Real Exchange Rates and Currency Risk Premia

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Keywords: foreign currency returns, predictability, real exchange rates, variance decomposition, bootstrap

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ABSTRACT

We exploit the link between deviations from uncovered interest rate parity (UIP), long-run relative purchasing power parity (PPP), and deviations from real rate equality, to develop more powerful tests of the predictive power of real exchange rates for excess currency returns. Assuming long-run relative PPP, we obtain much stronger evidence of predictability than if we test UIP in isolation. The real exchange rate is also the main driver of long-horizon UIP deviations and a dominant fraction of the real exchange rate variance is due to UIP deviations. Modified versions of the "habit" and "long-run risks" models qualitatively replicate these findings.

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A useful tool to analyze exchange rate movements is the following present value representation of the real exchange rate (see, for example, Froot and Ramadorai, 2005, and Engel, 2016):

$$\tilde{s}_t - E(\tilde{s}_t) = -\sum_{i=1}^{\infty} E_t(\xi_{t+i}) + \sum_{i=1}^{\infty} E_t(d\tilde{r}_{t+i}), \tag{1}$$

where $\tilde{s}_t$ is the log real exchange rate, which measures deviations from purchasing power parity (PPP); ξ_t is the log currency return, in excess of the differential between the domestic and foreign nominal interest rate; and $d\tilde{r}_t$ is the real log bond return differential between the foreign and the domestic country. Note that by assuming that $E(\tilde{s}_t)$ is well-defined, we are effectively assuming that relative PPP holds in the long-run. The two terms on the right hand side (r.h.s.) of (1) capture infinite-horizon cumulative *deviations* from uncovered interest rate parity (UIP) and real rate equality (RRE), respectively.

Equation (1) above highlights the fact that real exchange rate fluctuations are affected by *two* factors: deviations from UIP ("risk premia") and deviations from RRE ("fundamentals"). Expectations of more "traditional" macro variables—money-growth, inflation, and GDP-growth differentials, for example—may still matter in the determination of real exchange rates according to (1), but they can only do so through their effect on risk premia and fundamentals.

Equation (1) motivates the first research question addressed in this paper: do real exchange rates predict (negatively) excess currency returns? This seems a natural and important question, and, yet, the literature has mainly focused on other instruments—most notably, the nominal interest rate differential—to characterize the time variation in currency risk premia. Moreover, the existing evidence on the predictive ability of real exchange rates is weak; see for example, the review article by Rossi (2013). A closely related question is whether real exchange rates predict (positively) real bond return differentials: under the UIP null, the first term on the r.h.s. of (1) is constant, and, accordingly, any variation of the real exchange rate reflects RRE deviations, i.e., fundamentals. This also seems a natural question to address, but the literature has mainly focused on other macro variables that exchange rates may predict, such as differentials in money supply, output, price level, and interest rates (e.g., Engel and West, 2005). Finally, both the predictability of excess currency returns and the predictability of real bond return differentials are directly related to the determinants of the variance of the real exchange rate. While several studies have performed variance decomposition exercises for stock returns and dividend yields (e.g., Campbell and Shiller, 1988, and Cochrane, 2008), very little work has been done in the international finance context.

Our paper addresses the questions above using monthly data for a panel of 34 currencies (and five currency "baskets") over the December 1983–April 2012 sample period. First, we perform both a "direct" test and an "indirect" test of the UIP null hypothesis that excess log currency returns are unpredictable. The direct test investigates whether the instruments have predictive power with respect to excess currency returns. The indirect test investigates whether, given long-run relative PPP, real bond return differentials are predictable in a way consistent with the UIP null. In other words, UIP, together with long-run relative PPP, implies deviations from the RRE null. We test whether these implied deviations from RRE are borne out in the data. The indirect test we develop here is a multivariate and multi-period generalization of the test of stock return predictability developed by Cochrane (2008). The extension of Cochrane (2008) to a multi-variate setting is especially useful as it allows to compare the predictive power of several instruments and to analyze the implications of no-arbitrage models featuring several state variables.

Second, we test UIP in the context of implied infinite-horizon regressions. Specifically, we test whether the infinite-horizon cumulative UIP deviation—the first infinite sum on the r.h.s of (1)—is time varying as a function of the real exchange rate and other instruments. Third, we use the present value representation (1) to decompose the variance of the real exchange rate into shares due to risk premia and fundamentals, respectively.

Our empirical results, based on bootstrap inference, are easily summarized. We find little direct evidence of predictive power of the real exchange rate. For example, at the three-month horizon, the no-predictability null is rejected in only seven out of 39 currencies and currency baskets. Conversely, in the indirect tests, there is significant evidence of predictability in 37 out of 39 tests. In other words, assuming long-run relative PPP, the evidence from RRE regressions *reinforces* the evidence of UIP deviations. The infinite-horizon regressions are also supportive of the predictive power of the real exchange rate: it is significant in 12 out of 34 tests. Results are similar, although statistically much more significant, in a panel-regression setting. In particular, the panel-regression estimates quantify at 93% the risk premium share of the variance of the real exchange rate.

A size and power study demonstrates that the indirect and infinite-horizon tests are substantially more powerful than the standard direct tests. We also show that our results are robust to possible spurious-regression biases, alternative parameterizations of the indirect null, the correction for small-sample biases in the parameterization of the null hypothesis, the inclusion of additional predictors, and the use of alternative reference currencies.

Having established that i) real exchange rates do predict excess currency returns, and ii) that the risk premium component dominates real exchange rate variation, in the second part of the paper, we relate our analysis to the implications of no-arbitrage models of exchange rate determination, specifically, the "habit" and "long-run risks" models. We discuss the economic mechanisms driving the predictive power of the real exchange rate in the two models and we derive population values for regression and infinite-horizon statistics. Both models replicate the result that the real exchange rate (nominal interest rate differential) predicts negatively (positively) excess currency returns and the fact that indirect tests of UIP are more powerful than direct tests. Both models also imply that most of the real exchange rate variability is due to risk premia, rather than fundamentals, although they overstate the magnitude of the effect. Indeed, both models imply a negative covariance between the real exchange rate and the differential between foreign and domestic real interest rates, leading to a negative fundamental variance share and a risk-premium share in excess of 100%.

The paper is organized as follows: Section 1 discusses the contribution of our paper relative the related literature. Section 2 illustrates the empirical methodology. Section 3 illustrates the empirical analysis. Section 4 discusses the empirical implications of the two theoretical models. Section 5 concludes. In the interest of space, several derivations and detailed discussions are relegated to the Internet Appendix.

1 Related literature

The literature on exchange rate determination and predictability is vast. This section focuses on the *four* studies that are most closely related to the present paper.[1] Froot and Ramadorai (2005) use the real exchange rate as a predictor of currency returns, in the context of a VAR estimated with daily data in a panel setting, for the sample from June 20, 1994, to February 9, 2001. Following Campbell (1991), they decompose the variance of innovations in currency returns into shares attributable to risk premium news and fundamental news, finding that risk premium news dominates. Their focus is different from ours, though, as they do not concentrate on the predictive power of the real exchange rate, but on the effect of net order flow on currency prices. In addition, they do not perform indirect tests of predictability, nor do they report or make inference on implied infinite-horizon regression coefficients.

Engel and West (2005) study the relation between exchange rates and macro variables, using quarterly data for the January 1974–September 2001 sample. They investigate whether nominal currency returns Granger-cause macro variables (differentials in nominal money growth, inflation, nominal interest rates, and GDP growth), finding some supportive evidence. Moreover, similarly to our variance decomposition exercise, they test whether nominal currency returns are correlated with changes in the *present values* of several macro variables, finding that in most cases the correlations are insignificant. We improve upon their analysis by providing a framework—the present value representation in equation (1)—that identifies the real bond return differential as the *single* macro variable being anticipated by exchange rates. This unifying framework allows us to relate the predictive power of real exchange rates for excess currency returns and real bond return differentials, respectively, to the roles of risk premia and fundamentals in determining (real) exchange rate variation.

[1] For a summary of the main strands of the literature on currency price determination and further discussion of the contribution of our paper, see the Internet Appendix (Section IA.1).

Evans (2012) also starts from a present value representation of the log real exchange rate. His empirical analysis attributes most of the variance of changes in log real exchange rates to "dark matter." Differently from our study, Evans (2012) models the real exchange rate as a *non-stationary* variable, assuming that investors constantly update their expectation of infinite-horizon deviations from absolute PPP. Hence, what he denotes as dark matter is the *combined* effect of changes in risk premia and revisions of expected infinite-horizon PPP deviations, and he does not distinguish between the two effects. When we apply the methodology of Evans (2012) to our setting, and we distinguish between the two effects, we find that virtually *all* of the variability of changes in real exchange rates is due to revisions of expected infinite-horizon PPP deviations. This result seems implausible, and we attribute it mainly to the misspecification of the joint dynamics of the real exchange rate, currency returns, and inflation differentials.[2]

Finally, Engel (2016) studies the relation between the infinite-horizon cumulative UIP deviation and the current expected real bond return differential. He finds that the covariance between the two quantities is *negative*: high real-interest-rate currencies tend to experience low cumulative excess returns in the long run. This result stands in contrast with the well-documented deviations from UIP: high real-interest-rate currencies tend to experience high excess returns in the short run. Engel (2016) demonstrates that the two stylized facts cannot be accommodated by existing equilibrium models. Our analysis differs from that of Engel (2016) because we focus on the relation between the infinite-horizon cumulative UIP deviations and the real exchange rate, rather than the expected real bond return differential. Indeed, we show that the real

[2] Interestingly, the theoretical model put forward by Evans (2012) postulates that the real exchange rate has a stationary steady-state distribution and, hence, the share of the variability of changes in real exchange rates due to the revision of infinite-horizon PPP deviations is *nil.*

exchange rate is the most robust predictor of infinite-horizon cumulative UIP deviations. Moreover, our panel-data results show that, once we control for the real exchange rate, the sign of the coefficient of the nominal or real interest rate differential remains positive as we extend the return horizon.

2 Methodology

2.1 Preliminaries

Let r_t and r_t^f denote the continuously-compounded domestic and foreign nominal risk-free rates and let $dr_t \equiv r_t^f - r_t$ denote the interest rate differential. Throughout, the superscript f denotes a variable of the foreign country, and d denotes the differential between foreign and domestic variables: $dX \equiv X^f - X$. Δ denotes first differences: $\Delta X_t \equiv X_t - X_{t-1}$. Finally $\tilde{X}$ denotes a real quantity, and $\hat{X}$ denotes an estimate.

Let s_t denote the log of the directly quoted nominal exchange rate and let $\xi_{t+1} \equiv s_{t+1} - s_t + dr_t$ denote the time-$t+1$ *excess* log currency return, i.e., the log currency return in excess of the cost of carry $(-dr_t)$. Our empirical analysis focuses on testing the null hypothesis that:

$$E_t(\xi_{t+1}) = E(\xi_{t+1}). \quad (2)$$

We denote this null hypothesis the UIP null.

Let p_t and p_t^f denote the log domestic and foreign price levels. We define the log *real* exchange rate $\tilde{s}_t$ as:

$$\tilde{s}_t \equiv s_t + p_t^f - p_t. \quad (3)$$

Note that if absolute PPP holds, the real exchange rate equals one, and the *log* real exchange rate equals zero. Taking first differences of (3), we have:

$$\begin{aligned}\Delta\tilde{s}_{t+1} &\equiv \tilde{s}_{t+1} - \tilde{s}_t = s_{t+1} - s_t + p^f_{t+1} - p^f_t - (p_{t+1} - p_t) \\ &\equiv s_{t+1} - s_t + \pi^f_{t+1} - \pi_{t+1} = s_{t+1} - s_t + dr_t - dr_t + d\pi_{t+1} \\ &\equiv \xi_{t+1} - d\tilde{r}_{t+1}, \end{aligned} \tag{4}$$

where π_{t+i} and π^f_{t+i} are the domestic and foreign continuously-compounded inflation rates, respectively, $d\pi_{t+1} \equiv \pi^f_{t+1} - \pi_{t+1}$ is the inflation differential, and $d\tilde{r}_{t+1} \equiv dr_t - d\pi_{t+1}$ is the real bond return differential.

2.2 Finite-horizon direct and indirect tests

The present value representation (1) motivates the real exchange rate as a predictor of excess currency returns. To the extent that currency risk premia exhibit serial correlation, the excess currency return should also be used as a predictor. Moreover, given the evidence from existing studies, we also include the interest rate differential as a predictor. Finally, the inflation differential is also a natural candidate as a predictor, as inflation is one of the macro variables typically considered in the international finance literature (see, for example, Engel and West, 2005). Hence, we define: $z_t \equiv [\tilde{s}_t, \xi_t, dr_t, d\pi_t, x_t^\top]^\top$, where x_t is a vector of K possible additional instruments. We then estimate the monthly predictive regressions—the "UIP" regressions corresponding to the direct tests of UIP:

$$\xi_{H,t+H} = \alpha_{\xi,H} + \beta^\top_{\xi,H} z_t + e_{\xi,t+H}, \tag{5}$$

where $\xi_{H,t+H} \equiv \sum_{h=1}^{H} \xi_{t+h}$ is the roll-over H-month excess return.

We test the individual null hypotheses:

$$\beta_{\xi,H,k} = 0, \tag{6}$$

where $\beta_{\xi,H,k}$ is the k-th element of $\beta_{\xi,H}$, and $k = 1, \ldots, K+4$. In addition, we test the joint null hypotheses:

$$\beta_{\xi,H} = \mathbf{0}_{4+K}. \tag{7}$$

Following Lustig, Roussanov, and Verdelhan (2014), we can also predict the excess return on *baskets* of currencies. In this case, the dependent and independent variables in (5) are replaced by their cross-sectional averages across currencies in the basket.

We now turn to the indirect tests of UIP, by noticing that the null hypotheses above ((6) or (7)) have implications for the coefficients of regressions predicting real bond return differentials. In fact, consider the identity:

$$\xi_{H,t+H} \equiv \Delta\tilde{s}_{H,t+H} + d\tilde{r}_{H,t+H}, \tag{8}$$

where $\Delta\tilde{s}_{H,t+H} \equiv \sum_{h=1}^{H} \Delta\tilde{s}_{t+h} = \tilde{s}_{t+H} - \tilde{s}_t$, and $d\tilde{r}_{H,t+H} = \sum_{h=1}^{H} d\tilde{r}_{t+h}$. We have the "PPP" and "RRE" regressions:

$$\Delta\tilde{s}_{H,t+H} = \alpha_{\Delta\tilde{s},H} + \beta_{\Delta\tilde{s},H}^{\top} z_t + e_{\Delta\tilde{s},t+H} \tag{9}$$

$$d\tilde{r}_{H,t+H} = \alpha_{d\tilde{r},H} + \beta_{d\tilde{r},H}^{\top} z_t + e_{d\tilde{r},t+H}, \tag{10}$$

where, from (8), $d\tilde{r}_{H,t+H} = \xi_{H,t+H} - \Delta\tilde{s}_{H,t+H}$, and $\beta_{d\tilde{r},H} = \beta_{\xi,H} - \beta_{\Delta\tilde{s},H}$.

Hence, we now consider the implications that the UIP null, *jointly* with a choice of $\beta_{\Delta\tilde{s},H}$ consistent with long-run relative PPP, has for deviations from

RRE. Specifically, we *assume* $\beta_{\Delta\tilde{s},H,k} = \bar{\beta}_{\Delta\tilde{s},H,k}$ (k denoting the element of the corresponding vector, as in (6), and a bar denoting an assumed value), and combine the restrictions (6) to obtain:

$$\beta_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}; \tag{11}$$

whereas combining (7) and the assumption $\beta_{\Delta\tilde{s},H} = \bar{\beta}_{\Delta\tilde{s},H}$, we obtain the joint restrictions:

$$\beta_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}. \tag{12}$$

In other words, if we assume that excess currency returns are not predictable, whereas the appreciation of the real exchange rate *is* predictable, then real bond return differentials must be predictable. Hence, we can test (6) and (11)—or (7) and (12)—both separately and *jointly*. This approach extends the analysis of Cochrane (2008), who only tests the two hypotheses separately.

It is easy to see why testing the indirect null can be more powerful in uncovering evidence of predictability. Consider the direct null in equation (7). Given the definition of $\xi_{H,t+H}$ in equation (8), we can rewrite (7) as:

$$\beta_{d\tilde{r},H} + \beta_{\Delta\tilde{s},H} = \mathbf{0}_{4+K}. \tag{13}$$

On the other hand, the indirect null in equation (12) can be written as:

$$\beta_{d\tilde{r},H} + \bar{\beta}_{\Delta\tilde{s},H} = \mathbf{0}_{4+K}. \tag{14}$$

Hence, by testing the indirect null, the econometrician takes a stand on $\beta_{\Delta\tilde{s},H}$ and "eliminates" the effect on $\hat{\beta}_{\xi,H}$ of the sampling variability in $\hat{\beta}_{\Delta\tilde{s},H}$ and of the sampling covariability between $\hat{\beta}_{d\tilde{r},H}$ and $\hat{\beta}_{\Delta\tilde{s},H}$. Also note that the estimates of the left-hand side of (13) and (14) are *not* perfectly correlated and, hence, there are potential power gains from testing the direct and indirect null hypotheses *jointly*, as discussed above.

2.3 Infinite-horizon tests

We assume that z_t follows a stationary VAR(1):[3]

$$z_t = A + Bz_{t-1} + v_t, \tag{15}$$

where the eigenvalues of B lie inside the unit circle. It is worth noting that if we replace z_t with $[\tilde{s}_t, \Delta s_t, d\pi_t]^\top$ in the VAR above, we obtain a conventional error correction model (ECM). In the ECM, s_t and $p_t^f - p_t$ are co-integrated with co-integrating vector $[1, 1]^\top$ and, as in our VAR, $\tilde{s}_t$ is stationary (see Jordà and Taylor, 2012, and Engel, 2016). Relative to the ECM, the VAR in (15) differs by including the dynamics of the interest rate differential, dr_t.

Based on the VAR in (15), we compute the theoretical regression coefficients from projecting infinite-horizon cumulative excess returns on the real exchange rate and other instruments:

$$\hat{\beta}_{\xi,\infty}^\top = \hat{\beta}_{\xi,1}^\top (I - \hat{B})^{-1}. \tag{16}$$

Hence, we can test the individual restrictions, $\beta_{\xi,\infty,k} = 0$, and the joint restriction:

$$\beta_{\xi,\infty} = \mathbf{0}_{4+K}. \tag{17}$$

[3]Note a restricted version of this VAR is used to generate bootstrap samples under the UIP null; see the Internet Appendix (Section IA.2) for details.

