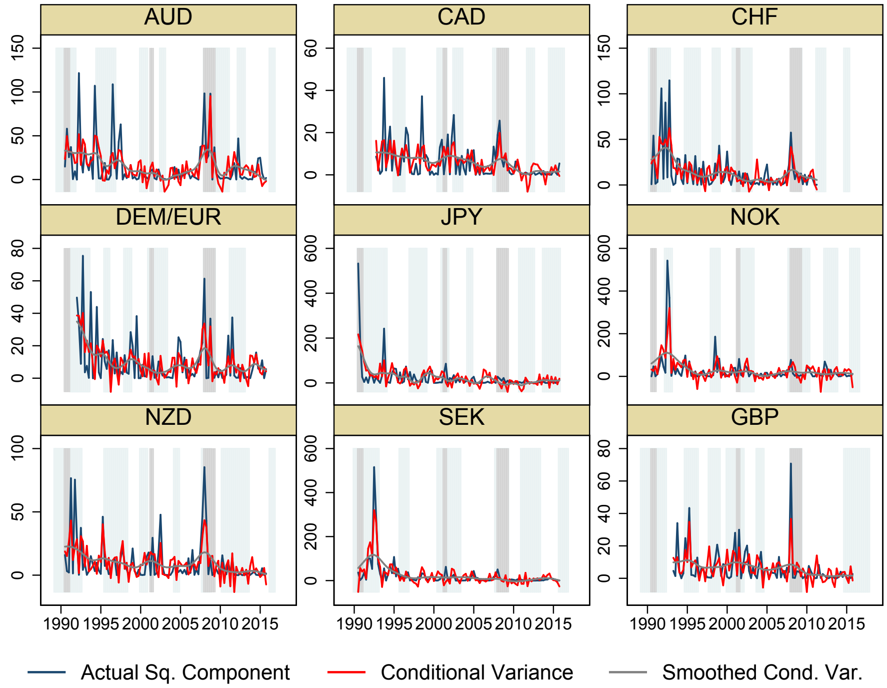

Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

Figure 9: Conditional and Realized Variance of the Nominal Exchange Rate Change



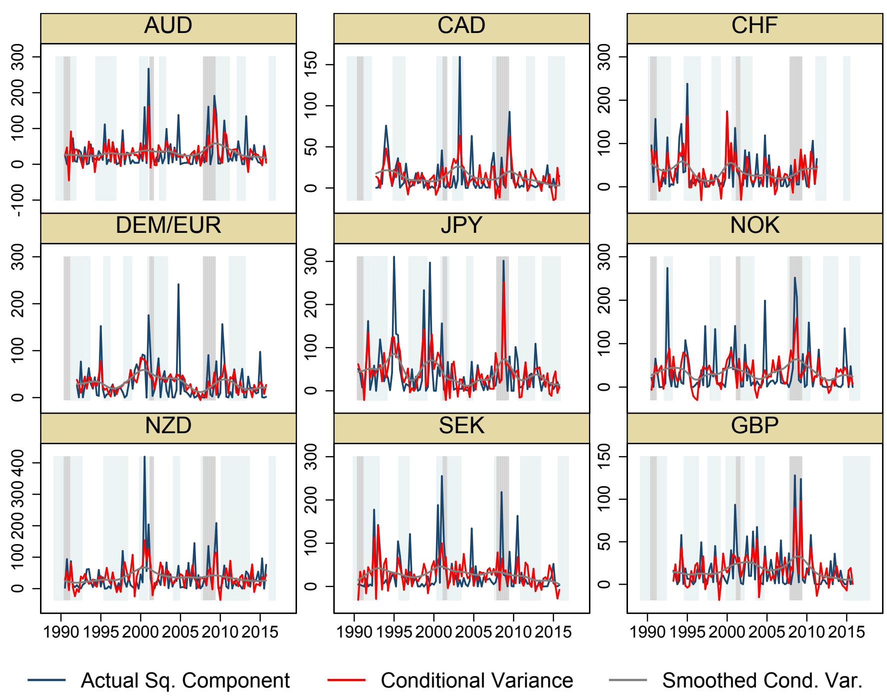

Note: The realized variances here are within-quarter variances of daily exchange rate changes.