Note that, in the infinite-horizon setting, the indirect restriction (12) takes the form $\beta_{d\tilde{r},\infty} = -\bar{\beta}_{\Delta\tilde{s},\infty}$, or, equivalently, $\beta_{d\tilde{r},\infty} + \bar{\beta}_{\Delta\tilde{s},\infty} = \mathbf{0}_{4+K}$. It is easy to show that this indirect restriction is equivalent to the *direct* restriction (17) above and the indirect test does not add any information, i.e, does not help reduce sampling errors. Given the assumed stationarity of $\tilde{s}_t$, the conditional expectation $E_t(\tilde{s}_t - \tilde{s}_\infty)$ changes in a one-to-one fashion in the opposite direction of $\tilde{s}_t$. Hence, *regardless of the assumed process for* $\Delta\tilde{s}_t$, the vector of infinite-horizon regression coefficients $\bar{\beta}_{\Delta\tilde{s},\infty}$ equals $-\iota_1 \equiv -[1\ 0\ 0\ 0\ \mathbf{0}_K^\top]^\top$, and $\hat{\beta}_{d\tilde{r},\infty} + \bar{\beta}_{\Delta\tilde{s},\infty} = \hat{\beta}_{d\tilde{r},\infty} - \iota_1$.[4] It follows from equations (13) and (14) that testing the indirect restriction $\beta_{d\tilde{r},\infty} - \iota_1 = \mathbf{0}_{4+K}$ is equivalent to testing the *direct* restriction $\beta_{\xi,\infty} = \mathbf{0}_{4+K}$.

Using the VAR in equation (15), we can revisit the present value representation of the real exchange rate in equation (1). We have:

$$\begin{aligned}
\tilde{s}_t - E(\tilde{s}_t) &= -\sum_{i=1}^{\infty} E_t(\xi_{t+i} - d\tilde{r}_{t+i}) \\
&= -\sum_{i=1}^{\infty} E_t[\xi_{t+i} - E(\xi_t)] + \sum_{i=1}^{\infty} E_t[d\tilde{r}_{t+i} - E(d\tilde{r}_t)] - \sum_{i=1}^{\infty}[E(\xi_t) - E(d\tilde{r}_t)] \\
&= -\sum_{i=1}^{\infty} E_t[\xi_{t+i} - E(\xi_t)] + \sum_{i=1}^{\infty} E_t[d\tilde{r}_{t+i} - E(d\tilde{r}_t)] \\
&= -\beta_{\xi,\infty}^\top[z_t - E(z_t)] + \beta_{d\tilde{r},\infty}^\top[z_t - E(z_t)], \qquad (18)
\end{aligned}$$

where, given the assumed stationarity of $\tilde{s}_t$, $E(\xi_t) - E(d\tilde{r}_t) \equiv E(\Delta\tilde{s}_t) = 0$, and $\hat{\beta}_{d\tilde{r},\infty}^\top = \hat{\beta}_{d\tilde{r},1}^\top(I - \hat{B})^{-1}$. Therefore, we can decompose the variance of the real exchange rate as:

$$\text{var}(\tilde{s}_t) = \text{cov}(\tilde{s}_t, -\beta_{\xi,\infty}^\top z_t) + \text{cov}(\tilde{s}_t, \beta_{d\tilde{r},\infty}^\top z_t); \qquad (19)$$

[4]This result follows directly from infinite-horizon versions of equations (8)–(10).

to obtain:

$$1 = \frac{\text{cov}(\tilde{s}_t, -\beta_{\xi,\infty}^{\top} z_t)}{\text{var}(\tilde{s}_t)} + \frac{\text{cov}(\tilde{s}_t, \beta_{d\tilde{r},\infty}^{\top} z_t)}{\text{var}(\tilde{s}_t)}, \tag{20}$$

where the first term—the "risk premium variance share"—captures the share of the variance due to changes in expected future risk premia, and the second term—the "fundamental variance share"—captures the variance due to changes in expected future real bond return differentials. In the case where the real exchange rate is the only predictor, the decomposition in (20) simplifies to:

$$1 = -\frac{\beta_{\xi}}{1-\rho_{\tilde{s}}} + \frac{\beta_{d\tilde{r}}}{1-\rho_{\tilde{s}}}, \tag{21}$$

where β_{ξ} and $\beta_{d\tilde{r}}$ are the coefficients of regressions of ξ_{t+1} and $d\tilde{r}_{t+1}$ on $\tilde{s}_t$, respectively, and where $\rho_{\tilde{s}}$ is the serial correlation coefficient of $\tilde{s}_t$. In the empirical analysis, we use the difference between the risk-premium variance share in equation (20) and in the equation above, as an indicator of the role of the real exchange rate in capturing the long-run dynamics of ξ_t. If the difference is small, as it is in our sample, we can then conclude that the real exchange rate alone captures most of the long-term dynamics of excess currency returns.

Equation (21) is also useful in interpreting the implications of no-arbitrage models of currency pricing. We find that both the habit and long-run risks models imply a risk premium share of the volatility of the real exchange rate that exceeds 100%. Since the variance-decomposition results in the univariate and multi-variate settings are quite similar, based on (21), we can interpret this implication of the two models as being due to the fact that they imply a negative covariance between $\tilde{s}_t$ and $d\tilde{r}_{t+1}$.

3 Empirical analysis

3.1 Data and empirical strategy

Our dataset, available from Datastream, includes monthly observations, over the period December 1983–April 2012, of foreign exchange rates, interest rates, and (seasonally-unadjusted) consumer price indexes (CPIs) of the following 34 countries:[5]

> *G10 countries*: Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, and United Kingdom.
>
> *Non-G10 developed countries*: Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Netherlands, Portugal, Singapore, and Spain.
>
> *Emerging countries*: Czech Republic, Hungary, India, Indonesia, Kuwait, Malaysia, Mexico, Philippines, Poland, South Africa, South Korea, Taiwan, and Thailand.

In most of our tests, we parameterize the restricted VAR based on a panel-data estimator, which uses data on all currencies and controls for currency-specific fixed effects. The panel-data approach has two, related, advantages relative to the estimation of separate VARs for each country. First, we employ more data, and, as a result, we obtain *much* more precise estimates. Second, the panel-data VAR estimates lead to stable dynamics of the state variables, whereas some country-specific VAR estimates lead to unstable dynamics.[6]

[5]See the Internet Appendix (Section IA.3) for further details on the data set. Note that the G10 countries are selected based on trading volume in the currency market, not on measures of economic development. In addition, one of the G10 countries is the U.S. and, hence, the list only contains nine countries.

[6]It is well documented that panel-data estimation leads to more reliable estimates of exchange rate dynamics than pure time-series approaches: Mark and Sul (2001), Rapach

We consider four finite investment horizons: one, three, six, and 12 months. Wald statistics are Newey-West adjusted for heteroskedasticity and moving-average serial correlation of order equal to the investment horizon minus one. We report both asymptotic and bootstrap results, where the bootstrap inference is based on a bootstrap of the VAR residuals. We bootstrap the residuals from the VAR equations, *separately* for each currency, but jointly across all of the predictors for the same currency, to preserve properties of the joint distribution, such as asymmetry, fat tails, and cross-sectional dependence. The number of bootstrap repetitions is 5,000. To minimize the possible bias introduced by an arbitrary choice of starting values, in each bootstrap repetition we employ a new starting value randomly drawn from the time series of z_t, and we also use a warm-up period of 60 months.

3.2 Results: individual currencies

We start with the results for 39 currencies and currency baskets in total. Based on the bootstrap inference, the direct tests uncover only weak evidence of predictability, whereas the evidence of predictability is very strong in the indirect and joint direct/indirect tests. For example, at the three-month horizon (Table 1), in the direct tests, the UIP null is rejected in seven, one, ten, and zero instances, for the real exchange rate, excess currency return, interest rate differential, and inflation differential, respectively.[7] In the *indirect* tests, on the other hand, the UIP null is rejected in 37, 34, 32, and 18 instances. Similarly, in the joint direct-indirect tests, we see 36, 34, 33, and 16 rejections (38 rejections in the joint test for all four predictors).

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and Wohar (2002), and Jordà and Taylor (2012), all use panel-data vector ECMs, similar to our VAR, to produce robust forecasts of exchange rates.

[7]In the interest of space, results at the other horizons are detailed in the Internet Appendix (Tables IA.1–IA.3).

As the return horizon increases, the evidence from direct tests is similar, with an increase in the predictive power of the inflation differential. In the indirect tests, on the other hand, the predictive power of the real exchange rate persists, whereas the predictive power of the other predictors—the excess currency return and the inflation differential, in particular—diminishes. At the 12-month horizon, for example, in the *direct* test, the UIP null is rejected in nine, zero, 11, and 13 instances, for the real exchange rate, excess currency return, interest rate differential, and inflation differential, respectively. In the *indirect* test, on the other hand, the UIP null is rejected in 38, 23, 28, and four instances. In the joint direct-indirect tests, at the 12-month horizon, we see markedly lower rejection rates for the excess currency return and the inflation differential. Interestingly, the number of rejections for the nominal interest rate differential, 31, is *higher* than the number of rejections in either the direct (11) or indirect (28) tests alone, showing how the joint implementation of the direct and indirect tests can indeed improve the power to detect predictability patterns.

Table 2 reports results for the infinite-horizon inference. Across currencies, there are 12 rejections, out of 34 tests, for the real exchange rate, and ten rejections for the nominal interest rate differential.[8] Hence, for the real exchange rate, the rejection rate (35%, i.e., 12 out of 34 test assets) is higher than the rejection rates from the direct tests (at most 26%), but lower than the rejection rates from the indirect tests (at least 95%). The excess currency return and inflation differential, on the other hand, are significant in only one and three tests, respectively. The joint tests lead to 13 rejections, the risk premium variance share is significant in nine instances, and the increase in variance share due to the addition of instruments to the real exchange rate is

[8]We have to exclude five currencies from the infinite-horizon analysis, because the corresponding VARs imply non-stationary dynamics.

significant in seven instances.

In summary, we see much stronger evidence of predictability from the indirect and joint direct-indirect tests, than from the direct tests. Of the four instruments, it is the real exchange rate to exhibit the strongest predictive power, followed by the nominal interest rate differential. The infinite-horizon tests also uncover more predictive power for the real exchange rate than the direct tests, although not as much as the indirect and joint direct-indirect tests. The evidence on the predictive power of the nominal interest rate differential is consistent with the extensive existing evidence on deviations from UIP reviewed, for example, by Sarno (2005). On the other hand, the evidence on the predictive power of the real exchange rate is largely a novel contribution of this paper.

3.3 Results: panel evidence

Table 3 presents evidence based on the panel-regression estimation. Given the large total number of observations—7,826 currency-month observations—inference here is based on asymptotics, where standard errors are clustered by currency *and* time. In the analysis presented here, we control for currency fixed effects.[9]

As one would expect, imposing a panel structure on the data leads to substantial additional power in all tests. Panel A shows evidence of predictability in the direct tests, especially strong for the real exchange rate and the interest rate differential. In order to assess the economic magnitude of the effects, we also compute the *scaled* regression coefficients, which give us effects on the dependent variable in units of standard deviation, for a one-standard-deviation change in the independent variable. While not tabulated here, the scaled

[9]We also experimented with *both* currency and time fixed effects, with analogous results.

regression coefficients associated with the real exchange rate range between -0.36 and -0.11, whereas the scaled coefficients associated with the interest rate differential range between 0.07 and 0.12, corroborating the notion of stronger predictive power of real exchange rates than interest rate differentials. With the notable exception of the inflation differential, the evidence of predictive power is confirmed in the indirect and joint direct-indirect tests (panels B and C).

As to the infinite-horizon evidence, we have very strong rejections of the UIP null for both the real exchange rate and the nominal interest rate differential. The risk premium variance share is a strongly significant 93%, and the addition of other instruments to the real exchange rate further increases the risk premium share only by 7%.[10]

It is worth noting that in this panel setting where we control for the real exchange rate, the nominal interest rate differential predicts *positively* excess currency returns at *all* horizons. Conversely, in untabulated results, the sign of a regression of expected infinite-horizon excess currency returns on either the nominal or real interest rate differential alone—i.e., not controlling for the real exchange rate—is negative, consistent with the evidence of Engel (2016).[11]

Finally, we also performed the panel-data analysis *separately* for the three groups of countries: G10, non-G10, and emerging. Results are qualitatively similar to those obtained for a single panel of countries: the indirect tests uncover much stronger evidence of predictability than the direct tests, especially for the real exchange rate; the implied infinite-horizon regression coefficients are also especially significant for the real exchange rate; and a large fraction of the variance of the real exchange rate can be attributed to changes in risk pre-

[10]The risk premium variance share in the single-predictor case is 86%, which, combined with the 7% change in share, leads to the 93% overall share.

[11]While Engel (2016) focuses on the predictive role of the expected real bond return differential, he finds similar results using the nominal interest rate differential.

mia (between 82% and 100%), where the inclusion of instruments in addition to the real exchange rate makes little difference (at most 9%).

3.4 Size and power

Two natural questions arise at this stage: First, does the bootstrap adjustment lead to the correct inference? Second, are the indirect and infinite-horizon tests indeed more powerful than the standard direct tests? To the best of our knowledge, we are the first to perform a size and power study of the indirect and infinite-horizon tests introduced by Cochrane (2008). We believe that this is a valuable methodological contribution of our paper.

In summary, we find that the bootstrap correction of the inference is needed and eliminates size distortions.[12] We also find that the power of the indirect and infinite-horizon test is substantially higher than that of the traditional direct test. In particular, for the realistic predictability patterns simulated in the power study, the indirect, joint direct-indirect, and infinite-horizon tests seem especially apt at detecting predictability stemming from the real exchange rate. These findings further reassure us that we are indeed uncovering new, and reliable, predictability patterns that would not be apparent using standard methods.

3.5 Extensions and robustness checks

We perform several extensions of our analysis and we implement several robustness checks of our baseline results:[13] i) non-stationarity of the real exchange rate; ii) correction of possible spurious-regression biases; iii) alternative choices

[12]See the Internet Appendix (Section IA.4) for details.

[13]In the interest of space, the details of this analysis can be found in the Internet Appendix (Section IA.5).

of $\bar{\beta}_{\Delta\tilde{s},H}$; iv) UIP null hypothesis parameterized according to currency-specific VARs; v) correction of VAR parameter estimates for small-sample biases; vi) controlling for additional predictors; vii) use of alternative approaches to bootstrap; and viii) use of different reference currencies.

We find that the assumption of non-stationarity of the real exchange rate leads to the implausible result that essentially 100% of the variance of the monthly real exchange rate appreciation can be attributed to revisions of expected infinite-horizon PPP deviations. We also find that the predictability patterns uncovered in this study are *very* robust, and that indirect and infinite-horizon tests are *crucial* to uncover such predictability.

4 Implications of the theory

In studying the implications of the theory, we start by focusing on three univariate predictability patterns that any model of currency returns should confront.[14] First, the real exchange rate predicts negatively excess currency returns. Second, the nominal interest rate differential predicts positively excess currency returns. Third, the real exchange rate has a positive, albeit moderate, predictive power for real bond return differentials. The first pattern is at the center of the empirical analysis of the paper. The second pattern is the violation of UIP studied in much of the existing literature on currency premia. The third pattern is related to our finding that a small, but positive, share of the variability of real exchange rates is due to fundamentals.

In the following, we briefly analyze the three patterns discussed above in terms of a general no-arbitrage model of currency prices. Let $d\tilde{u}_t$ denote the differential between the foreign and domestic log marginal utilities of con-

[14] These three patterns are supported by untabulated results of univariate panel-data regressions.

sumption. The differential between the foreign and domestic real log pricing kernels is given by $d\tilde{m}_t \equiv \Delta d\tilde{u}_t$. Absent arbitrage, we have $\Delta\tilde{s}_t = d\tilde{m}_t$. Hence, assuming stationarity of the log marginal utility differential, we have:

$$d\tilde{u}_t - E(d\tilde{u}_t) = -\sum_{i=1}^{\infty} E_t(d\tilde{m}_{t+i}) = -\sum_{i=1}^{\infty} E_t(\Delta\tilde{s}_{t+i}) = \tilde{s}_t - E(\tilde{s}_t). \qquad (22)$$

Assuming lognormality, symmetric economies, and homoskedastic and neutral inflation ($d\sigma_\pi = d\sigma_{\tilde{m}\pi} = 0$), as we do in the context of the two specialized models below, we have $E_t(\xi_{t+1}) = -\frac{1}{2}d\sigma^2_{\tilde{m}t}$ and:[15]

$$\text{cov}[\tilde{s}_t, E_t(\xi_{t+1})] = -\frac{1}{2}\text{cov}(d\tilde{u}_t, d\sigma^2_{\tilde{m}t}). \qquad (23)$$

The nominal interest rate differential equals $dr_t = -d\mu_{mt} - \frac{1}{2}d\sigma^2_{mt} = -d\mu_{\tilde{m}t} - \frac{1}{2}d\sigma^2_{\tilde{m}t} + d\mu_{\pi t}$, where dm_t is the nominal log pricing kernel differential, and we have:

$$\text{cov}[dr_t, E_t(\xi_{t+1})] = \frac{1}{2}\text{cov}(d\mu_{\tilde{m}t}, d\sigma^2_{\tilde{m}t}) + \frac{1}{4}\text{var}(d\sigma^2_{\tilde{m}t}). \qquad (24)$$

Finally, the expected real bond return differential equals $E_t(d\tilde{r}_{t+1}) = dr_t - d\mu_{\pi t} = -d\mu_{mt} - \frac{1}{2}d\sigma^2_{mt} - d\mu_{\pi t} = -d\mu_{\tilde{m}t} - \frac{1}{2}d\sigma^2_{\tilde{m}t}$ and we have:

$$\text{cov}[\tilde{s}_t, E_t(d\tilde{r}_{t+1})] = -\text{cov}(d\tilde{u}_t, d\mu_{\tilde{m}t}) - \frac{1}{2}\text{cov}(d\tilde{u}_t, d\sigma^2_{\tilde{m}t}). \qquad (25)$$

Equations (23)–(25) afford some general insights. First, we see that $\text{cov}[\tilde{s}_t, E_t(\xi_{t+1})] < 0$ is not due to the stationarity of the real exchange rate (i.e, $\text{cov}(d\tilde{u}_t, d\mu_{\tilde{m}t}) < 0$), but it requires $\text{cov}(d\tilde{u}_t, d\sigma^2_{\tilde{m}t}) > 0$—i.e., a positive relation between the

[15]Here and in the following, μ_{Xt}, σ_{Xt}, σ_{XYt}, and ρ_{XYt} denote the mean, standard deviation, covariance, and correlation coefficient of the corresponding X and Y variables conditional on time-t available information. In the absence of a time subscript, the moments are to be interpreted as constant over time.

differentials in the levels and in the variances of the marginal utilities in the two countries. Second, a sufficient condition for $\text{cov}[dr_t, E_t(\xi_{t+1})] > 0$ is that $\text{cov}(d\mu_{\tilde{m}t}, d\sigma^2_{\tilde{m}t}) > 0$, which is unlikely to be the case if the real exchange rate is stationary ($\text{cov}(d\tilde{u}_t, d\mu_{\tilde{m}t}) < 0$) and it predicts negatively excess currency returns ($\text{cov}(d\tilde{u}_t, d\sigma^2_{\tilde{m}t}) > 0$). Third, in order for $\text{cov}[\tilde{s}_t, E_t(d\tilde{r}_{t+1})] > 0$, we need the mean reversion effect ($-\text{cov}[d\tilde{u}_t, E_t(d\tilde{m}_{t+1})] > 0$) to be stronger than the relationship between the real exchange rate and the currency risk premium ($-\frac{1}{2}\text{cov}(d\tilde{u}_t, d\sigma^2_{\tilde{m}t}) < 0$). In summary, it is unclear whether a single theoretical model can deliver all three predictability patterns.[16]

In the next two sections, we re-examine the three univariate predictability patterns discussed above, as well as the multi-variate predictability patterns documented in the empirical analysis, in the context of two no-arbitrage models of currency returns, the habit model (Verdelhan, 2010) and the long-run risks model (Bansal and Shaliastovich, 2013). Both models are modified relative to their original formulations to deliver a stationary real exchange rate.[17]

4.1 The habit model

4.1.1 Preferences and equilibrium quantities

The symmetric habit model Verdelhan (2010) assumes that the real log pricing kernel differential equals:

$$d\tilde{m}_t = -\gamma(\Delta dh_t + \Delta d\tilde{c}_t); \tag{26}$$

[16]Indeed, the Internet Appendix (Section IA.7) shows that a single-factor affine model is unable to contemporaneously match all three inequalities.

[17]A recent model of currency prices whose implications we do not pursue is the liquidity model of Engel (2016). In his model, there is no direct channel connecting the real exchange rate to expected excess currency returns: the connection between the two quantities only takes place through the reaction function of monetary authorities in the two countries. See the Internet Appendix (Section IA.6) for further discussion.

where dh_t is the differential in log consumption surplus ratios, $dh_t \equiv \ln[(\tilde{C}_t^f - \tilde{X}_t^f)/\tilde{C}_t^f] - \ln[(\tilde{C}_t - \tilde{X}_t)/\tilde{C}_t]$, where $\tilde{C}_t^f$ and $\tilde{C}_t$ are foreign and domestic real per-capita consumption, respectively, and $\tilde{X}_t^f$ and $\tilde{X}_t$ are the foreign and domestic external "habit" consumption, respectively; and $d\tilde{c}_t \equiv \ln(\tilde{C}_t^f/\tilde{C}_t)$ is the differential in real log per-capita consumption.[18] We have:

$$\tilde{s}_t - E(\tilde{s}_t) = -\gamma(dh_t + d\tilde{c}_t) = -\gamma[d\ln(\tilde{C}_t - \tilde{X}_t)]. \tag{27}$$

The equation above highlights how the real exchange rate is driven by the differential in log *excess* consumption: what matters is not the differential in the absolute consumption level, but the differential in consumption relative to the external habit. Hence, two countries may have the same level of consumption, but experience different marginal utilities of consumption because of different external habit levels. In turn, the difference in marginal utilities leads to deviations from PPP.

As in Verdelhan (2010), we have:[19]

$$E_t(\xi_{t+1}) = \frac{\gamma^2\sigma^2_{\epsilon_c}}{\bar{H}^2} dh_t, \tag{28}$$

where $\bar{H}$ is a "tuning" parameter. Note that dh_t affects the real exchange rate and the currency risk premium in opposite directions. A higher differential in the habit level of consumption increases both the differential in marginal utility

[18]The domestic representative agent's intertemporal marginal rate of substitution and the domestic economy's pricing kernel is given by:

$$\exp(\tilde{m}_t) = \beta\left(\frac{\tilde{C}_t - \tilde{X}_t}{\tilde{C}_{t-1} - \tilde{X}_{t-1}}\right)^{-\gamma} = \beta\left(\frac{H_t}{H_{t-1}}\right)^{-\gamma}\left(\frac{\tilde{C}_t}{\tilde{C}_{t-1}}\right)^{-\gamma},$$

where β is the time discount factor and $H_t \equiv (\tilde{C}_t - \tilde{X}_t)/\tilde{C}_t$ is the surplus consumption ratio. Taking logs, we have $\tilde{m}_t = \ln(\beta) - \gamma\Delta h_t - \gamma\Delta\tilde{c}_t$, where $h_t \equiv \ln(H_t)$ and $\tilde{c}_t \equiv \ln\tilde{C}_t$. Analogous expressions apply to the foreign economy.

[19]See the Internet Appendix (Section IA.8.1) for details.

of consumption and the differential in the volatility of the marginal utility of consumption. The first effect drives up the real exchange rate, whereas the second effect drives down the currency risk premium. Indeed, the covariance between the real exchange rate and the currency risk premium is given by:[20]

$$\begin{aligned} \mathrm{cov}[\tilde{s}_t, E_t(\xi_{t+1})] &= -\frac{\gamma^3 \sigma^2_{\epsilon_{\tilde{c}}}}{\bar{H}^2}[\mathrm{var}(dh_t) + \mathrm{cov}(dh_t, d\tilde{c}_t)] \\ &= -\frac{\gamma^3 \sigma^2_{\epsilon_c}}{\bar{H}^2}\{\mathrm{var}(dh_t) + 2E[\lambda(h_t)](1 - \rho_{\epsilon_{\tilde{c}}\epsilon^f_{\tilde{c}}})\sigma^2_{\epsilon_{\tilde{c}}}\}. \end{aligned} \quad (29)$$

For our choice of parameters, this covariance is negative.

Turning to the nominal interest rate differential, we have:

$$dr_t = -bdh_t + \gamma(\phi_c - 1)d\tilde{c}_t + \phi_\pi d\pi_t, \quad (30)$$

where $b \equiv \gamma(1-\phi_h) - \frac{\gamma^2\sigma^2_{\epsilon_c}}{\bar{H}^2}$.[21] Note that the second and third term in the expression above are absent in the solutions of Verdelhan (2010): Verdelhan (2010) does not impose the stationarity of the real exchange rate and derives the real, rather than the nominal, interest rate differential.

Following Verdelhan (2010), we choose $b < 0$. Hence, an increase in dh_t affects the nominal interest differential and the currency risk premium in the same direction. The covariance between the two quantities equals:

$$\mathrm{cov}[dr_t, E_t(\xi_{t+1})] = \frac{\gamma^2 \sigma^2_{\epsilon_c}}{\bar{H}^2}[-b\mathrm{var}(dh_t) + \gamma(\phi_c - 1)\mathrm{cov}(dh_t, d\tilde{c}_t)]. \quad (31)$$

For our choice of parameter values, the covariance above is positive, implying that the nominal interest rate differential predicts positively the excess currency return.

[20] See the Internet Appendix (Section IA.8.2) for the derivation of the conditional moments of dh_t.

[21] ϕ_X denotes the serial correlation coefficient of the X variable.

Finally, the expected real bond return differential equals:

$$E_t(d\tilde{r}_{t+1}) \quad = \quad dr_t - \phi_\pi d\pi_t \equiv -bdh_t + \gamma(\phi_c - 1)d\tilde{c}_t. \qquad (32)$$

Note that dh_t affects the real exchange rate and the expected real bond return differential in opposite directions and the covariance between the two quantities is given by:

$$\text{cov}[\tilde{s}_t, E_t(d\tilde{r}_{t+1})] = \gamma b \text{var}(dh_t) - \gamma^2(\phi_c - 1)\text{var}(d\tilde{c}_t). \qquad (33)$$

For our choice of parameter values, the covariance above is negative and the real exchange rate predicts the real bond return differential in the "wrong" direction and the model implies a risk premium variance share of the real exchange rate in excess of 100%.

4.1.2 Calibration

As in Verdelhan (2010) and Bansal and Shaliastovich (2013), we focus on the implications of the model for the Dollar/British Pound exchange rate. Following Verdelhan (2010) we set as baseline values: $\gamma = 2$, $\phi_h = 0.99$, and $b = -0.01$. Based on our data for the U.S. and U.K., we set (quarterly frequency): $\phi_c = 0.97$, $\phi_\pi = -0.24$, $\sigma_{\epsilon_{\tilde{c}}} = 0.0066$, $\sigma_{\epsilon_\pi} = 0.0078$, $\rho_{\epsilon^f_{\tilde{c}}\epsilon_{\tilde{c}}} = 0.44$, and $\rho_{\epsilon^f_\pi \epsilon_\pi} = 0.24$.

The results from the calibration exercise are reported in Table 4, where we also consider the effect of deviations of γ and b from the baseline scenario: "high" denotes a value twice as large as the baseline, whereas "low" denotes a value equal to one half of the baseline value. The population PPP, UIP, and RRE regression statistics are based on regressions with three regressors: $\tilde{s}_t$, dr_t, and $d\pi_t$, since there are only three state variables in this model. Similarly, the infinite-horizon statistics are based on a VAR(1) modeling the joint dynamics of $\tilde{s}_t$, dr_t, and $d\pi_t$.[22] We calculate population p-values associated with the regression coefficients, assuming that the analysis is performed with a sample of 96 quarterly observations, to match the number of quarterly observations in the sample.

Across choices of parameter values, a few implications of the habit model stand out. First, similarly to Verdelhan (2010), the model overstates the volatility of changes in the (log) real exchange rate and the persistence of the level of the (log) real exchange rate. This is a result of the fact that the variable that dominates the variability of the log pricing kernel differential is dh_t, which is very volatile and persistent. Second, in the UIP regressions, the model underestimates the magnitudes the coefficients associated with the real exchange rate and the nominal interest rate differential, although it reproduces their signs. Consistent with the empirical evidence, the model implies that the indirect test leads to a strong rejections of the UIP null, when focusing on the real exchange rate. On the other hand, for the nominal interest rate differential there is very little gain in power. Finally, the model overstates the risk premium variance share: for example, 141% for the baseline choice of parameters, as compared to a sample value of 60%. This result is due to the fact that the the real exchange rate predicts negatively the real bond return differential.

In summary, the habit model replicates a number of features of the data, including the fact that indirect tests of UIP are more powerful than the direct tests, and that a dominant portion of the variance of real exchange rates can be attributed to risk premia. On the other hand, the model overstates the

[22] As shown in the Internet Appendix (Section IA.9), by employing as many instruments in the VAR as the number of underlying state variables—three, in this case—the VAR-implied variance decomposition coincides with the theoretical variance decomposition.

volatility of real exchange rate appreciation, as well as the risk premium share of the real exchange rate variance.

4.2 The long-run risks model

4.2.1 Preferences and equilibrium quantities

Following Bansal and Yaron (2004) and Bansal and Shaliastovich (2013), we assume:

$$\tilde{m}_t = \text{constant} - \frac{\theta}{\psi}\Delta\tilde{c}_t + (\theta - 1)\tilde{r}_{ct}, \tag{34}$$

where $\theta \equiv (1-\gamma)/(1-1/\psi)$. ψ is the elasticity of intertemporal substitution; and $\tilde{r}_{ct}$ is the rate of return on the portfolio that delivers aggregate consumption, the "wealth portfolio." Following the literature, we assume $\gamma > 1$ and $\psi > 1$. As a result, we have $\theta < 0$.

Given the assumptions above, we have the log real pricing kernel differential:[23]

$$d\tilde{m}_t = -\gamma\Delta d\tilde{c}_t + m_y^\top(\kappa dy_t - dy_{t-1}); \tag{35}$$

where $dy_t \equiv [d\tilde{c}_t \; dv_t \; d\pi_t]^\top$ and $m_y \equiv [m_{dc} \; m_{dv} \; 0]^\top$, where dv_t denotes the differential in the conditional variance of log consumption in the two countries. We also have:[24]

$$\tilde{s}_t - E(\tilde{s}_t) = -\gamma d\tilde{c}_t + m_y^\top dy_t = (-\gamma + m_{dc})d\tilde{c}_t + m_{dv}dv_t. \tag{36}$$

[23]See the Internet Appendix (Sections IA.10.1 and IA.10.2) for details of the assumptions and solution.

[24]See the Internet Appendix (Section IA.10.3) for details.

The differential in marginal utilities reflects not just the difference in current consumption, but also the difference in equity valuations in the two countries. This difference, in turn, is driven by the log consumption differential as well as the volatility differential dv_t. Hence, two countries may have the same level of current consumption, but different expected consumption growth and volatility of consumption growth, leading to deviations from PPP.

Turning to the currency risk premium, it is driven by the differential consumption volatility process, dv_t:

$$E_t(\xi_{t+1}) = -\frac{1}{2} m_{dc}^2 dv_t. \tag{37}$$

Given our choice of parameters, $m_{dv} > 0$: an increase in consumption volatility reduces the valuation of the wealth portfolio, and an increase in the the consumption volatility differential increases the foreign pricing kernel relative to the domestic pricing kernel. Hence, the covariance:

$$\text{cov}[\tilde{s}_t, E_t(\xi_{t+1})] = -\frac{1}{2} m_{dv} m_{dc}^2 \text{var}(dv_t) \tag{38}$$

is negative. The intuition for the result is that when dv_t increases, both the level and the volatility of the foreign pricing kernel increase, relative to the domestic pricing kernel. The relative increase in the foreign pricing kernel drives the real exchange rate higher, whereas the relative increase in the volatility of consumption growth drives the currency risk premium lower, leading to the negative covariance above.

The nominal interest rate differential equals:

$$dr_t = (-\gamma + m_{dc})(1 - \phi_c) d\tilde{c}_t + \left[m_{dv}(1 - \phi_v) - \frac{1}{2} m_{dc}^2 \right] dv_t + \phi_\pi d\pi_t. \tag{39}$$

Note that the consumption volatility differential, dv_t, affects the nominal interest rate differential through two channels. First, an increase in dv_t reduces the valuation of the foreign wealth portfolio and increases its expected rate of return, relative to the domestic wealth portfolio. This effect drives down the expected pricing kernel differential—the two pricing kernels are inversely related to the rate of return on the corresponding wealth portfolios—and drives up the interest rate differential. Second, an increase in the consumption volatility differential increases the precautionary savings motive in the foreign country relative to the domestic country, driving down the interest rate differential. As a result, we have:

$$\mathrm{cov}[dr_t, E_t(\xi_{t+1})] = \left[\frac{1}{2}m_{dc}^2 - m_{dv}(1-\phi_v)\right]\frac{1}{2}m_{dc}^2\mathrm{var}(dv_t), \qquad (40)$$

whose sign depends on the sign of the quantity inside the square brackets. For our choice of parameters, this quantity is positive.

Finally, the expected real bond return differential equals:

$$E_t(d\tilde{r}_{t+1}) = [(-\gamma + m_{dc})(1-\phi_c)]d\tilde{c}_t + \left[m_{dv}(1-\phi_v) - \frac{1}{2}m_{dc}^2\right]dv_t; \qquad (41)$$

and:

$$\begin{aligned}\mathrm{cov}[\tilde{s}_t, E_t(d\tilde{r}_{t+1})] &= (-\gamma + m_{dc})^2(1-\phi_c)\mathrm{var}(d\tilde{c}_t) \\ &\quad + m_{dv}\left[m_{dv}(1-\phi_v) - \frac{1}{2}m_{dc}^2\right]\mathrm{var}(dv_t). \qquad (42)\end{aligned}$$

Given our choice of parameter values, the covariance above is negative. Hence, as in the habit model, a higher real exchange rate predicts a lower real bond return differential, and a variance decomposition exercise attributes more than 100% of the variance of the real exchange rate to risk premium variation.

Note that there is a parallel between the result above and the findings of Engel (2016). Engel (2016) finds that both the habit and long-run risks models counterfactually imply that $\text{cov}\left[E_t(d\tilde{r}_{t+1}), E_t\left(\sum_{i=1}^{\infty} \xi_{t+1}\right)\right] > 0$. We find that the habit and long-run risks models imply that $\text{cov}\left[E_t\left(\sum_{i=1}^{\infty} d\tilde{r}_{t+i}\right), E_t\left(\sum_{i=1}^{\infty} \xi_{t+1}\right)\right] > 0$, which is a necessary condition for more than 100% of the variance of the real exchange rate to be explained by the time variation in risk premia.[25]

4.2.2 Calibration

Following Bansal and Shaliastovich (2013), we set $\gamma = 12$ and $\psi = 1.81$. The mean equations for consumption growth and inflation are parameterized similarly to the habit model. As to the process for the volatility of consumption innovations, we follow Bansal and Shaliastovich (2013) and assume $\phi_v = 0.994$ and $\rho_{\epsilon_v^f \epsilon_v} = 0.94$.[26] As in the case of the habit model, we consider the effect of deviations of the preference parameters (γ and ψ) from the baseline scenario.

We derive population statistics for the UIP regressions and for the infinite-horizon analysis and we assume that the instruments in the predictive regressions and the VAR are: $\tilde{s}_t$, dr_t and $d\pi_t$. Similarly to the habit model, across parameter choices, the long-run risks model matches some features of the data, but misses other features; see Table 4. In particular, the model roughly matches the predictive power of the nominal interest rate differential for the excess currency return and, at least qualitatively, the improvement in inference from the indirect tests. On the other hand, the model grossly overstates the risk-premium share of the variance of the real exchange: 215% for the baseline choice of parameters v. 60% in the data.

[25]Let $Z = X + Y$. For $\text{cov}(Z, X) > \text{var}(Z)$ we need $\text{var}(X) + \text{cov}(X, Y) > \text{var}(X) + \text{var}(Y) + 2\text{cov}(X, Y)$ and $\text{var}(Y) + \text{cov}(X, Y) < 0$, which is only possible if $\text{cov}(X, Y) < 0$.

[26]See the Internet Appendix (Section IA.10.4) for details of the calibration of the volatility process.

5 Conclusions

We provide new evidence that real exchange rates contain important information about currency risk premia, and that they vary over time mainly because of time-varying expected risk premia, not changes in fundamentals. We perform multi-variate direct, indirect, joint, and infinite-horizon tests of the predictive power or the real exchange rate and a variance decomposition exercise.

While the direct tests uncover little predictive power, the indirect and joint direct-indirect tests strongly reject the no-predictability null, with the real exchange rate as the main predictor. The implied infinite-horizon regression statistics also reject the no-predictability null, although not as strongly as the indirect tests. The variance decomposition exercise shows that 93% of the variability of the real exchange rate can be attributed to changing expectations of future excess currency returns (panel-regression evidence). Moreover, the real exchange rate alone captures most of the infinite-horizon predictability of currency excess returns.

We relate our empirical findings to the implications of the habit and long-run risks models. Both models reproduce the predictive ability of the real exchange rate and the nominal interest rate differential for excess currency returns, and the fact that indirect tests of UIP are more powerful than direct tests. On the other hand, both models imply that the real exchange rate is negatively related to expected real bond return differentials. As a result, they substantially overstate the fraction of the volatility of the real exchange rate due to risk premia.

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Table 1: Testing UIP, Baseline Case, Three-month Investment Horizon: Summary

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), and joint tests (Panel C) of the UIP null on all currencies and currency baskets. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the numbers and the fractions of asymptotic tests or of bootstrap tests yielding p-values smaller than 0.05.

Panel A: Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	7	1	10	0
Frac. of Boot. $p < 0.05$	0.18	0.03	0.26	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.05				

Panel B: Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	37	34	32	18
Frac. of Boot. $p < 0.05$	0.95	0.87	0.82	0.46
No. of Assets: 39				

Panel C: Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	11	39	38	36	34	33	16
Frac. of Boot. $p < 0.05$	0.28	1.00	0.97	0.92	0.87	0.85	0.41
No. of Assets: 39							

Table 2: Testing UIP, Baseline Case, Infinite-horizon Regressions: Summary

This table summarizes the infinite-horizon regression results of all currencies and currency baskets with stationary VAR processes, and reports the numbers and the fractions of tests yielding asymptotic or bootstrap p-values smaller than 0.05. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	12	1	10	3	13	9	7
Frac. of Boot. $p < 0.05$	0.35	0.03	0.29	0.09	0.38	0.26	0.21
No. of Assets: 34							

Table 3: Testing UIP, Baseline Case, Panel Regressions

This table reports predictive regression estimates (Panels A and B), joint test statistics (Panel C), and infinite-horizon regression estimates and variance shares (Panel D), obtained from panel regressions using all currencies and controlling for currency fixed effects. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Asymptotic p-values, based on covariance matrix estimators clustered by both currency and time, are reported in parentheses under each estimate or test statistic.