Figure 10: Conditional Variance of Interest Rate Component



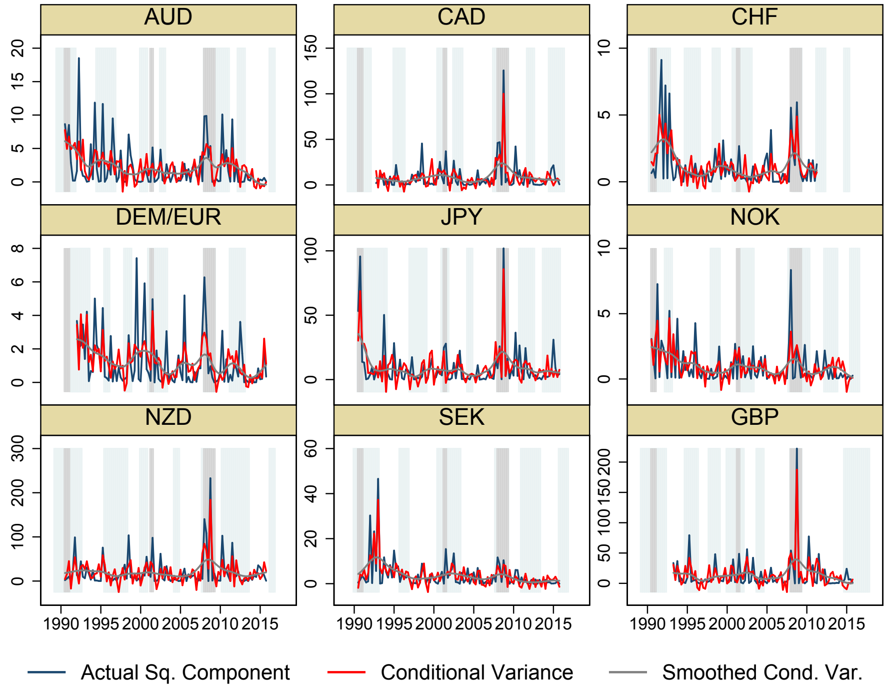

Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

Figure 11: Conditional Variance of Currency Premia Component



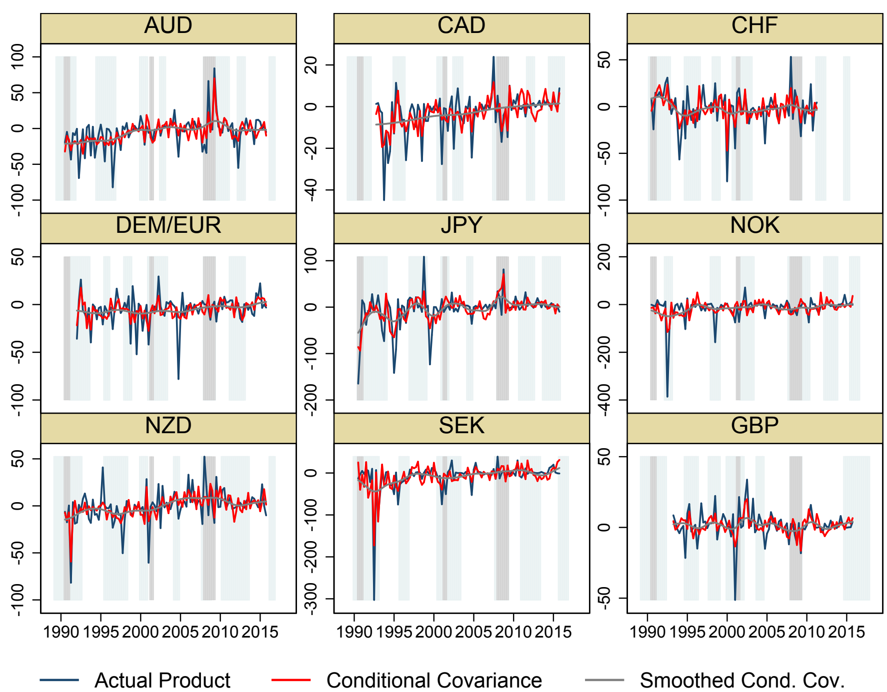

Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

Figure 12: Conditional Variance of Long-term Exchange Rate Component



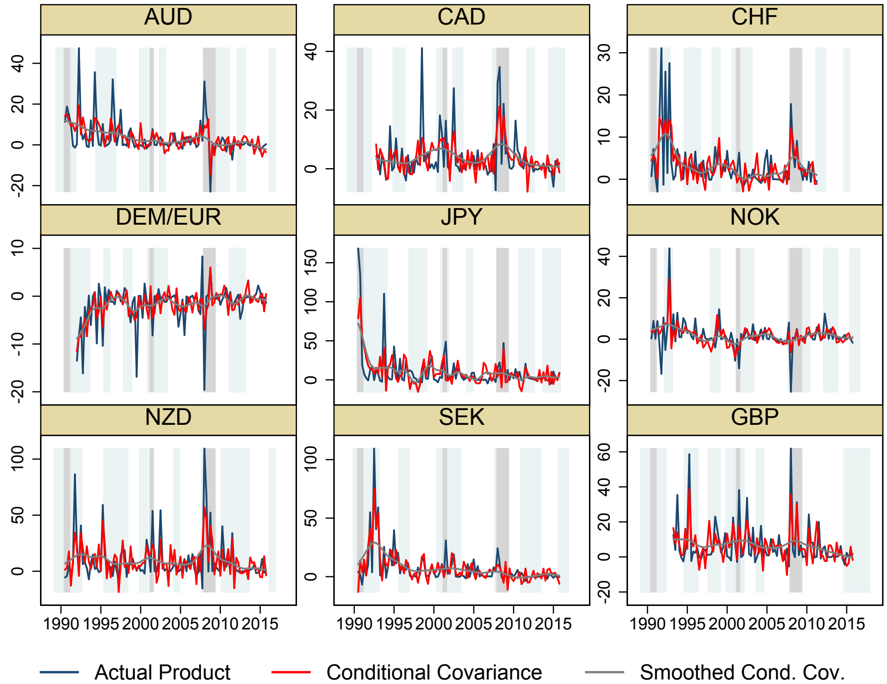

Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

Figure 13: Conditional Covariance of Interest Rate and Currency Premia Components



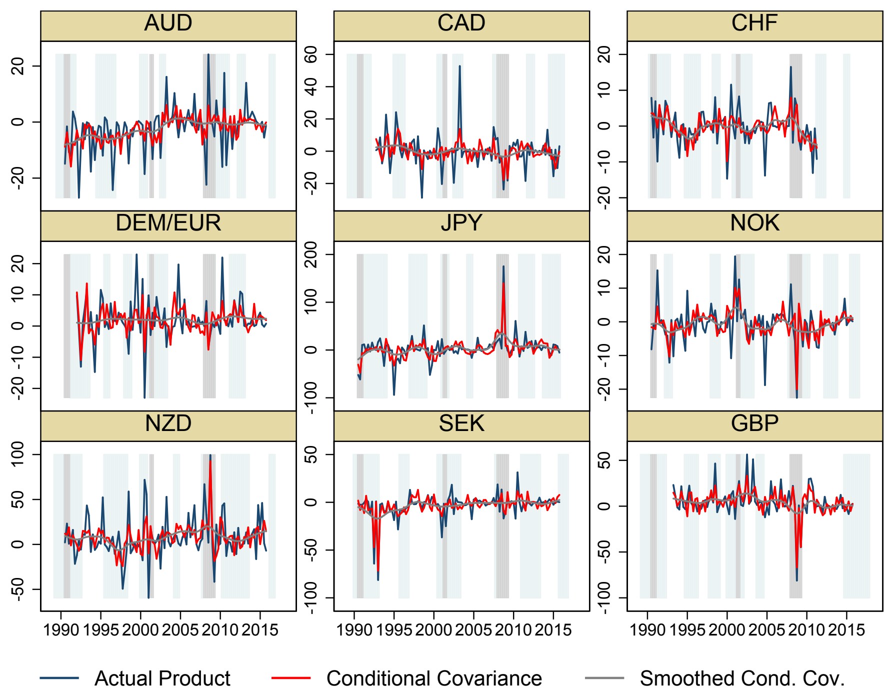

Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

Figure 14: Conditional Covariance of Interest Rate and Long-term Exchange Rate Components




Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

Figure 15: Conditional Covariance of Long-term Exchange Rate and Currency Premia Components




Note: Smoothing is done by local polynominal smoothing with a Gaussian kernel and a bandwidth that minimizes the conditional weighted mean integrated squared error.

# Appendix

## A Details on Mapping VAR to Survey Forecasts

The VAR augmented with survey data given by equations (8) and (10) in the main text can be written in the following more compact state-space form:

$$Z_{t+1} = \bar{\mathbf{\Gamma}} Z_t + \bar{\mathbf{\Xi}}_{t+1} \tag{A-1}$$

$$\begin{bmatrix} Y^A_{t+1} \\ Y^S_{t+1} \end{bmatrix} = \underbrace{\begin{bmatrix} E^A \\ E^S_{t+1} \end{bmatrix}}_{\mathbf{E}_{t+1}} Z_{t+1} + \begin{bmatrix} 0 \\ \Xi^s_{t+1} \end{bmatrix} \tag{A-2}$$

where $Z$ includes a constant, the elements in $X$ as described in Section 3, and the additional lags of $X$ that appear in equation (10). $\bar{\mathbf{\Gamma}}$ thus includes the coefficients in $\bar{\mathbf{X}}$ and $\mathbf{\Gamma}$ as well as additional ones and zeros. $\bar{\mathbf{\Xi}}_{t+1}$ contains $\mathbf{\Xi}_{t+1}$ and zeros. $Y^A_{t+1}$ contains observed actuals which are mapped using a selection matrix $E^A$ to the elements in the state vector $Z_{t+1}$. $Y^S_{t+1}$ contains survey forecasts which are a linear function of $Z_{t+1}$ where $E^S_{t+1}$ is a product of selection matrices and powers of $\bar{\Gamma}$, as shown below. The time variation in $E^S_{t+1}$ results from the nature of the survey forecasts, which will be detailed below. $\Xi^s_{t+1}$ are i.i.d. Gaussian errors whose variances are, for parsimony, parameterized by country-variable-horizon groups (following Crump, Eusepi, and Moench (2016)). Within each country and survey variable, forecasts for horizons up to two quarters out form one group, those for horizons three quarters to two years out form another and those for long-run averages of the 3-month interest rates form the final group.

The mapping between actual data and the survey forecasts is given by the matrix:

$$E^S_{t+1} = H^S_{t+1} \underbrace{\begin{bmatrix} I \\ \bar{\Gamma} \\ \vdots \\ \bar{\Gamma}^{h_{\max}} \end{bmatrix}}_{\widetilde{\bar{\Gamma}}},$$

where $h_{\max}$ is the longest available horizon for our set of survey variables. Right-multiplying $\widetilde{\Gamma}$ by the state vector $Z_{t+1}$ results in a large matrix containing model-implied forecasts for horizons 0 to $h_{\max}$. Each row of $H^S_{t+1}$ corresponds to the mapping for a single survey forecast. Most rows of $H^S_{t+1}$ are selection vectors selecting the relevant forecast horizon and variable.

There are a few notable exceptions discussed below:

1. Mapping annualized quarterly log growth rate actuals to annual average percent growth rates (e.g., 0-2 years ahead inflation forecasts):
   Let $z_{j,t}$ be an annualized quarterly log growth rate of some variable $X_t$ so that we have

$$\begin{aligned} z_{j,t} &\approx 400\Delta x_t \\ \text{where } x_t &\equiv \ln X_t \end{aligned}$$