Panel A: Direct Tests

Horizon	Explanatory Variables			
	$\tilde{s}$ (Asy. p)	ξ (Asy. p)	dr (Asy. p)	$d\pi$ (Asy. p)
1	-0.02	0.10	0.57	-0.01
	(0.00)	(0.03)	(0.00)	(0.97)
3	-0.07	0.17	1.26	0.02
	(0.00)	(0.00)	(0.02)	(0.91)
6	-0.15	0.19	2.55	0.63
	(0.00)	(0.05)	(0.00)	(0.02)
12	-0.29	0.20	3.68	1.90
	(0.00)	(0.06)	(0.03)	(0.00)

Panel B: Indirect Tests

Horizon	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$			
	$\tilde{s}$ (Asy. p)	ξ (Asy. p)	dr (Asy. p)	$d\pi$ (Asy. p)
1	0.00	0.03	0.76	-0.26
	(0.00)	(0.00)	(0.00)	(0.92)
3	0.01	0.06	1.30	-0.23
	(0.00)	(0.00)	(0.00)	(0.44)
6	0.01	0.08	2.00	-0.16
	(0.00)	(0.00)	(0.00)	(0.23)
12	0.01	0.09	3.33	-0.12
	(0.00)	(0.00)	(0.00)	(0.37)

Panel C: Joint Tests

Horizon	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
	Wald	Wald	Wald	Wald	Wald	Wald	Wald
	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)
1	26.56	1750.99	2009.41	663.44	122.68	53.57	0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.99)
3	41.74	2886.28	3723.97	1390.38	66.26	255.73	0.69
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.71)
6	46.80	3650.29	4684.74	1871.06	39.89	36.60	6.83
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.03)
12	38.16	3385.44	4283.45	1518.91	20.87	17.78	9.49
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)

Panel D: Infinite-horizon Regression Statistics

Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)	(Asy. p)
-0.93	0.04	1.57	-0.14	817.16	0.93	0.07
(0.00)	(0.01)	(0.00)	(0.07)	(0.00)	(0.00)	(0.02)

Table 4: Calibration

The table reports the empirical implications of the habit and long-run risks (LRR) models. The models are calibrated for a sample of 96 quarterly observations. Panel A reports annualized summary statistics based on quarterly observations. Panel B reports statistics of the UIP regression. Panel C reports infinite-horizon statistics. "High" and "low" denote scenarios where a parameter is set to a value double or one half of its baseline value, respectively. See the main text for further details.

Panel A: Summary Statistics

	$\sigma_{\Delta\tilde{s}}$	$\rho_{\tilde{s}}$	σ_{dr}	σ_{ξ}	$\sigma_{d\tilde{r}}$
Habit, baseline	0.3395	0.9889	0.0081	0.3406	0.0203
Habit, high γ	0.4620	0.9885	0.0051	0.4625	0.0193
Habit, low γ	0.1929	0.9881	0.0079	0.1946	0.0202
LRR, baseline	0.1060	0.9940	0.0082	0.1082	0.0009
LRR, high γ	0.4527	0.9940	0.0278	0.4554	0.0006
LRR, low γ	0.0242	0.9934	0.0050	0.0306	0.0009
LRR, high ψ	0.1083	0.9940	0.0085	0.1105	0.0012
LRR, low ψ	0.1019	0.9939	0.0077	0.1040	0.0002
Sample	0.1027	0.8054	0.0051	0.1043	0.0881

Panel B: UIP Tests

	R^2	$\beta_{\xi,\tilde{s}}$	$p(\beta_{\xi,\tilde{s}} = 0)$	$\beta_{\xi,dr}$	$p(\beta_{\xi,dr} = 0)$	$p(\beta_{d\tilde{r},\tilde{s}} = -\bar{\beta}_{\Delta\tilde{s},\tilde{s}})$	$p(\beta_{d\tilde{r},dr} = -\bar{\beta}_{\Delta\tilde{s},dr})$
Habit, baseline	0.0089	−0.0129	0.7959	0.4286	0.9803	0.0000	0.6617
Habit, high γ	0.0058	−0.0115	0.4680	0.3846	0.9886	0.0000	0.7313
Habit, low γ	0.0133	−0.0150	0.5306	0.5000	0.9155	0.0000	0.2846
LRR, baseline	0.0133	−0.0107	0.8647	0.3252	0.9710	0.3218	0.8329
LRR, high γ	0.0132	−0.0105	0.9668	0.3207	0.9933	0.3076	0.8361
LRR, low γ	0.0085	−0.0110	0.6241	0.3353	0.8944	0.4197	0.8270
LRR, high ψ	0.0140	−0.0108	0.9342	0.3304	0.9855	0.6242	0.9139
LRR, low ψ	0.0118	−0.0103	0.7239	0.3144	0.9428	0.0482	0.6884
Sample	0.0689	−0.2096	0.0022	1.6850	0.1309	0.0000	0.0000

Panel C: Infinite-horizon Statistics

	Variance Share ξ	Δ Variance Share ξ	Variance Share $d\tilde{r}$
Habit, baseline	1.4145	0.1448	−0.4145
Habit, high γ	1.1576	0.1491	−0.1576
Habit, low γ	1.8059	0.2936	−0.8059
LRR, baseline	2.1484	0.0101	−1.1484
LRR, high γ	2.1067	0.0005	−1.1067
LRR, low γ	2.2019	0.1975	−1.2019
LRR, high ψ	2.2021	0.0025	−1.2021
LRR, low ψ	2.0374	0.0414	−1.0374
Sample	0.6032	−0.2586	0.3968

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IA.1 Relation to other existing literature

Several studies have documented departures from uncovered interest rate parity and, specifically, the fact that interest rate differentials predict excess currency returns. Early examples of this literature are Bilson (1981), Hansen and Hodrick (1983), Fama (1984), and Hodrick (1987); while Lewis (1995), Engel (1996), and, more recently, Sarno (2005) provide reviews of the literature. We contribute to this stream of literature by showing that *indirect* tests of (excess) currency-return predictability uncover stronger evidence of predictive power not only for real exchange rates, but also for interest rate differentials.

Among the many studies documenting a weak relation between currency returns and macro variables, we can recall Meese and Rogoff (1983), Mark and Sul (2001), Rapach and Wohar (2002), and Groen (2005); also, see Sarno (2005) and Engel, Mark, and West (2007) for reviews. Similarly, we also conclude that fundamentals explain little of the (real) exchange rate variation. We improve upon the existing literature by identifying expectations of real bond return differentials as the *sole* fundamental, and by quantifying the importance of fundamentals in a variance decomposition exercise.

Several authors, on the other hand, have tested whether *long-run* relative PPP holds, i.e., whether the real exchange rate is stationary; see, for example, Diebold, Husted, and Rush (1991), Cheung and Lai (1993), Lothian and Taylor (1996), Frankel and Rose (1996), Wu (1996), Flood and Taylor (1996), Taylor and Sarno (1998), Papell (2002), Imbs, Mumtaz, Ravn, and Rey (2005), and Engel (2012); and see Froot and Rogoff (1995), Taylor (1995), Rogoff (1996), Sarno and Taylor (2002), Taylor and Taylor (2004), and Sarno (2005), for reviews. Although the evidence is somewhat mixed, the consensus is that the real exchange rate indeed mean-reverts in the long run. Motivated by this finding, our assumption of stationarity of the real exchange rate plays a key role in the parameterization of the indirect null, the derivation of the infinite-horizon regression statistics, and the implementation of finite-sample inference.

Backus, Foresi, and Telmer (2001), Brandt, Cochrane, and Santa-Clara (2006), Leippold and Wu (2007), and Sarno, Schneider, and Wagner (2012) attempt at reconciling the properties of currency returns with the properties of pricing kernels. The properties of currency returns have also been studies in the context of general equilibrium models; see, for example, Alvarez, Atkeson, and Kehoe (2002), Bacchetta and van Wincoop (2010), Verdelhan (2010), Bansal and Shaliastovich (2013), and Gourio, Siemer, and Verdelhan (2013). Our analysis differs from these studies in that we are not restricted by any single partial- or general-equilibrium model. Indeed, we only assume that foreign-currency investors have rational expectations, and we rely on this assumption only in the infinite-horizon analysis.

Other studies have focused on time-series predictability patterns, beyond deviations from UIP; see, for example, Beber, Breedon, and Buraschi (2010), Adrian, Etula, and Shin (2010), Jordà and Taylor (2012), Bakshi and Panayotov (2013), Lustig, Roussanov, and Verdelhan (2014), and Della Corte, Ramadorai, and Sarno (2016). Jordà and Taylor (2012) include the real exchange rate as an instrument in a predictive model. They find that a trading rule accounting for deviations of the real exchange rate from its long-run mean (in addition to the interest rate and inflation differentials and the lagged currency return) outperforms a rule that does not. Differently from the current paper, though, they do not implement an indirect test of the predictive power of the real exchange rate, nor do they decompose the variance of real exchange rates.[1] There are also authors who have focused on *cross-sectional* predictability patterns, such as Lustig and Verdelhan (2007), Farhi, Fraiberger, Gabaix, Ranciere, and Verdelhan (2009), Ang and Chen (2010), Burnside, Eichenbaum, and Rebelo (2011), Lustig, Roussanov, and Verdelhan (2011), Asness, Moskwitz, and Pedersen (2013), and Menkhoff, Sarno, Schmeling, and Schrimpf (2016). The latter two studies use real exchange rates to sort portfolios, finding that a portfolio long in undervalued currencies, and short in overvalued currencies, earns significant excess returns: Asness, Moskwitz, and Pedersen (2013) measure under and overvaluation based on the lagged five-year change in real exchange rates, whereas Menkhoff, Sarno, Schmeling, and Schrimpf (2016) adjust the level of the real exchange rate for aggregate productivity and the quality of export goods. Our empirical exercises are very different as we focus on time-series, rather than cross-sectional, predictability patterns.

[1] See also Qiu, Pinfold, and Rose (2011), who use *changes* in real exchange rates to predict currency returns.

IA.2 Small-sample inference and parameterizing the indirect null

In testing the UIP null, we want to control for possible small-sample biases deriving from the high persistence of some of the predictors. We also want to control for the effect of the correlation between innovations in the predictors and innovations in the dependent variables: a possible "Stambaugh" bias (Stambaugh, 1999). In addition, in several of our tests, we employ overlapping observations, which, coupled with the persistence of the predictors, also tend to generate biases against the UIP null in small samples (see Valkanov, 2003, and Boudoukh, Richardson, and Whitelaw, 2008). These biases need to be controlled for.

Finally, as discussed in Section 2.2, the joint null of no-predictability in excess currency returns and predictability of changes in (log) real exchange rates has very specific implications for the predictability of real bond return differentials. These restrictions need to be properly accounted for if we want to test the direct and/or indirect null hypotheses. To our knowledge, this is the first paper to test UIP by performing small-sample inference, while at the same time accounting for the extra restrictions on the dynamics of the instruments implied by the UIP null.[2]

Using (8) and (15), we have:

$$\begin{aligned}\xi_{t+1} &= A_2 + B_2 z_t + v_{2,t+1} \\ &= (A_1 - A_4) + [B_1 + (\iota_3 - \iota_1)^\top - B_4] z_t + (v_{1,t+1} - v_{4,t+1}),\end{aligned} \tag{IA.1}$$

where A_n is the n-th element of the A vector, B_n is the n-th row of the B matrix, and $v_{n,t+1}$ is the n-th element of the v_{t+1} vector. Hence, the definition of ξ_t implies:

$$A_2 = A_1 - A_4 \tag{IA.2}$$

$$B_2 = B_1 - B_4 + (\iota_3 - \iota_1)^\top \tag{IA.3}$$

$$v_{2,t+1} = v_{1,t+1} - v_{4,t+1}. \tag{IA.4}$$

The null hypothesis that we consider is that excess currency returns are unpredictable, $E_t(\xi_{t+1}) = E(\xi_{t+1})$, which means that, in (IA.1),

$$B_2 = B_1 + (\iota_3 - \iota_1)^\top - B_4 = \mathbf{0}_{4+K}^\top, \tag{IA.5}$$

which, in turn, implies

$$B_4 = B_1 + (\iota_3 - \iota_1)^\top. \tag{IA.6}$$

Moreover, (IA.1) implies:

$$\xi_{t+1} = A_2 + v_{2,t+1} = A_1 - A_4 + v_{1,t+1} - v_{4,t+1}. \tag{IA.7}$$

[2]Mark (1995), for example, also performs bootstrap inference on predictive regressions for currency returns by simulating an autoregressive process. His instrument set, though, only includes the deviation of the exchange rate from its fundamental value—a function of nominal money supply and real output—and, hence, he does not have to account for the indirect restrictions deriving from the UIP null. The same comment applies to Killian (1999), who simulates an ECM. Indeed, the restrictions on the dynamics of the instruments implied by equation (4) only apply when excess currency returns, real bond return differentials, and real exchange rates are all instruments included in the analysis.

Hence, in the bootstrap exercise, we generate bootstrap samples of z_t under the UIP null, according to the law of motion:

$$\tilde{s}^b_{t+1} = \bar{A}_1 + \bar{B}_1 z^b_t + v^b_{1,t+1} \tag{IA.8}$$

$$\xi^b_{t+1} = \bar{A}_2 + v^b_{1,t+1} - v^b_{4,t+1} \tag{IA.9}$$

$$dr^b_{t+1} = \bar{A}_3 + \bar{B}_3 z^b_t + v^b_{3,t+1} \tag{IA.10}$$

$$d\pi^b_{t+1} = \bar{A}_1 - \bar{A}_2 + [\bar{B}_1 + (\delta_3 - \iota_1)^\top] z^b_t + v^b_{4,t+1} \tag{IA.11}$$

$$x^b_{t+1} = \bar{A}_x + \bar{B}_x z^b_t + v^b_{x,t+1}, \tag{IA.12}$$

where $\bar{A}_x$ and $v^b_{x,t+1}$ are $K \times 1$ vectors, and $\bar{B}_x$ is a $K \times (4+K)$ matrix. The bootstrap residuals $v^b_{1,t+1}$, $v^b_{3,t+1}$, $v^b_{4,t+1}$, and $v^b_{x,t+1}$ are generated via a non-parametric bootstrap.

It is worth noting that when we test the indirect restrictions (11) and (12), we impose the consistency between short- and long-run predictability patterns. Specifically, let $\bar{B}$ denote the restricted autoregressive matrix consistent with the UIP null, as per equations (IA.8)–(IA.12) above and set:

$$\bar{\beta}^\top_{\Delta\tilde{s},H} = (\bar{B}^H)_1 - \iota^\top_1, \tag{IA.13}$$

where $(\bar{B}^H)_1$ denotes the first row of $\bar{B}^H$.[3,4]

IA.3 Data

The selection of countries follows Lustig, Roussanov, and Verdelhan (2014) and the grouping follows Ang and Chen (2010). As in Ang and Chen (2010), we keep Germany after January 1999, to represent the Eurozone, drop Greece after June 2000, and drop other Eurozone countries after January 1999. The spot exchange rate data are collected by Reuters. We acquire exchange rates against the British Pound since they have the longest time series, and convert them into exchange rates against the U.S. Dollar. The interest rates are Eurocurrency rates whenever available, otherwise we compute covered interest rate parity implied interest rates. CPI data are at monthly frequency in most countries, but at quarterly frequency in Australia and New Zealand, and, for these two countries, we linearly interpolate log CPI observations to obtain monthly observations.

We use monthly log CPI growth to measure inflation. Note that there are issues of comparability of the CPI data across countries: base-year differences and heterogeneity of the goods baskets. These issues are largely avoided in our setting, because we only perform a time-series analysis: the differences in base year are eliminated by taking log differences of the CPI. Moreover, to the extent that the heterogeneity in goods basket is constant over time and has a only multiplicative effect on the CPIs of different countries, this effect is captured by the intercept terms in the regression analysis. Indeed, these effects are also captured in the panel-regression setting, as currency-specific fixed effects are controlled for.

We also construct five currency baskets, using the currencies of: (1) G10 countries, (2) non-G10 developed countries, (3) developed countries (the union of G10 countries and non-G10 developed countries), (4) emerging countries, or (5) all countries. The rules for basket construction are based on Ang and Chen (2010) and Lustig, Roussanov, and Verdelhan (2014).

[3] In the empirical implementation, we set $\bar{A}_1 = \hat{A}_1$, $\bar{A}_2 = \hat{A}_2$, $\bar{A}_3 = \hat{A}_3$, $\bar{A}_x = \hat{A}_x$, $\bar{B}_1 = \hat{B}_1$, $\bar{B}_3 = \hat{B}_3$, and $\bar{B}_x = \hat{B}_x$.

[4] While the procedure illustrated above allows us to generate bootstrap samples under the UIP null in equation (2), we are also interested in generating bootstrap samples under the RRE null:

$$E_t(d\tilde{r}_{t+1}) = E(d\tilde{r}_t). \tag{IA.14}$$

This second null hypothesis implies that real exchange rates do not predict future real bond return differentials, and equivalently, that all the variability in real exchange rates is due to changes in risk premia. Simulating this null hypothesis allows us to make inference on the second term in (20).

IA.4 Size and power

IA.4.1 Size study

The steps of the size study are:

1. simulate one sample from the *restricted* VAR estimated with panel data, where we bootstrap the residuals for the Deutsche Mark;

2. perform asymptotic and bootstrap inference (5,000 draws) on the simulated sample;[5]

3. repeat 5,000 times.

The main results of the size study are easily summarized: after a bootstrap adjustment, the actual size of the tests is *very* close to the nominal size. For example, at the three-month horizon, when the nominal size is 5%, the actual size of the direct (indirect) tests is 4%, 4%, 5%, and 6% (4%, 5%, 5%, and 6%) for the real exchange rate, excess currency return, nominal interest rate differential, and inflation differential, respectively. Importantly, the corresponding actual sizes based on asymptotic inference can be significantly distorted: the corresponding rejection rates in direct (indirect) tests are 15%, 5%, 10%, and 7% (12%, 6%, 9%, and 8%). Results are analogous for the joint direct-indirect test.

In the infinite-horizon inference, again we have that bootstrap-corrected rejection rates are quite close to the nominal size of the tests, whereas, in some instances, the asymptotic inference leads to *lower*, rather than higher, rejection rates. For example, for a 5% nominal size, the actual size of the bootstrap-adjusted tests is 4%, 4%, 4%, and 5%, for the real exchange rate, excess currency return, nominal interest rate differential, and inflation differential, respectively. The actual sizes of the asymptotic tests are, instead: 27%, 9%, 2%, and 1%.

IA.4.2 Power study

The steps of the power study are:

1. simulate one sample from the *unrestricted* VAR estimated with panel data, where we bootstrap the residuals for the Deutsche Mark;

2. perform both asymptotic and bootstrap inference (5,000 draws) on the simulated sample;[6]

3. repeat 5,000 times.