   Let $y^S_{i,t}$ be a forecast of the annual average percent growth rate of $X_t$ between years $h-1$ and $h$ ahead of the current year. Then we have,

$$\begin{aligned} y^S_{i,t} &= 100E_t\left[\frac{X_{t-q}+X_{t-q+1}+X_{t-q+2}+X_{t-q+3}}{X_{t-q-1}+X_{t-q-2}+X_{t-q-3}+X_{t-q-4}}-1\right] \quad \text{where } q=Q\left(t\right)-4h-1 \\ &= 100E_t\left[\Delta x_{t-q+3}+2\Delta x_{t-q+2}+3\Delta x_{t-q+1}+4\Delta x_{t-q}+3\Delta x_{t-q-1}+2\Delta x_{t-q-2}+\Delta x_{t-q-3}\right] \\ &= \sum_{l=-3}^{3}\underbrace{\frac{4-|l|}{4}}_{w_l}E_t[z_{j,t-q+l}] \end{aligned}$$

   In the above expression, $Q\left(t\right)$ gives the quarter of the year that $t$ falls in. In the context of the framework above, the relevant row of $H^S_{t+1}$ would contain a vector of zeros and the elements of $\{w_l\}$ in a way that results in the weighted average shown above.

2. Mapping real exchange rate forecasts to nominal exchange rate forecasts:
   Our model contains real exchange rates $q_t$ while the survey participants forecast the nominal exchange rate $s_t$. We use the relationship below to obtain model-implied forecasts of $s_t$ which we map to the survey data.

$$\hat{E}_t s_{t+h}=\hat{E}_t q_{t+h}+\sum_{i=1}^{h}\hat{E}_t\tilde{\pi}_{t+i}+\tilde{p}_t$$

   where $E^S_t s_{t+h}$ is the observed $h$-period ahead forecast, $E^M_t s_{t+h}$ is the model-implied forecast and $\tilde{p}_t$ is the actual relative price level.

# B Note on the Estimation Procedure

The size of the VAR presents computational issues that prevent us from estimating the entire system of equations at once. Rather, we make use of the block-wise sequential nature of the VAR given by the restrictions in equation (9). Since the equations for the financial variables for a country are independent of the macroeconomic equations, we estimate them first. We then estimate a system that's expanded to include the macroeconomic equations, holding fixed the coefficients in the financial equations. Finally, we add the exchange rate equation to the model and estimate this system, holding fixed the previously estimated coefficients in the financial and macroeconomic blocks.

# C Data Details

## C.1 Macroeconomic and Financial Variables

- *Exchange rates*: End-of-quarter exchange rates are obtained using daily data from Global Financial Data.
- *Short-term rates*: End-of-quarter 3-month bill rates were obtained from the following sources:
  - Australia, Canada, New Zealand, Norway, Sweden, Switzerland, United Kingdom, and United States: Central bank data obtained through Haver Analytics.
  - Germany: Reuters data obtained through Haver Analytics. German 3-month bill rates are replaced with 3-month EONIA OIS swap rates starting in 1999:Q1.
  - Japan: Bloomberg
- *Zero-coupon yields:* End-of-quarter zero-coupon yields were obtained from the following sources:
  - Canada, Germany, Sweden, Switzerland, and United Kingdom: Central banks
  - Norway: Data from Wright (2011) extended with data from the BIS
  - Australia, New Zealand: Data from Wright (2011) extended with data from central banks
  - Japan: Bloomberg.
  - United States: Gürkaynak, Sack, and Wright (2007)
- *Output gap and current account-to-GDP ratio:* All macro data are from the OECD Main Economic Indicators and Economic Outlook databases. The GDP gap is computed using the OECD's annual estimates of potential GDP, which were log-linearly interpolated to the quarterly frequency. German data are replaced with euro-area data starting in 1999:Q1.
- *CPI inflation:* Government statistical agencies.

- *Market-Based interest rate surprises and expected changes:* These are computed using prices of futures on 3-month interest rates on the last trading day of each quarter. These expectations refer to the 3-month rates on each contract's last trading day, which typically falls within the second-to-last week of each quarter. When computing the surprises and expected changes in these interest rates, the actual rate used is the underlying rate of each futures contract. The futures data are all obtained from Bloomberg and are based on the following underlying rates:
  - Australia: Australian 90-day bank accepted bills
  - Canada: Canadian 3-month bankers' acceptance
  - Switzerland: 3-month Euroswiss
  - Germany/EU: ICE 3-month Euribor
  - Norway: 3-month NIBOR
  - New Zealand: New Zealand 90-day bank accepted bills
  - Sweden: 3-month Swedish T-bill (1992:Q4–2007:Q4); 3-month STIBOR (2008:Q1-present)
  - United Kingdom: 3-month Sterling Libor
  - United States: 3-month Eurodollar

Data Sample Ranges

| | |
|---|---|
| Australia | 1989:Q4 – 2015:Q4 |
| Canada | 1992:Q2 – 2015:Q4 |
| Germany | 1991:Q2 – 2015:Q4 |
| Japan | 1992:Q3 – 2015:Q4 |
| New Zealand | 1990:Q1 – 2015:Q1 |
| Norway | 1989:Q4 – 2015:Q4 |
| Sweden | 1992:Q4 – 2015:Q4 |
| Switzerland | 1992:Q1 – 2011:Q2 |
| United Kingdom | 1992:Q4 – 2015:Q4 |
| United States | 1989:Q4 – 2015:Q1 |

## C.2 Survey data details

In the VAR, we include the following survey data for 3-month interest rates, CPI inflation and exchange rates:

- Blue Chip Economic Indicators:
  - Countries: Australia, Canada, Germany/Eurozone, Japan, United Kingdom, United States
  - Date range: 1993:Q3 - 2015:Q4
  - Variables for non-U.S. countries: Current, one, and two years ahead forecasts of 3-month interest rates, CPI inflation and exchange rates.
  - Variables for the U.S.: 7-11 year ahead average 3-month bill rate for only the U.S. (data start in 1990:Q1).
- Blue Chip Financial Forecasts:
  - Countries: Australia, Canada, Germany/Eurozone, Japan, Switzerland, United Kingdom, United States
  - Date range: 1993:Q1 - 2015:Q4
  - Variables: 3, 6 and 12 month ahead 3-month interest rate, 10-year yield, and exchange rate forecasts.
- Consensus Economics:
  - Country coverage: Australia, Canada, Germany/Eurozone, Japan, Norway, New Zealand, Sweden, Switzerland, United Kingdom, United States
  - Date range: 1990:Q1 - 2015:Q4
  - Variables: Current, one, and two years ahead for CPI inflation; 3M and 12M ahead for 3-month interest rates and 10-year yields; 3M, 12M, and 24M ahead for exchange rates.
  - Long run data: 6-10 year ahead average CPI inflation forecasts. Additionally, 6-10 year ahead GDP growth forecasts are used to impute long-horizon non-U.S. 3-month bill rate forecasts, as described in the main text, but are not directly included in the VAR estimation.
- Notes:
  - All inflation forecasts are for an annual-average (price index) over annual-average basis. Annual interest rate and exchange rate forecasts are for end-of-year values. Months-ahead forecasts are for end-of-month values.
  - Surveys are usually published within the first two weeks of the month and typically contain responses from survey participants from the end of the prior month. In

order to maintain consistency between the data available to the forecasters and the end-of-quarter financial data used in our model, we backdate the survey variables (for example, a January publication is mapped to model-implied forecasts as of the end of Q4).

– CPI forecasts for the U.K. begin in 2004:Q2 in all databases. Previous inflation forecasts for the U.K. were for the retail price index.

– 3-month interest rate forecasts, for certain countries, are explicitly for interbank rather than bill rates. There are also some cases in which the survey does not specify the particular rate that respondents should forecast. To account for this, we allow a constant in the rows of equation (10) that correspond to 3-month interest rate forecast data. Though often statistically significant, these estimated constants are small and are of an order of magnitude that is consistent with average spreads between interbank and bill rates. For the purposes of assessing fit of survey data, we treat the model-implied forecast with this additional constant as our model-implied counterpart to the surveyed forecast. However, this additional constant is not considered to be part of the model-implied 3-month bill rate forecasts.