The results of the power study are striking. Based on the bootstrap-adjusted inference, the power of the indirect test is almost uniformly higher than the power of the direct test. For example, at the three-month horizon, for a nominal size of 5%, the rejection rates in the bootstrap-adjusted direct test are 49%, 17%, 6%, and 7%, for the real exchange rate, excess currency return, nominal interest rate differential, and inflation differential, respectively; the corresponding values for the indirect test are 100%, 100%, 67%, and 15%. The power is especially high for the real exchange rate: rejection rates in the indirect test are 100%, for *all* return horizons and nominal sizes. Results are similar for the joint direct-indirect tests.

The power of the infinite-horizon tests is also substantially higher than that of the direct tests. For a nominal size of 5%, the rejection rates in bootstrap-adjusted tests are 96%, 67%, 77%, and 27%, for the real exchange rate, excess currency return, nominal interest rate differential, and inflation differential, respectively. In addition, the rejection rate of the null of a zero risk premium variance share is 96%.

[5] The indirect test conditions on the parameters of the restricted VAR used to simulate the data in the first step. Similarly, the bootstrap inference uses the parameters of the restricted VAR to generate bootstrap samples.

[6] As in the size study, the indirect test conditions on the parameters of the *restricted* VAR, and the bootstrap inference uses the parameters of the restricted VAR to generate bootstrap samples.

IA.5 Extensions and robustness checks

- *Non-stationarity of the real exchange rate.* In Section IA.1, we have reviewed literature that tests for the stationarity of the real exchange rate. We concluded that the consensus is that the real exchange rate is indeed mean-reverting. We revisit the issue of real exchange stationarity in this section, by providing some further discussion of the issue, and by amending our methodology to account for possible non-stationarity.

  Our derivation of (1) relies on the assumption that the log real exchange rate—i.e., the deviation from absolute PPP—is stationary and has a well-defined unconditional mean. In other words, we have assumed that relative PPP holds in the long run and $E_t(\tilde{s}_{t+\infty}) = E(\tilde{s}_t)$. Alternatively, one can follow Evans (2012), and assume that market participants *revise* the conditional expectation of the infinite-horizon deviation from absolute PPP, $E_t(\tilde{s}_{t+\infty})$, as time goes by. Given that conditional expectations are martingales, the updating of expected infinite-horizon PPP deviations leads to a unit-root component in the real exchange rate:

$$\tilde{s}_t = -\sum_{i=1}^{\infty} E_t(\xi_{t+i}) + \sum_{i=1}^{\infty} E_t(d\tilde{r}_{t+i}) + E_t(\tilde{s}_{t+\infty}). \tag{IA.15}$$

  Following Evans (2012), we can take first differences of (IA.15), and rearrange, to obtain a decomposition of the *changes* of the (log) real exchange rate:

$$\Delta\tilde{s}_t = -\Delta\left[\sum_{i=1}^{\infty} E_t(\xi_{t+i})\right] + \Delta\left[\sum_{i=1}^{\infty} E_t(d\tilde{r}_{t+i})\right] + \Delta E_t(\tilde{s}_{t+\infty}). \tag{IA.16}$$

  The expression above, rather than (1), can then be used to decompose the variance of the changes of the real exchange rate:

$$\begin{aligned}\operatorname{var}(\Delta\tilde{s}_t) \quad = \quad & \operatorname{cov}\left\{\Delta\tilde{s}_t, -\Delta\left[\sum_{i=1}^{\infty} E_t(\xi_{t+i})\right]\right\} + \operatorname{cov}\left\{\Delta\tilde{s}_t, \Delta\left[\sum_{i=1}^{\infty} E_t(d\tilde{r}_{t+i})\right]\right\} \\ & + \operatorname{cov}\left\{\Delta\tilde{s}_t, \Delta E_t(\tilde{s}_{t+\infty})\right\}. \end{aligned} \tag{IA.17}$$

  The second term in the r.h.s. of equation (IA.17) above captures the role of fundamentals in explaining changes in real exchange rates. The first and third terms, on the other hand, capture the effects of what Evans (2012) denotes as dark matter.

  While $E_t(\tilde{s}_{t+\infty})$ is not directly observable and the third term on the r.h.s. of (IA.15) cannot be computed, the other two terms can be computed using a VAR analogous to (15), where the level of the real exchange rate, $\tilde{s}_t$, is replaced by its first differences, $\Delta\tilde{s}_t$. Hence, $\Delta E_t(\tilde{s}_{t+\infty})$ in (IA.16) can be computed as a residual, much like the "cash-flow news" component of returns in the standard implementation of the Campbell (1991) return decomposition.

  Hence, we can compute the variance decomposition:

$$\operatorname{var}(\Delta\tilde{s}_t) = \operatorname{cov}(\Delta\tilde{s}_t, -\Delta\beta_{\xi,\infty}^{\top} z_t) + \operatorname{cov}(\Delta\tilde{s}_t, -\Delta\beta_{d\tilde{r},\infty}^{\top} z_t) + \operatorname{cov}[\Delta\tilde{s}_t, \Delta E_t(\tilde{s}_{t+\infty})]. \tag{IA.18}$$

  Note that the variance decomposition above is more detailed than the decomposition in Evans (2012), in that we distinguish between the variability of real exchange rate appreciation due to changes in the infinite-horizon risk premia and the variability due to revisions of the expected infinite-horizon absolute PPP deviation. When we implement the decomposition (IA.18) using estimates from a panel-data VAR, we find that essentially 100% of the variance of the monthly real exchange rate appreciation can be attributed to the last term, $\operatorname{cov}[\Delta\tilde{s}_t, \Delta E_t(\tilde{s}_{t+\infty})]$. In other words, all the variability of changes in the real exchange rate is due to revisions of the expected infinite-horizon PPP deviation.

  This result does not seem plausible and we attribute it to an econometric problem, rather than to true revisions of $E_t(\tilde{s}_{t+\infty})$. The VAR in first differences proposed by Evans (2012) is misspecified because it misses the long-run dynamics of the real exchange rate due to the co-integration between the (log) nominal exchange rate and the (log) price differential. Indeed, in the VAR in first differences, the lagged change in the real exchange rate impacts the current change with a negative coefficient of -0.2, suggesting *overdifferencing*.

Since $\Delta E_t(\tilde{s}_{t+\infty})$ is calculated as a residual, the misspecification of the VAR translates into a large variability of $\Delta E_t(\tilde{s}_{t+\infty})$. Indeed, in his theoretical analysis, Evans (2012) assumes a *stationary* steady-state distribution of the real exchange rate. As a result, in his model, the dark matter in real exchange rates is uniquely due to the effect of risk premia, and $\text{cov}[\Delta\tilde{s}_t, \Delta E_t(\tilde{s}_{t+\infty})] = 0$.

In addition to the variance-decomposition exercise, we also implement the direct and indirect predictability tests, as well as the test of infinite-horizon cumulative UIP deviations. As in our baseline case that assumes real exchange rate stationarity, the indirect tests uncover stronger rejections of UIP than the direct tests. On the other hand, there is no significant evidence of infinite-horizon cumulative UIP deviations. This result is also suggestive that the VAR in first differences is misspecified.

- *Correction of possible spurious-regression biases.* Following Ferson, Sarkissian, and Simin (2003), we simulate an economy where z_t (the vector including $\tilde{s}_t$, ξ_t, dr_t and $d\pi_t$) does not predict excess currency returns, whereas four instruments, *unobservable* to the econometrician, predict excess currency returns in the same way as z_t predicts excess currency returns in the actual data.

  Specifically, we assume that excess currency returns are unpredictable based on the observable instruments in z_t, but they are *predictable* based on a set of unobservable instruments y_t. We also assume that y_t predicts ξ_{t+1} exactly in the same way as z_t predicts ξ_{t+1} in the data, and that y_t also evolves over time in the same way as z_t in the data. Hence, in the bootstrap exercise, we generate bootstrap samples of z_t and y_t according to the law of motion:

$$\tilde{s}^b_{t+1} = \bar{A}_1 + \bar{B}_1 z^b_t + v^b_{1,t+1} \tag{IA.19}$$
$$\xi^b_{t+1} = \bar{A}_2 + \bar{B}_2 y_t + v^b_{1,t+1} - v^b_{4,t+1} \tag{IA.20}$$
$$dr^b_{t+1} = \bar{A}_3 + \bar{B}_3 z^b_t + v^b_{3,t+1} \tag{IA.21}$$
$$d\pi^b_{t+1} = \bar{A}_1 - \bar{A}_2 + [\bar{B}_1 + (\delta_3 - \delta_1)^\top] z^b_t - \bar{B}_2 y_t + v^b_{4,t+1} \tag{IA.22}$$
$$y^b_{t+1} = \bar{A}_y + \bar{B}_y y^b_t + v^b_{y,t+1}, \tag{IA.23}$$

  where $v^b_{y,t+1}$ is created by separately bootstrapping the innovations v_{t+1}.[7] The equation for the inflation differential reflects the identity: $d\pi_t \equiv \Delta\tilde{s}_t - \xi_t + dr_{t-1}$. Correcting for spurious regression bias leads to results that are very similar to those obtained with the standard bootstrap inference.

- *Alternative choices of $\bar{\beta}_{\Delta\tilde{s},H}$.* Instead of simply setting $\bar{\beta}_{\Delta\tilde{s},H} = \hat{\beta}_{\Delta\tilde{s},H}$, we choose several different values of $\bar{\beta}_{\Delta\tilde{s},H}$, and we keep track of the p-values associated with the direct, indirect, and infinite-horizon tests. The values of $\bar{\beta}_{\Delta\tilde{s},H}$ are chosen to be realistic: we draw 5,000 samples from the asymptotic distribution of the *restricted* panel-VAR estimates, the $\bar{B}$ matrix, but excluding draws that imply explosive dynamics. For each draw, we perform the different tests and we report the sample test p-values and the root mean squared error (RMSE) of the p-values across draws, relative to the sample value. As in the size and power study, the exercise is calibrated on the Deutsche Mark. The results of our direct and joint direct-indirect tests are very robust across choices of $\bar{\beta}_{\Delta\tilde{s},H}$, especially as far as the predictive power of the real exchange rate is concerned.

- *UIP null hypothesis parameterized according to currency-specific VARs.* We parameterize the null hypothesis tested in the indirect tests conditioning on estimates from *currency-specific* restricted VARs, and we use currency-specific restricted VARs to generate bootstrap samples under the null.[8] Results are similar to those for the baseline case. For example, in the indirect test, we have rejections in 91%, 61%, 83%, and 52% of the currencies and currency baskets, for the real exchange rate, excess currency return, nominal interest rate differential, and

[7] We set $\bar{A}_1 = \hat{A}_1$, $\bar{A}_2 = \hat{A}_2$, $\bar{A}_3 = \hat{A}_3$, $\bar{A}_y = \hat{A}$, $\bar{B}_1 = \hat{B}_1$, $\bar{B}_2 = \hat{B}_2$, $\bar{B}_3 = \hat{B}_3$, and $\bar{B}_y = \hat{B}$.

[8] Given the restriction that the dynamics of the restricted VAR is stationary, the cross-section of currencies and currency baskets drops from 39 to 23, even in the finite-horizon tests.

inflation differential, respectively (three-month horizon, 5% nominal size, bootstrap-adjusted inference). The corresponding percentages for the baseline case are: 95%, 87%, 82%, and 46%. Similarly, in the infinite-horizon tests, we have rejections in 48%, 13%, 17%, and 4% of the tests, whereas the corresponding baseline results are 35%, 3%, 29%, and 9%. Hence, conditioning on the noisier VAR estimates obtained separately for each currency does not materially alter our results.

- *Correction of VAR parameter estimates for small-sample biases.* We correct the restricted panel-data VAR estimates as well as the estimates obtained from currency-specific restricted VARs, used to generate data under the UIP null, for possible small-sample biases. Following Bekaert, Hodrick, and Marshall (1997), we use a Monte Carlo simulation to correct the biases in the VAR estimates: we simulate the restricted VAR process using sample slope estimates and innovations drawn from a multivariate normal distribution with zero mean and covariance matrix equal to the sample covariance matrix of the residuals. We then estimate new VAR parameters using the simulated data. After repeating many times, we add the difference between the original sample estimates and the average of many simulated estimates to the original sample estimates, to obtain the bias-corrected VAR estimates.

  In the case of the panel-data VAR, the small-sample bias is minimal, and all of our results are essentially unchanged. In the case of currency-specific VARs, for the currencies exhibiting stationary dynamics (after bias adjustment of the VAR coefficients), our results are qualitatively the same as those discussed in the previous point.

- *Controlling for additional predictors.* We check whether other predictors have predictive power, over and above the existing four baseline predictors, and whether the addition of these predictors affects the inference on the real exchange rate. The additional predictors are chosen based on the evidence of recent articles. We set $K = 1$, and the extra predictor x_t is one of the following variables:

  - the average forward discount (Lustig, Roussanov, and Verdelhan, 2014);
  - the growth rate of U.S. industrial production (Lustig, Roussanov, and Verdelhan, 2014);
  - the real exchange rate appreciation (Qiu, Pinfold, and Rose, 2011);
  - the yield curve level (i.e., the average of ten-year and one-month yields) differential, the yield curve slope (i.e., the ten-year minus the one-month yield) differential, and the change of the yield curve level differential (Ang and Chen, 2010);
  - the "momentum" factor (the three-month cumulative currency excess return; Ang and Chen, 2010);
  - the "value" factor (the five-year cumulative currency return; Ang and Chen, 2010).

In order to implement some of the exercises described above, we need to formulate the VAR dynamics when some instruments are affine functions of other contemporaneous and lagged instruments. Specifically, assume that:

$$z_t = A + Bz_{t-1} + Cw_{t-1} + v_t, \tag{IA.24}$$

where

$$w_t = D + [F_0 \quad F_1 \quad \cdots \quad F_q] \begin{bmatrix} z_t \\ z_{t-1} \\ \vdots \\ z_{t-q} \end{bmatrix}. \tag{IA.25}$$

We have:

$$
\begin{aligned}
w_t &= D + [F_0 \quad F_1 \quad \cdots \quad F_q] \begin{bmatrix} A + Bz_{t-1} + Cw_{t-1} + v_t \\ A + Bz_{t-2} + Cw_{t-2} + v_{t-1} \\ \vdots \\ A + Bz_{t-q-1} + Cw_{t-q-1} + v_{t-q} \end{bmatrix} \\
&= D + \sum_{h=0}^{q} F_h A + [F_0 B \quad F_1 B \quad \cdots \quad F_q B] \begin{bmatrix} z_{t-1} \\ z_{t-2} \\ \vdots \\ z_{t-q-1} \end{bmatrix} \\
&\quad + [F_0 C \quad F_1 C \quad \cdots \quad F_q C] \begin{bmatrix} w_{t-1} \\ w_{t-2} \\ \vdots \\ w_{t-q-1} \end{bmatrix} + [F_0 \quad F_1 \quad \cdots \quad F_q] \begin{bmatrix} v_t \\ v_{t-1} \\ \vdots \\ v_{t-q} \end{bmatrix}.
\end{aligned}
\tag{IA.26}
$$

We have the following first-order companion form of the VAR in equation (IA.24):

$$
\mathcal{Z}_t^q = \mathcal{A} + \mathcal{B}\mathcal{Z}_{t-1}^q + \mathcal{V}_t, \tag{IA.27}
$$

where

$$
\mathcal{Z}_t^q \equiv \begin{bmatrix} z_t \\ w_t \\ z_{t-1} \\ w_{t-1} \\ \vdots \\ z_{t-q} \\ w_{t-q} \end{bmatrix}, \quad \mathcal{A} \equiv \begin{bmatrix} A \\ D + \sum_{h=0}^{q} F_h A \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \end{bmatrix},
$$

$$
\mathcal{B} \equiv \begin{bmatrix} B & C & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ F_0 B & F_0 C & F_1 B & F_1 C & \dots & F_{q-1} B & F_{q-1} C & F_q B & F_q C \\ I & 0 & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ 0 & I & 0 & 0 & \dots & 0 & 0 & 0 & 0 \\ \vdots & \vdots & \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & 0 & 0 & \dots & I & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & \dots & 0 & I & 0 & 0 \end{bmatrix}, \quad \mathcal{V}_t \equiv \begin{bmatrix} v_t \\ \sum_{h=0}^{q} F_h v_{t-h} \\ 0 \\ 0 \\ \vdots \\ 0 \\ 0 \end{bmatrix}. \tag{IA.28}
$$

Interestingly, in direct tests, these additional predictors tend to exhibit little power: the rejections of the null of no predictive power are at most 14% of the total number of tests, for the yield curve level and slope differentials (three-month horizon, 5% nominal size, bootstrap-adjusted inference). Results are even weaker for the infinite-horizon tests, where the rejections are at most 9% of the total, for the real exchange rate appreciation as the extra predictor. The indirect tests, on the other hand, uncover more frequent rejections of the UIP null, in as many as 67% of the currencies and currency baskets, for the yield curve level and slope differentials. Importantly, though, even after the addition of these extra predictors, the real exchange rate is still the strongest predictor in indirect, joint direct-indirect, and infinite-horizon tests. In the indirect tests, for example, the rejections are between 90% and 100% of the total; and in the infinite-horizon tests, the rejections are between 10% and 47% of the total.

- *Use of alternative approaches to bootstrap.* We experiment with the following alternative bootstrap settings, one at a time:

  - resampling VAR residuals with a *block* bootstrap, with block length dependent on the autocorrelation of the residuals;
  - resampling VAR residuals with a *block* bootstrap, with block length dependent on the autocorrelation of the *squares* of residuals, to capture possible heteroskedasticity effects;
  - simulating VAR innovations with Monte Carlo simulation under normality;
  - a longer initial warm-up period (600 months);
  - a higher number of bootstrap repetitions, 50,000.

  All these modifications to the bootstrap inference make little difference to our results. In particular, the real exchange rate still emerges as the most reliable predictor with rejections between 95% and 97% of the total number of tests (5% nominal size, bootstrap-adjusted inference) in indirect tests at the three-month horizon, and between 38% and 41% in infinite-horizon tests.

- *Use of different reference currencies.* We replicate our baseline analysis for different reference currencies: the Japanese Yen, the Deutsche Mark, and the British Pound. In these exercises, variables are redefined from the perspective of a Japanese, German, or British investor, respectively. As in the previous robustness checks, the main message does not change. For example, the fractions of rejections (5% nominal size, bootstrap-adjusted inference) for the real exchange rate are between 92% and 97% in indirect tests (three-month horizon). It is only in the case of the British Pound as reference currency and the infinite-horizon tests that we see a significant drop in the number of rejections: 9%. In this case, we also see few significant risk premium shares of the variance of the real exchange rate: only 11%. For the Deutsche Mark and Japanese Yen as reference currencies, on the other hand, the rejections in the infinite-horizon regressions are 41% and 66% of the total, respectively, and the risk premium variance share is significant in 48% and 66% of the instances.

IA.6 The liquidity model

In the liquidity model of Engel (2016), the representative agent derives immediate utility from holding liquid interest-bearing assets, such as bank deposits and Treasury securities. Hence, in a representative agent economy, the Euler equation pinning down the nominal interest rate is given by:

$$E_t[\exp(m_{t+1})\exp(r_t)] = 1 - L_t, \tag{IA.29}$$

where L_t denotes the current marginal liquidity services. Hence, we have:

$$dr_t = -d\mu_{mt} - \frac{1}{2}d\sigma^2_{mt} + dl_t, \tag{IA.30}$$

where $dl_t \equiv \ln(1 - L^f_t) - \ln(1 - L_t) \approx L_t - L^f_t$. The currency risk premium equals:[9]

$$\begin{aligned} E_t(\xi_{t+1}) &= E_t(\Delta s_{t+1}) + dr_t \\ &= d\mu_{mt} - d\mu_{mt} - \frac{1}{2}d\sigma^2_{mt} + dl_t \\ &= -\frac{1}{2}d\sigma^2_{mt} + dl_t. \end{aligned} \tag{IA.31}$$

Note that when the marginal utility of liquidity services is higher in the domestic country than in the foreign country, both the interest rate differential and the currency risk premium are higher than in the absence of liquidity effects. In Engel (2016), the monetary authority affects the marginal utility of liquidity services through open market operations: by purchasing Treasury securities, and injecting money in the economy, the central bank increases the marginal utility of the liquidity services of these securities and reduces their yield. As a result, a relatively expansionary domestic monetary policy increases both dr_t and $E_t(\xi_{t+1})$.

Following Engel (2016), we assume additively separable preferences over consumption and liquidity services and we set $d\sigma^2_{mt} = 0$. Moreover, we assume CRRA preferences over consumption. We have:

$$dr_t = \gamma E_t(\Delta d\tilde{c}_{t+1}) + E_t(d\pi_t) + dl_t \tag{IA.32}$$

$$E_t(\xi_{t+1}) = dl_t \tag{IA.33}$$

$$\begin{aligned} \tilde{s}_t - E(\tilde{s}_t) &= -\sum_{i=1}^{\infty} E_t(\xi_{t+i}) + \sum_{i=1}^{\infty} E_t(dr_{t+i-1} - d\pi_{t+i}) \\ &= -\sum_{i=1}^{\infty} E_t(dl_{t+i-1}) + \sum_{i=1}^{\infty}[\gamma E_t(\Delta d\tilde{c}_{t+i}) + E_t(dl_{t+i-1})] \\ &= -\gamma d\tilde{c}_t. \end{aligned} \tag{IA.34}$$

Hence, differently from the habit and long-run risks models, in the liquidity model there is no direct channel for the real exchange rate to predict excess currency returns. On the other hand, similarly to the other two models, one component of the nominal interest rate differential—in this case, the liquidity differential—drives the currency risk premium.

Note, though, that a direct channel for real exchange rate to predict excess currency returns would arise if liquidity services affected the marginal utility of consumption and, hence, $d\tilde{m}_t$. Specifically, we would need: $d\tilde{m}_t = d\tilde{m}(d\tilde{c}_t, dl_t)$, where $\frac{\partial d\tilde{m}}{\partial dl_t} > 0$. In other words, we would need that an increase in domestic liquidity (recall that $dl_t \approx L_t - L^f_t$) decreases the domestic marginal utility of consumption.

[9] We are using the no-arbitrage condition: $\Delta s_{t+1} = dm_{t+1}$.

IA.7 A general single-factor model

Assume:

$$
\begin{aligned}
d\tilde{u}_t &= \phi_u d\tilde{u}_{t-1} + d\epsilon_{\tilde{u}t} && \text{(IA.35)}\\
(\sigma^f_{ut})^2 &= \sigma_0 + \sigma_1 d\tilde{u}_t && \text{(IA.36)}\\
\sigma^2_{ut} &= \sigma_0 - \sigma_1 d\tilde{u}_t. && \text{(IA.37)}
\end{aligned}
$$

We have:

$$
\begin{aligned}
d\mu_{\tilde{m}t} &= -(1-\phi_u)d\tilde{u}_t && \text{(IA.38)}\\
d\sigma^2_{\tilde{m}t} &= 2\sigma_1 d\tilde{u}_t. && \text{(IA.39)}
\end{aligned}
$$

Hence, we have:

$$
\begin{aligned}
\tilde{s}_t &= d\tilde{u}_t && \text{(IA.40)}\\
E_t(\xi_{t+1}) &= -\sigma_1 d\tilde{u}_t && \text{(IA.41)}\\
dr_t &= (1-\phi_u)d\tilde{u}_t - \sigma_1 d\tilde{u}_t + d\mu_{\pi t} && \text{(IA.42)}\\
E_t(d\tilde{r}_{t+1}) &= (1-\phi_u)d\tilde{u}_t - \sigma_1 d\tilde{u}_t; && \text{(IA.43)}
\end{aligned}
$$

and:

$$
\begin{aligned}
\text{cov}[\tilde{s}_t, E_t(\xi_{t+1})] &= -\sigma_1 \text{var}(d\tilde{u}_t) && \text{(IA.44)}\\
\text{cov}[dr_t, E_t(\xi_{t+1})] &= -(1-\phi_u)\sigma_1 \text{var}(d\tilde{u}_t) + \sigma_1^2 \text{var}(d\tilde{u}_t) && \text{(IA.45)}\\
\text{cov}[\tilde{s}_t, E_t(d\tilde{r}_{t+1})] &= (1-\phi_u)\text{var}(d\tilde{u}_t) - \sigma_1 \text{var}(d\tilde{u}_t). && \text{(IA.46)}
\end{aligned}
$$

Hence, for $\text{cov}[\tilde{s}_t, E_t(\xi_{t+1})] < 0$, we need $\sigma_1 > 0$. For $\text{cov}[dr_t, E_t(\xi_{t+1})] > 0$, we need $\sigma_1^2 > (1-\phi_u)\sigma_1$, and for $\text{cov}[\tilde{s}_t, E_t(d\tilde{r}_{t+1})] > 0$, we need $(1-\phi_u) > \sigma_1$. Obviously, the three conditions cannot co-exist.

IA.8 Habit model

IA.8.1 Forcing processes

In the original formulation of the model in Verdelhan (2010), the real log consumption differential $d\tilde{c}_t$ follows a random walk. In order to achieve stationarity, we assume that domestic and foreign log consumption are co-integrated and follow the process:[10]

$$
\begin{aligned}
\Delta\tilde{c}_t &= \mu_c + k_c d\tilde{c}_{t-1} + \epsilon_{\tilde{c}t} && \text{(IA.47)}\\
\Delta\tilde{c}^f_t &= \mu_c - k_c d\tilde{c}_{t-1} + \epsilon^f_{\tilde{c}t}; && \text{(IA.48)}
\end{aligned}
$$

where $0 < k_c < 1$. We have:

$$
\begin{aligned}
d\tilde{c}_t &= (1-2k_c)d\tilde{c}_{t-1} + d\epsilon_{\tilde{c}t} && \text{(IA.49)}\\
&\equiv \phi_c d\tilde{c}_{t-1} + d\epsilon_{\tilde{c}t}.
\end{aligned}
$$

As in Verdelhan (2010), dh_t follows the process:

$$
\begin{aligned}
dh_{t+1} &= \phi_h dh_t + [\lambda(h^f_t)\epsilon^f_{\tilde{c},t+1} - \lambda(h_t)\epsilon_{\tilde{c},t+1}]\\
&\equiv \phi_h dh_t + d\epsilon_{h,t+1}; && \text{(IA.50)}
\end{aligned}
$$

[10]Indeed, in our analysis of the U.S. and U.K. economies, the empirical counterpart of $d\tilde{c}_t$ appears to be stationary.

where $0 < \phi_h < 1$ and $\lambda(.)$ is the "sensitivity" function defined as:

$$\lambda(h_t) = \frac{1}{\bar{H}}\sqrt{1 - 2(h_t - \bar{h})} - 1, \tag{IA.51}$$

where $\bar{h} \equiv \ln(\bar{H})$. As to the inflation differential, we assume:

$$d\pi_{t+1} = \phi_\pi d\pi_t + d\epsilon_{\pi,t+1}. \tag{IA.52}$$

Innovations in consumption and inflation are assumed to be Gaussian and homoskedastic. In summary, we have:

$$\begin{aligned} dy_t &\equiv \begin{bmatrix} d\tilde{c}_t \\ dh_t \\ d\pi_t \end{bmatrix} \\ &= \begin{bmatrix} \phi_c & 0 & 0 \\ 0 & \phi_h & 0 \\ 0 & 0 & \phi_\pi \end{bmatrix} \begin{bmatrix} d\tilde{c}_{t-1} \\ dh_{t-1} \\ d\pi_{t-1} \end{bmatrix} + \begin{bmatrix} d\epsilon_{\tilde{c}t} \\ d\epsilon_{ht} \\ d\epsilon_{\pi t} \end{bmatrix} \\ &\equiv \Phi dy_{t-1} + d\epsilon_{yt}. \end{aligned} \tag{IA.53}$$

IA.8.2 Moments of the innovations

We have:

$$\text{var}_t(d\epsilon_{h,t+1}) = [\lambda(h_t^f)^2 + \lambda(h_t)^2 - 2\lambda(h_t^f)\lambda(h_t)\rho_{\epsilon_c\epsilon_c^f}]\sigma_{\epsilon_c}^2 \tag{IA.54}$$

$$E[\text{var}_t(d\epsilon_{h,t+1})] = 2\{E[\lambda(h_t)^2] - E[\lambda(h_t^f)\lambda(h_t)]\rho_{\epsilon_c\epsilon_c^f}\}\sigma_{\epsilon_c}^2 \tag{IA.55}$$

$$E[\text{cov}_t(d\epsilon_{h,t+1}, d\epsilon_{\tilde{c},t+1})] = 2E[\lambda(h_t)](1 - \rho_{\epsilon_c\epsilon_c^f})\sigma_{\epsilon_c}^2; \tag{IA.56}$$

where:

$$E[\lambda(h_t)^2] = \frac{1}{\bar{H}^2} + 1 - \frac{2}{\bar{H}}E[\sqrt{1 - 2(h_t - \bar{h})}]; \tag{IA.57}$$

and:

$$\begin{aligned} E[\sqrt{1 - 2(h_t - \bar{h})}] &\approx 1 + \frac{1}{2}\frac{\partial^2}{\partial h_t^2}\sqrt{1 - 2(h_t - \bar{h})}|_{h_t=\bar{h}} \times \text{var}(h_t) \\ &= 1 + \frac{1}{2}\frac{E[\lambda(h_t)^2]\sigma_{\epsilon_c}^2}{1 - \phi_h^2}; \end{aligned} \tag{IA.58}$$

which leads to:

$$E[\lambda(h_t)^2] = \frac{1}{\bar{H}^2} + 1 - \frac{2}{\bar{H}}\left\{1 + \frac{1}{2}\frac{E[\lambda(h_t)^2]\sigma_{\epsilon_c}^2}{1 - \phi_h^2}\right\}; \tag{IA.59}$$

and:

$$E[\lambda(h_t)^2] = \frac{1 + \frac{1}{\bar{H}^2} - \frac{2}{\bar{H}}}{1 + \frac{1}{\bar{H}} \frac{\sigma^2_{\epsilon_c}}{1-\phi_h^2}}. \tag{IA.60}$$

Moreover, we have:

$$E[\lambda(h_t)] = \frac{1}{\bar{H}} \left(1 + \frac{1}{2} \frac{E[\lambda(h_t)^2]\sigma^2_{\epsilon_c}}{1 - \phi_h^2} \right) - 1; \tag{IA.61}$$

and:

$$\begin{aligned} E[\lambda(h_t^f)\lambda(h_t)] &\approx \lambda(\bar{h})^2 + \left[\frac{\partial}{\partial h_t^f} \lambda(h_t^f)|_{h_t^f=\bar{h}} \right] \left[\frac{\partial}{\partial h_t} \lambda(h_t)|_{h_t=\bar{h}} \right] \text{cov}(h_t^f, h_t) \\ &= \left(\frac{1}{\bar{H}^2} + 1 - \frac{2}{\bar{H}} \right) + \frac{1}{\bar{H}^2} \text{cov}(h_t^f, h_t) \\ &= \left(\frac{1}{\bar{H}^2} + 1 - \frac{2}{\bar{H}} \right) + \frac{1}{\bar{H}^2} \frac{1}{1 - \phi_h^2} E[\lambda(h_t^f)\lambda(h_t)] \rho_{\epsilon_c \epsilon_c^f} \sigma^2_{\epsilon_c}. \end{aligned} \tag{IA.62}$$

Hence, we have:

$$E[\lambda(h_t^f)\lambda(h_t)] \approx \frac{\frac{1}{\bar{H}^2} + 1 - \frac{2}{\bar{H}}}{1 - \frac{1}{\bar{H}^2} \frac{1}{1-\phi_h^2} \rho_{\epsilon_c \epsilon_c^f} \sigma^2_{\epsilon_c}}. \tag{IA.63}$$

IA.9 Theoretical v. VAR-implied quantities

The theoretical components of the variance of the real exchange rate are given by:

$$\text{cov}\left(\tilde{s}_t, \sum_{i=1}^{\infty} E_t(\xi_{t+i}) \right) = b_{E(\xi)}^\top (I - \Phi)^{-1} \Sigma_{dydy} b_{\tilde{s}} \tag{IA.64}$$

$$\text{cov}\left(\tilde{s}_t, \sum_{i=1}^{\infty} E_t(d\tilde{r}_{t+i}) \right) = b_{E(d\tilde{r})}^\top (I - \Phi)^{-1} \Sigma_{dydy} b_{\tilde{s}}, \tag{IA.65}$$

where $b_{E(\xi)}$, $b_{E(d\tilde{r})}$, $b_{\tilde{s}}$ are the vectors of loadings of the expected currency return, expected real bond return differential, and real exchange rate on the state variable differentials dy_t.

On the other hand, the VAR-implied variance components are given by:

$$\beta_{\xi,1}^\top (I - B)^{-1} b_z^\top \Sigma_{z\tilde{s}} = \beta_{\xi,1}^\top (I - B)^{-1} b_z^\top \Sigma_{dydy} b_{\tilde{s}} \tag{IA.66}$$

$$\beta_{d\tilde{r},1}^\top (I - B)^{-1} b_z^\top \Sigma_{z\tilde{s}} = \beta_{d\tilde{r},1}^\top (I - B)^{-1} b_z^\top \Sigma_{dydy} b_{\tilde{s}}; \tag{IA.67}$$

where b_z is the matrix of loadings of the variables on the state variable differentials, where we assume we have as many variables in the VAR as the number of instruments—b_z is a square matrix—and $\beta_{\xi,1}$ and $\beta_{d\tilde{r},1}$ are the two sets of theoretical regression coefficients, corresponding to UIP and RRE tests:

$$\beta_{\xi,1} = (b_z^\top \Sigma_{dydy} b_z)^{-1} b_z^\top \Sigma_{dydy} b_{E(\xi)} \tag{IA.68}$$

$$\beta_{d\tilde{r},1} = (b_z^\top \Sigma_{dydy} b_z)^{-1} b_z^\top \Sigma_{dydy} b_{E(d\tilde{r})}. \tag{IA.69}$$

Hence, we have:

$$\begin{aligned}
\beta_{\xi,1}^{\top}(I-B)^{-1}b_z^{\top}\Sigma_{z\tilde{s}} &= b_{E(\xi)}^{\top}\Sigma_{dydy}b_z(b_z^{\top}\Sigma_{dydy}b_z)^{-1}(I-B)^{-1}b_z^{\top}\Sigma_{dydy}b_{\tilde{s}} \\
&= b_{E(\xi)}^{\top}(b_z^{\top})^{-1}(I-B)^{-1}b_z^{\top}\Sigma_{dydy}b_{\tilde{s}} \qquad \text{(IA.70)} \\
\beta_{d\tilde{r},1}^{\top}(I-B)^{-1}b_z^{\top}\Sigma_{z\tilde{s}} &= b_{E(d\tilde{r})}^{\top}\Sigma_{dydy}b_z(b_z^{\top}\Sigma_{dydy}b_z)^{-1}(I-B)^{-1}b_z^{\top}\Sigma_{dydy}b_{\tilde{s}} \\
&= b_{E(d\tilde{r})}^{\top}(b_z^{\top})^{-1}(I-B)^{-1}b_z^{\top}\Sigma_{dydy}b_{\tilde{s}}. \qquad \text{(IA.71)}
\end{aligned}$$

We want to show that the theoretical variance shares coincide with the VAR-implied variance shares. Hence, we need to show that:

$$(b_z^{\top})^{-1}(I-B)^{-1}b_z^{\top} = (I-\Phi)^{-1}. \qquad \text{(IA.72)}$$

We have:

$$B = (b_z^{\top}\Sigma_{dydy}b_z)^{-1}b_z^{\top}\Sigma_{dy_{-1}dy}b_z; \qquad \text{(IA.73)}$$

where:

$$\Sigma_{dy_{-1}dy} = \Sigma_{dydy}\Phi^{\top}. \qquad \text{(IA.74)}$$

Hence, we have:

$$B = (b_z^{\top}\Sigma_{dydy}b_z)^{-1}b_z^{\top}\Sigma_{dydy}\Phi^{\top}b_z = b_z^{-1}\Phi^{\top}b_z; \qquad \text{(IA.75)}$$

and:

$$I-B = b_z^{-1}b_zb_z^{-1}b_z - b_z^{-1}\Phi^{\top}b_z = b_z^{-1}(I-\Phi^{\top})b_z; \qquad \text{(IA.76)}$$

and:

$$(I-B)^{-1} = b_z^{-1}(I-\Phi)^{-1}b_z. \qquad \text{(IA.77)}$$

Substituting, we have:

$$(b_z^{\top})^{-1}(I-B)^{-1}b_z^{\top} = (b_z^{\top})^{-1}b_z^{-1}(I-\Phi)^{-1}b_zb_z^{\top} = (I-\Phi)^{-1}, \qquad \text{(IA.78)}$$

which proves the result.

IA.10 Long-run risks model

IA.10.1 Forcing processes

We model the mean equations for log consumption growth and inflation in the same way as we did for the habit model; see equations (IA.50) and (IA.52)). Note that by imposing that domestic and foreign log consumption are co-integrated we are inducing a persistent component in expected (log) consumption growth, precisely in the spirit of the long-run risks model.

Following Bansal and Yaron (2004), we add heteroskedasticity in the innovations in realized consumption growth. Specifically, we assume that $\epsilon_{\tilde{c}t}$ has conditional variance v_t following the process:

$$v_t = (1-\phi_v)v_0 + \phi_v v_{t-1} + \epsilon_{vt}, \qquad \text{(IA.79)}$$

and an analogous expression holds for the foreign country. Hence, we have:

$$dv_t = \phi_v dv_{t-1} + d\epsilon_{vt}. \tag{IA.80}$$

Note that, as a result of the heteroskedasticity in realized consumption growth, expected consumption growth is also heteroskedastic:

$$\begin{aligned} \text{var}_t[E_{t+1}(\Delta\tilde{c}_{t+2})] &= k_c^2 \text{var}_t(d\tilde{c}_{t+1}) \\ &= k_c^2[v_t^f + v_t - 2\text{cov}_t(\epsilon_{\tilde{c}^f}\epsilon_{\tilde{c}})] \\ &= k_c^2\left(v_t^f + v_t - 2\sqrt{v_t^f v_t}\rho_{v^f v}\right), \end{aligned} \tag{IA.81}$$

where we have assumed that the correlation between $\epsilon_{\tilde{c}t}^f$ and $\epsilon_{\tilde{c}t}$, $\rho_{v^f v}$, is constant.

In summary, we have:

$$\begin{aligned} \begin{bmatrix} d\tilde{c}_t \\ d\pi_t \\ dv_t \end{bmatrix} &\equiv dy_t \\ &= \begin{bmatrix} \phi_c & 0 & 0 \\ 0 & \phi_\pi & 0 \\ 0 & 0 & \phi_v \end{bmatrix} \times \begin{bmatrix} d\tilde{c}_{t-1} \\ d\pi_{t-1} \\ dv_{t-1} \end{bmatrix} + \begin{bmatrix} d\epsilon_{\tilde{c}t} \\ d\epsilon_{\pi t} \\ d\epsilon_{vt} \end{bmatrix} \\ &\equiv \Phi dy_{t-1} + d\epsilon_{yt}. \end{aligned} \tag{IA.82}$$

IA.10.2 Pricing kernel

Using a standard approximation (e.g., Campbell and Shiller, 1988), the log real return on the consumption portfolio can be written as

$$\tilde{r}_{ct} = \kappa pc_t - pc_{t-1} + \Delta\tilde{c}_t, \tag{IA.83}$$

where κ is an approximation constant. Hence, the Euler equation for the rate of return on the consumption portfolio is given by:

$$\begin{aligned} &E_t(\tilde{m}_{t+1} + \tilde{r}_{c,t+1}) + \frac{1}{2}\text{var}_t(\tilde{m}_{t+1} + \tilde{r}_{c,t+1}) = \\ &E_t(\tilde{m}_{t+1} + \kappa pc_{t+1} - pc_t + \Delta\tilde{c}_{t+1}) + \frac{1}{2}\text{var}_t(\tilde{m}_{t+1} + \kappa pc_{t+1} - pc_t + \Delta\tilde{c}_{t+1}) = 0; \end{aligned} \tag{IA.84}$$

where:

$$\begin{aligned} \tilde{m}_t &= \text{constant} - \frac{\theta}{\psi}\Delta\tilde{c}_t + (\theta - 1)\tilde{r}_{ct} \\ &= \text{constant} - \gamma\Delta\tilde{c}_t + (\theta - 1)(\kappa pc_t - pc_{t-1}). \end{aligned} \tag{IA.85}$$

Hence, we have:

$$\tilde{m}_t + (\kappa pc_t - pc_{t-1}) + \Delta\tilde{c}_t = \text{constant} - \gamma\Delta\tilde{c}_t + (\theta - 1)(\kappa pc_t - pc_{t-1}) + (\kappa pc_t - pc_{t-1}) + \Delta\tilde{c}_t$$
$$= \text{constant} + (1-\gamma)\Delta\tilde{c}_t + \theta(\kappa pc_t - pc_{t-1}). \quad \text{(IA.86)}$$

We conjecture:

$$pc_t = A_0 + A_{dc}d\tilde{c}_t + A_v v_t + A_{sv}sv_t, \quad \text{(IA.87)}$$
$$pc_t^f = A_0 - A_{dc}d\tilde{c}_t + A_v v_t^f + A_{sv}sv_t, \quad \text{(IA.88)}$$

where $sv_t \equiv v_t^f + v_t$. Substituting the conjectured log price-consumption ratio in the Euler equation, we have:

$$\begin{aligned}
&\text{constant}\\
&+(1-\gamma)k_c d\tilde{c}_t\\
&+\theta(\kappa A_{dc}\phi_c - A_{dc})d\tilde{c}_t\\
&+\theta(\kappa A_v\phi_v - A_v)v_t\\
&+\theta(\kappa A_{sv}\phi_v - A_{sv})sv_t\\
&+\frac{1}{2}[(1-\gamma)^2k_c^2\text{var}_t(\epsilon_{c,t+1}) + \theta^2\kappa^2A_{dc}^2\text{var}_t(d\epsilon_{c,t+1}) + 2(1-\gamma)k_c\theta\kappa A_{dc}\text{cov}_t(d\epsilon_{c,t+1},\epsilon_{c,t+1})] = 0;
\end{aligned} \quad \text{(IA.89)}$$

where:

$$\text{var}_t(d\epsilon_{\tilde{c},t+1}) = sv_t - 2\text{cov}_t(\epsilon_{\tilde{c},t+1}^f, \epsilon_{\tilde{c},t+1}) \quad \text{(IA.90)}$$
$$\text{cov}_t(d\epsilon_{\tilde{c},t+1}, \epsilon_{\tilde{c},t+1}) = \text{cov}_t(\epsilon_{\tilde{c},t+1}^f, \epsilon_{\tilde{c},t+1}) - v_t; \quad \text{(IA.91)}$$

and:

$$\begin{aligned}
\text{cov}_t(\epsilon_{\tilde{c},t+1}^f, \epsilon_{\tilde{c},t+1}) &= \sqrt{v_t^f v_t}\rho_v\\
&\approx v_0\rho_v + \frac{1}{2v_0}\rho_v[(v_t^f - v_0)v_0 + (v_t - v_0)v_0]\\
&= \frac{1}{2}\rho_v(v_t^f + v_t).
\end{aligned} \quad \text{(IA.92)}$$

Hence, we have:

$$\begin{aligned}
&(1-\gamma)^2k_c^2\text{var}_t(\epsilon_{\tilde{c},t+1}) + \theta^2\kappa^2A_{dc}^2\text{var}_t(d\epsilon_{\tilde{c},t+1}) + 2(1-\gamma)k_c\theta\kappa A_{dc}\text{cov}_t(d\epsilon_{\tilde{c},t+1},\epsilon_{\tilde{c},t+1}) =\\
&(1-\gamma)^2k_c^2v_t + \theta^2\kappa^2A_{dc}^2(sv_t - \rho_v sv_t + 2v_t) + (1-\gamma)k_c\theta\kappa A_{dc}(\rho_v sv_t - 2v_t);
\end{aligned} \quad \text{(IA.93)}$$

and:

$$\begin{aligned}
&[(1-\gamma)k_c + \theta A_{dc}(\kappa\phi_c - 1)]d\tilde{c}_t\\
&+\left[\theta A_v(\kappa\phi_v - 1) + \frac{1}{2}(1-\gamma)^2k_c^2 + \theta^2\kappa^2A_{dc}^2 - (1-\gamma)k_c\theta\kappa A_{dc}\right]v_t\\
&+\left\{\theta A_{sv}(\kappa\phi_v - 1) + \frac{1}{2}[\theta^2\kappa^2A_{dc}^2(1-\rho_v) + (1-\gamma)k_c\theta\kappa A_{dc}\rho_v]\right\}sv_t = 0.
\end{aligned} \quad \text{(IA.94)}$$

Matching coefficients, we have:

$$(1-\gamma)k_c + \theta A_{dc}(\kappa\phi_c - 1) = 0 \tag{IA.95}$$

$$\theta A_v(\kappa\phi_v - 1) + \frac{1}{2}(1-\gamma)^2 k_c^2 + \theta^2\kappa^2 A_{dc}^2 - (1-\gamma)k_c\theta\kappa A_{dc} = 0 \tag{IA.96}$$

$$\theta A_{sv}(\kappa\phi_v - 1) + \frac{1}{2}[\theta^2\kappa^2 A_{dc}^2(1-\rho_v) + (1-\gamma)k_c\theta\kappa A_{dc}\rho_v] = 0. \tag{IA.97}$$

Hence, we have:

$$A_{dc} = -\frac{(\gamma-1)k_c}{\theta(1-\kappa\phi_c)} \tag{IA.98}$$

$$A_v = \frac{\theta^2\kappa^2 A_{dc}^2 + \frac{1}{2}(1-\gamma)^2 k_c^2 - (1-\gamma)k_c\theta\kappa A_{dc}}{\theta(1-\kappa\phi_v)} \tag{IA.99}$$

$$A_{sv} = \frac{\theta^2 A_{dc}^2(1-\rho_v) + (1-\gamma)k_c\theta\kappa A_{dc}\rho_v}{2\theta(1-\kappa\phi_v)}. \tag{IA.100}$$

Given the definitions of A_{dc} and A_v above, we have $d\tilde{m}_t = m_{dy}^\top dy_t$, where:

$$m_{dc} = -2(\theta-1)A_{dc} \tag{IA.101}$$

$$m_{dv} = (\theta-1)A_v. \tag{IA.102}$$

In the calibration exercise, we assume $\gamma > 1$ and $\psi > 1$. Hence, we have $A_{dc} > 0$. For our choice of parameter values, we also have $A_v < 0$.

IA.10.3 The real exchange rate

Note that using the no-arbitrage condition $\Delta\tilde{s}_t = d\tilde{m}_t$, the real log pricing kernel differential in (35), and the VAR in (IA.82), we have:

$$\begin{aligned}
\tilde{s}_t - E(\tilde{s}_t) &= -\sum_{i=1}^{\infty} E_t(d\tilde{m}_{t+i}) \\
&= \gamma\iota_1^\top\left(\sum_{i=1}^{\infty}\Phi^i - \sum_{i=0}^{\infty}\Phi^i\right)dy_t - m_y^\top(\kappa\Phi - I)\sum_{i=0}^{\infty}\Phi^i dy_t \\
&= \gamma\iota_1^\top[\Phi(I-\Phi)^{-1} - (I-\Phi)^{-1}]dy_t - m_y^\top[\kappa\Phi(I-\Phi)^{-1} - (I-\Phi)^{-1}]dy_t \\
&= -\gamma d\tilde{c}_t + m_y^\top(I-\kappa\Phi)(I-\Phi)^{-1}dy_t;
\end{aligned} \tag{IA.103}$$

which implies:

$$\Delta\tilde{s}_t = -\gamma\Delta d\tilde{c}_t + m_y^\top(I-\kappa\Phi)(I-\Phi)^{-1}\Delta dy_t. \tag{IA.104}$$

On the other hand, from (35), the real log pricing kernel differential equals

$$d\tilde{m}_t = -\gamma\Delta d\tilde{c}_t + m_y^\top(\kappa dy_t - dy_{t-1}). \tag{IA.105}$$

The two expressions above, (IA.104) and (IA.105), should be equal. This is true only if we set $\kappa = 1$.

IA.10.4 Calibrating the volatility process

Bansal and Shaliastovich (2013) parameterize the process for the conditional volatility of innovations in expected consumption growth, as the innovation in consumption are assumed to be homoskedastic. In our setting, both the innovations in consumption growth and in expected consumption growth are heteroskedastic. We have:

$$\begin{aligned} \text{var}\{\text{var}_t[E_{t+1}(\Delta\tilde{c}_{t+2})]\} &= \text{var}[\text{var}_t(k_c d\tilde{c}_{t+1})] \\ &\approx \text{var}\{k_c^2[v_t^f + v_t - 2\sqrt{v_t^f v_t}\rho_{v^f v}]\}. \end{aligned} \tag{IA.106}$$

We approximate $\sqrt{v_t^f v_t}\rho_{v^f v}$ as:

$$\text{constant} + \frac{1}{2}\rho_{v^f v} v_0 (v_t^f + v_t). \tag{IA.107}$$

Hence, we have:

$$\begin{aligned} \text{var}\{k_c^2[v_t^f + v_t - 2\sqrt{v_t^f v_t}\rho_{v^f v}]\} &= \text{var}\{k_c^2(v_t^f + v_t)(1 - \rho_{v^f v} v_0)\} \\ &= k_c^4(1 - \rho_{v^f v} v_0)^2 2\text{var}(v_t)(1 + \rho_{v^f v}). \end{aligned} \tag{IA.108}$$

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Table IA.1: Testing UIP, Baseline Case, One-month Investment Horizon: Summary

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), and joint tests (Panel C) of the UIP null on all currencies and currency baskets. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the numbers and the fractions of asymptotic tests or of bootstrap tests yielding p-values smaller than 0.05.

Panel A: Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	18	1	18	2
Frac. of Asy. $p < 0.05$	0.46	0.03	0.46	0.05
No. of Boot. $p < 0.05$	10	1	16	2
Frac. of Boot. $p < 0.05$	0.26	0.03	0.41	0.05
No. of Assets: 39				
Avg. Adj-R^2: 0.02				

Panel B: Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	37	37	32	22
Frac. of Asy. $p < 0.05$	0.95	0.95	0.82	0.56
No. of Boot. $p < 0.05$	37	37	32	20
Frac. of Boot. $p < 0.05$	0.95	0.95	0.82	0.51
No. of Assets: 39				

Panel C: Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	18	38	38	37	37	33	19
Frac. of Asy. $p < 0.05$	0.46	0.97	0.97	0.95	0.95	0.85	0.49
No. of Boot. $p < 0.05$	13	38	38	37	37	31	19
Frac. of Boot. $p < 0.05$	0.33	0.97	0.97	0.95	0.95	0.79	0.49
No. of Assets: 39							

Table IA.2: Testing UIP, Baseline Case, Six-month Investment Horizon: Summary

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), and joint tests (Panel C) of the UIP null on all currencies and currency baskets. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the numbers and the fractions of asymptotic tests or of bootstrap tests yielding p-values smaller than 0.05.

Panel A: Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	25	1	20	4
Frac. of Asy. $p < 0.05$	0.64	0.03	0.51	0.10
No. of Boot. $p < 0.05$	6	1	12	2
Frac. of Boot. $p < 0.05$	0.15	0.03	0.31	0.05
No. of Assets: 39				
Avg. Adj-R^2: 0.10				

Panel B: Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	36	24
Frac. of Asy. $p < 0.05$	0.97	0.90	0.92	0.62
No. of Boot. $p < 0.05$	38	34	32	18
Frac. of Boot. $p < 0.05$	0.97	0.87	0.82	0.46
No. of Assets: 39				

Panel C: Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	29	39	39	39	34	39	23
Frac. of Asy. $p < 0.05$	0.74	1.00	1.00	1.00	0.87	1.00	0.59
No. of Boot. $p < 0.05$	15	39	38	36	31	33	15
Frac. of Boot. $p < 0.05$	0.38	1.00	0.97	0.92	0.79	0.85	0.38
No. of Assets: 39							

Table IA.3: Testing UIP, Baseline Case, 12-month Investment Horizon: Summary

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), and joint tests (Panel C) of the UIP null on all currencies and currency baskets. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the numbers and the fractions of asymptotic tests or of bootstrap tests yielding p-values smaller than 0.05.

Panel A: Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	26	4	19	18
Frac. of Asy. $p < 0.05$	0.67	0.10	0.49	0.46
No. of Boot. $p < 0.05$	9	0	11	13
Frac. of Boot. $p < 0.05$	0.23	0.00	0.28	0.33
No. of Assets: 39				
Avg. Adj-R^2: 0.17				

Panel B: Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	29	35	14
Frac. of Asy. $p < 0.05$	0.97	0.74	0.90	0.36
No. of Boot. $p < 0.05$	38	23	28	4
Frac. of Boot. $p < 0.05$	0.97	0.59	0.72	0.10
No. of Assets: 39				

Panel C: Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	31	39	39	39	27	37	19
Frac. of Asy. $p < 0.05$	0.79	1.00	1.00	1.00	0.69	0.95	0.49
No. of Boot. $p < 0.05$	11	38	38	38	18	31	11
Frac. of Boot. $p < 0.05$	0.28	0.97	0.97	0.97	0.46	0.79	0.28
No. of Assets: 39							

Table IA.4: Size Study

This table reports the rejection ratios of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D) of the UIP null, based on 5,000 simulated samples from the *restricted* VAR estimated with panel data, where we bootstrap the residuals for the Deutsche Mark. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the probabilities of asymptotic tests or of bootstrap tests (with 5,000 bootstrap repetitions for each sample) yielding p-values smaller than nominal significance levels of 0.01, 0.05, or 0.10. The *restricted* VAR implies the hypotheses of indirect tests and joint tests, and determines the data-generating process in all bootstrap tests.

Panel A: Direct Tests

	Signif.		Explanatory Variables			
Horizon	Level	Test	$\tilde{s}$	ξ	dr	$d\pi$
1	1%	Asy.	0.02	0.01	0.01	0.01
		Boot.	0.01	0.01	0.01	0.01
	5%	Asy.	0.08	0.05	0.06	0.06
		Boot.	0.05	0.05	0.05	0.05
	10%	Asy.	0.15	0.10	0.10	0.11
		Boot.	0.10	0.09	0.09	0.10
3	1%	Asy.	0.07	0.01	0.03	0.02
		Boot.	0.01	0.01	0.01	0.01
	5%	Asy.	0.15	0.05	0.10	0.07
		Boot.	0.04	0.04	0.05	0.06
	10%	Asy.	0.23	0.10	0.16	0.14
		Boot.	0.10	0.10	0.10	0.11
6	1%	Asy.	0.07	0.01	0.03	0.02
		Boot.	0.00	0.01	0.01	0.01
	5%	Asy.	0.17	0.05	0.10	0.07
		Boot.	0.04	0.05	0.04	0.05
	10%	Asy.	0.25	0.10	0.16	0.12
		Boot.	0.09	0.09	0.10	0.10
12	1%	Asy.	0.09	0.02	0.03	0.02
		Boot.	0.01	0.01	0.01	0.01
	5%	Asy.	0.19	0.06	0.09	0.08
		Boot.	0.04	0.05	0.04	0.05
	10%	Asy.	0.28	0.12	0.15	0.14
		Boot.	0.08	0.11	0.08	0.11

Panel B: Indirect Tests

Horizon	Signif. Level	Test	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\tilde{s}$	ξ	dr	$d\pi$
1	1%	Asy.	0.01	0.01	0.01	0.01
		Boot.	0.01	0.01	0.01	0.00
	5%	Asy.	0.06	0.05	0.05	0.04
		Boot.	0.05	0.05	0.05	0.04
	10%	Asy.	0.12	0.09	0.09	0.09
		Boot.	0.11	0.09	0.09	0.08
3	1%	Asy.	0.04	0.02	0.03	0.02
		Boot.	0.01	0.01	0.01	0.01
	5%	Asy.	0.12	0.06	0.09	0.08
		Boot.	0.04	0.05	0.05	0.06
	10%	Asy.	0.19	0.10	0.15	0.15
		Boot.	0.10	0.09	0.10	0.10
6	1%	Asy.	0.04	0.02	0.03	0.03
		Boot.	0.01	0.01	0.01	0.01
	5%	Asy.	0.12	0.06	0.10	0.11
		Boot.	0.05	0.05	0.04	0.05
	10%	Asy.	0.21	0.12	0.15	0.16
		Boot.	0.09	0.10	0.10	0.11
12	1%	Asy.	0.07	0.04	0.03	0.04
		Boot.	0.01	0.01	0.01	0.01
	5%	Asy.	0.14	0.08	0.09	0.11
		Boot.	0.06	0.05	0.04	0.06
	10%	Asy.	0.22	0.14	0.17	0.18
		Boot.	0.11	0.10	0.08	0.10

Panel C: Joint Tests

Horizon	Signif. Level	Test	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
						$\tilde{s}$	ξ	dr	$d\pi$
1	1%	Asy.	0.02	0.01	0.02	0.03	0.02	0.01	0.01
		Boot.	0.00	0.01	0.01	0.01	0.01	0.01	0.01
	5%	Asy.	0.07	0.07	0.08	0.10	0.06	0.05	0.06
		Boot.	0.04	0.04	0.05	0.05	0.05	0.04	0.04
	10%	Asy.	0.13	0.11	0.15	0.16	0.11	0.11	0.11
		Boot.	0.09	0.10	0.09	0.10	0.10	0.09	0.09
3	1%	Asy.	0.06	0.05	0.12	0.09	0.02	0.04	0.03
		Boot.	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	5%	Asy.	0.17	0.15	0.25	0.20	0.06	0.12	0.10
		Boot.	0.04	0.04	0.05	0.05	0.05	0.04	0.06
	10%	Asy.	0.24	0.23	0.34	0.28	0.12	0.19	0.16
		Boot.	0.09	0.10	0.10	0.10	0.10	0.09	0.11
6	1%	Asy.	0.09	0.09	0.19	0.10	0.02	0.04	0.04
		Boot.	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	5%	Asy.	0.20	0.19	0.34	0.23	0.09	0.12	0.12
		Boot.	0.04	0.05	0.03	0.03	0.05	0.04	0.05
	10%	Asy.	0.29	0.27	0.45	0.31	0.13	0.22	0.18
		Boot.	0.08	0.10	0.08	0.08	0.11	0.08	0.11
12	1%	Asy.	0.15	0.14	0.32	0.14	0.04	0.06	0.05
		Boot.	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	5%	Asy.	0.25	0.25	0.46	0.27	0.10	0.13	0.14
		Boot.	0.04	0.05	0.04	0.04	0.06	0.05	0.05
	10%	Asy.	0.34	0.34	0.56	0.37	0.17	0.20	0.22
		Boot.	0.09	0.10	0.10	0.09	0.10	0.08	0.10

Panel D: Infinite-horizon Tests

Signif. Level	Test	Explanatory Variables $\tilde{s}$	ξ	dr	$d\pi$	$\hat{\beta}_{\xi,\infty}=0$ Wald	Variance Share	Δ Variance Share
1%	Asy.	0.20	0.03	0.00	0.00	0.27	0.19	0.01
	Boot.	0.01	0.01	0.01	0.01	0.01	0.01	0.01
5%	Asy.	0.27	0.09	0.02	0.01	0.35	0.27	0.03
	Boot.	0.04	0.04	0.04	0.05	0.03	0.04	0.04
10%	Asy.	0.32	0.15	0.06	0.05	0.40	0.32	0.06
	Boot.	0.11	0.09	0.10	0.11	0.08	0.11	0.09

Table IA.5: Power Study

This table reports the rejection ratios of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D) of the UIP null, based on 5,000 simulated samples from the *unrestricted* VAR estimated with panel data, where we bootstrap the residuals for the Deutsche Mark. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the probabilities of asymptotic tests or of bootstrap tests (with 5,000 bootstrap repetitions for each sample) yielding p-values smaller than nominal significance levels of 0.01, 0.05, or 0.10. The *restricted* VAR implies the hypotheses of indirect tests and joint tests, and determines the data-generating process in all bootstrap tests.

	Signif.		Explanatory Variables			
Horizon	Level	Test	$\tilde{s}$	ξ	dr	$d\pi$
1	1%	Asy.	0.32	0.21	0.01	0.02
		Boot.	0.16	0.19	0.01	0.02
	5%	Asy.	0.65	0.41	0.07	0.06
		Boot.	0.48	0.40	0.06	0.06
	10%	Asy.	0.81	0.54	0.14	0.12
		Boot.	0.68	0.52	0.13	0.11
3	1%	Asy.	0.57	0.05	0.04	0.02
		Boot.	0.18	0.05	0.02	0.01
	5%	Asy.	0.82	0.18	0.11	0.08
		Boot.	0.49	0.17	0.06	0.07
	10%	Asy.	0.90	0.28	0.19	0.15
		Boot.	0.68	0.27	0.12	0.13
6	1%	Asy.	0.65	0.02	0.03	0.02
		Boot.	0.17	0.01	0.01	0.01
	5%	Asy.	0.85	0.12	0.10	0.08
		Boot.	0.50	0.10	0.05	0.06
	10%	Asy.	0.93	0.20	0.17	0.14
		Boot.	0.69	0.19	0.09	0.11
12	1%	Asy.	0.73	0.02	0.03	0.02
		Boot.	0.14	0.01	0.01	0.01
	5%	Asy.	0.90	0.10	0.10	0.08
		Boot.	0.48	0.08	0.04	0.05
	10%	Asy.	0.95	0.17	0.16	0.14
		Boot.	0.69	0.14	0.09	0.10

Panel B: Indirect Tests

Horizon	Signif. Level	Test	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\tilde{s}$	ξ	dr	$d\pi$
1	1%	Asy.	1.00	1.00	0.63	0.01
		Boot.	1.00	1.00	0.61	0.01
	5%	Asy.	1.00	1.00	0.82	0.05
		Boot.	1.00	1.00	0.81	0.05
	10%	Asy.	1.00	1.00	0.90	0.11
		Boot.	1.00	1.00	0.89	0.10
3	1%	Asy.	1.00	1.00	0.59	0.09
		Boot.	1.00	1.00	0.41	0.05
	5%	Asy.	1.00	1.00	0.76	0.22
		Boot.	1.00	1.00	0.67	0.15
	10%	Asy.	1.00	1.00	0.83	0.32
		Boot.	1.00	1.00	0.77	0.26
6	1%	Asy.	1.00	0.97	0.38	0.15
		Boot.	1.00	0.95	0.22	0.07
	5%	Asy.	1.00	0.99	0.57	0.29
		Boot.	1.00	0.99	0.43	0.20
	10%	Asy.	1.00	1.00	0.68	0.36
		Boot.	1.00	0.99	0.57	0.30
12	1%	Asy.	1.00	0.61	0.21	0.14
		Boot.	1.00	0.38	0.08	0.06
	5%	Asy.	1.00	0.79	0.38	0.24
		Boot.	1.00	0.70	0.25	0.17
	10%	Asy.	1.00	0.88	0.50	0.31
		Boot.	1.00	0.82	0.36	0.24

Panel C: Joint Tests

Horizon	Signif. Level	Test	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
						$\tilde{s}$	ξ	dr	$d\pi$
1	1%	Asy.	0.35	1.00	1.00	1.00	1.00	0.55	0.01
		Boot.	0.24	1.00	1.00	1.00	1.00	0.47	0.01
	5%	Asy.	0.62	1.00	1.00	1.00	1.00	0.76	0.06
		Boot.	0.50	1.00	1.00	1.00	1.00	0.73	0.05
	10%	Asy.	0.75	1.00	1.00	1.00	1.00	0.85	0.13
		Boot.	0.66	1.00	1.00	1.00	1.00	0.83	0.11
3	1%	Asy.	0.48	1.00	1.00	1.00	1.00	0.51	0.10
		Boot.	0.13	1.00	1.00	1.00	1.00	0.30	0.04
	5%	Asy.	0.70	1.00	1.00	1.00	1.00	0.71	0.20
		Boot.	0.39	1.00	1.00	1.00	1.00	0.54	0.15
	10%	Asy.	0.82	1.00	1.00	1.00	1.00	0.80	0.31
		Boot.	0.54	1.00	1.00	1.00	1.00	0.68	0.22
6	1%	Asy.	0.56	1.00	1.00	1.00	0.94	0.35	0.17
		Boot.	0.09	1.00	1.00	1.00	0.88	0.13	0.06
	5%	Asy.	0.76	1.00	1.00	1.00	0.98	0.52	0.30
		Boot.	0.32	1.00	1.00	1.00	0.97	0.34	0.19
	10%	Asy.	0.86	1.00	1.00	1.00	0.99	0.63	0.41
		Boot.	0.53	1.00	1.00	1.00	0.98	0.45	0.29
12	1%	Asy.	0.69	1.00	1.00	1.00	0.53	0.20	0.16
		Boot.	0.09	1.00	1.00	1.00	0.29	0.06	0.07
	5%	Asy.	0.84	1.00	1.00	1.00	0.74	0.37	0.28
		Boot.	0.33	1.00	1.00	1.00	0.61	0.17	0.16
	10%	Asy.	0.90	1.00	1.00	1.00	0.82	0.46	0.35
		Boot.	0.52	1.00	1.00	1.00	0.74	0.27	0.24

Panel D: Infinite-horizon Tests

Signif. Level	Test	Explanatory Variables $\tilde{s}$	ξ	dr	$d\pi$	$\hat{\beta}_{\xi,\infty} = 0$ Wald	Variance Share	Δ Variance Share
1%	Asy.	1.00	0.59	0.50	0.04	1.00	1.00	0.08
	Boot.	0.85	0.29	0.62	0.13	0.91	0.86	0.92
5%	Asy.	1.00	0.82	0.70	0.17	1.00	1.00	0.38
	Boot.	0.96	0.67	0.77	0.27	0.98	0.96	0.97
10%	Asy.	1.00	0.90	0.78	0.29	1.00	1.00	0.62
	Boot.	0.98	0.81	0.83	0.36	0.99	0.98	0.98

Table IA.6: Testing UIP, Correction for Spurious-regression Bias: Summary

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D) of the null hypothesis that excess currency returns are unpredictable based on the observed instruments but predictable based on other latent predictors with the same process as the observable instruments; see Section IA.5. The four observable instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$). Each panel reports the numbers and the fractions of asymptotic tests or of bootstrap tests yielding p-values smaller than 0.05.

Panel A: 3-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	4	0	10	0
Frac. of Boot. $p < 0.05$	0.10	0.00	0.26	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.04				

Panel B: 3-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	35	33	31	7
Frac. of Boot. $p < 0.05$	0.90	0.85	0.79	0.18
No. of Assets: 39				

Panel C: 3-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\bar{\beta}_{\Delta\tilde{s},H,k}$			
			$\hat{\beta}_{d\tilde{r},H} = -\bar{\beta}_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	8	39	38	35	32	32	8
Frac. of Boot. $p < 0.05$	0.21	1.00	0.97	0.90	0.82	0.82	0.21
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	13	0	8	0	13	10	14
Frac. of Boot. $p < 0.05$	0.38	0.00	0.24	0.00	0.38	0.29	0.41
No. of Assets: 34							

Table IA.7: Robustness to Different Choices of $\bar{\beta}_{\Delta\tilde{s},H}$

This table reports sample asymptotic and bootstrapped p-values and their root mean squared errors (RMSEs) of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D) of the UIP null using the Deutsche Mark data. The RMSEs are calculated based on 5,000 simulations. Each simulation uses the same Deutsche Mark sample but draws a new restricted VAR from the asymptotic distribution of the panel-VAR estimates. The new *restricted* VAR implies the hypotheses of indirect tests and joint tests, and determines the data-generating process in the bootstrap tests (each uses 5,000 repetitions); see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Direct Tests

		Explanatory Variables			
Horizon		$\tilde{s}$	ξ	dr	$d\pi$
1	Asy. p	0.01	0.32	0.11	0.50
	RMSE	0.00	0.00	0.00	0.00
	Boot. p	0.03	0.33	0.12	0.51
	RMSE	0.01	0.01	0.02	0.01
3	Asy. p	0.00	0.14	0.07	0.98
	RMSE	0.00	0.00	0.00	0.00
	Boot. p	0.04	0.15	0.12	0.98
	RMSE	0.01	0.02	0.04	0.00
6	Asy. p	0.00	0.54	0.02	0.65
	RMSE	0.00	0.00	0.00	0.00
	Boot. p	0.04	0.54	0.05	0.67
	RMSE	0.01	0.03	0.03	0.01
12	Asy. p	0.00	0.26	0.01	0.01
	RMSE	0.00	0.00	0.00	0.00
	Boot. p	0.04	0.28	0.03	0.03
	RMSE	0.01	0.04	0.03	0.01

Panel B: Indirect Tests

Horizon		$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
		$\tilde{s}$	ξ	dr	$d\pi$
1	Asy. p	0.00	0.00	0.00	0.00
	RMSE	0.03	0.11	0.19	0.25
	Boot. p	0.00	0.00	0.00	0.00
	RMSE	0.03	0.11	0.19	0.25
3	Asy. p	0.00	0.00	0.00	0.00
	RMSE	0.02	0.17	0.04	0.21
	Boot. p	0.00	0.00	0.00	0.00
	RMSE	0.02	0.17	0.05	0.22
6	Asy. p	0.00	0.00	0.00	0.00
	RMSE	0.00	0.16	0.01	0.12
	Boot. p	0.00	0.00	0.00	0.00
	RMSE	0.01	0.17	0.02	0.13
12	Asy. p	0.00	0.00	0.00	0.02
	RMSE	0.00	0.18	0.01	0.36
	Boot. p	0.00	0.00	0.00	0.06
	RMSE	0.00	0.19	0.01	0.36

Panel C: Joint Tests

Horizon		$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
					$\tilde{s}$	ξ	dr	$d\pi$
1	Asy. p	0.03	0.00	0.00	0.00	0.00	0.00	0.00
	RMSE	0.00	0.00	0.00	0.00	0.10	0.08	0.28
	Boot. p	0.07	0.00	0.00	0.00	0.00	0.00	0.00
	RMSE	0.01	0.00	0.00	0.01	0.10	0.09	0.28
3	Asy. p	0.01	0.00	0.00	0.00	0.00	0.00	0.00
	RMSE	0.00	0.00	0.00	0.00	0.08	0.02	0.29
	Boot. p	0.06	0.00	0.00	0.00	0.00	0.00	0.00
	RMSE	0.01	0.00	0.00	0.01	0.09	0.04	0.30
6	Asy. p	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	RMSE	0.00	0.00	0.00	0.00	0.18	0.00	0.17
	Boot. p	0.04	0.00	0.00	0.00	0.00	0.00	0.00
	RMSE	0.01	0.00	0.00	0.01	0.20	0.01	0.19
12	Asy. p	0.00	0.00	0.00	0.00	0.00	0.00	0.01
	RMSE	0.00	0.00	0.00	0.00	0.13	0.00	0.02
	Boot. p	0.01	0.00	0.00	0.00	0.00	0.00	0.06
	RMSE	0.01	0.00	0.00	0.00	0.17	0.00	0.05

Panel D: Infinite-horizon Tests

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
Asy. p	0.00	0.51	0.18	0.36	0.00	0.00	0.13
RMSE	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boot. p	0.03	0.56	0.13	0.34	0.04	0.02	0.00
RMSE	0.03	0.05	0.07	0.05	0.04	0.02	0.16

Table IA.8: Testing UIP, Currency-specific VAR

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the restricted VAR is currency-specific; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	14	2	8	0
Frac. of Asy. $p < 0.05$	0.61	0.09	0.35	0.00
No. of Boot. $p < 0.05$	5	0	5	0
Frac. of Boot. $p < 0.05$	0.22	0.00	0.22	0.00
No. of Assets: 23				
Avg. Adj-R^2: 0.04				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	21	16	21	13
Frac. of Asy. $p < 0.05$	0.91	0.70	0.91	0.57
No. of Boot. $p < 0.05$	21	14	19	12
Frac. of Boot. $p < 0.05$	0.91	0.61	0.83	0.52
No. of Assets: 23				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	12	22	21	21	15	19	11
Frac. of Asy. $p < 0.05$	0.52	0.96	0.91	0.91	0.65	0.83	0.48
No. of Boot. $p < 0.05$	7	21	21	21	14	18	10
Frac. of Boot. $p < 0.05$	0.30	0.91	0.91	0.91	0.61	0.78	0.43
No. of Assets: 23							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	18	2	4	3	21	16	0
Frac. of Asy. $p < 0.05$	0.78	0.09	0.17	0.13	0.91	0.70	0.00
No. of Boot. $p < 0.05$	11	3	4	1	10	11	4
Frac. of Boot. $p < 0.05$	0.48	0.13	0.17	0.04	0.43	0.48	0.17
No. of Assets: 23							

Table IA.9: Testing UIP, Correcting Biases in Panel Estimates of VAR

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the restricted VAR is from a panel regression with bias correction; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	7	1	11	0
Frac. of Boot. $p < 0.05$	0.18	0.03	0.28	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.08				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	37	34	32	18
Frac. of Boot. $p < 0.05$	0.95	0.87	0.82	0.46
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	11	39	38	36	34	33	16
Frac. of Boot. $p < 0.05$	0.28	1.00	0.97	0.92	0.87	0.85	0.41
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	13	1	10	3	13	10	7
Frac. of Boot. $p < 0.05$	0.38	0.03	0.29	0.09	0.38	0.29	0.21
No. of Assets: 34							

Table IA.10: Testing UIP, Correcting Biases in Currency-specific VAR

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the restricted VAR is currency-specific and bias-corrected; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	6	0	3	0
Frac. of Asy. $p < 0.05$	0.60	0.00	0.30	0.00
No. of Boot. $p < 0.05$	3	0	2	0
Frac. of Boot. $p < 0.05$	0.30	0.00	0.20	0.00
No. of Assets: 10				
Avg. Adj-R^2: 0.08				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	7	7	9	8
Frac. of Asy. $p < 0.05$	0.70	0.70	0.90	0.80
No. of Boot. $p < 0.05$	7	7	9	7
Frac. of Boot. $p < 0.05$	0.70	0.70	0.90	0.70
No. of Assets: 10				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	6	10	10	7	7	9	7
Frac. of Asy. $p < 0.05$	0.60	1.00	1.00	0.70	0.70	0.90	0.70
No. of Boot. $p < 0.05$	4	10	10	7	7	9	6
Frac. of Boot. $p < 0.05$	0.40	1.00	1.00	0.70	0.70	0.90	0.60
No. of Assets: 10							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	9	2	3	1	9	8	0
Frac. of Asy. $p < 0.05$	0.90	0.20	0.30	0.10	0.90	0.80	0.00
No. of Boot. $p < 0.05$	6	2	2	0	5	4	2
Frac. of Boot. $p < 0.05$	0.60	0.20	0.20	0.00	0.50	0.40	0.20
No. of Assets: 10							

Table IA.11: Testing UIP with Average Forward Discount

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and the average forward discount (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	22	2	13	0	5
Frac. of Asy. $p < 0.05$	0.58	0.05	0.34	0.00	0.13
No. of Boot. $p < 0.05$	6	1	10	0	2
Frac. of Boot. $p < 0.05$	0.16	0.03	0.26	0.00	0.05
No. of Assets: 38					
Avg. Adj-R^2: 0.06					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	37	35	30	20	19
Frac. of Asy. $p < 0.05$	0.97	0.92	0.79	0.53	0.50
No. of Boot. $p < 0.05$	36	34	30	18	16
Frac. of Boot. $p < 0.05$	0.95	0.89	0.79	0.47	0.42
No. of Assets: 38					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	24	38	38	38	34	32	18	24
Frac. of Asy. $p < 0.05$	0.63	1.00	1.00	1.00	0.89	0.84	0.47	0.63
No. of Boot. $p < 0.05$	11	38	37	34	33	31	16	12
Frac. of Boot. $p < 0.05$	0.29	1.00	0.97	0.89	0.87	0.82	0.42	0.32
No. of Assets: 38								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	22	4	5	2	0	28	20	0
Frac. of Asy. $p < 0.05$	0.67	0.12	0.15	0.06	0.00	0.85	0.61	0.00
No. of Boot. $p < 0.05$	13	0	8	0	1	14	10	8
Frac. of Boot. $p < 0.05$	0.39	0.00	0.24	0.00	0.03	0.42	0.30	0.24
No. of Assets: 33								

Table IA.12: Testing UIP with Industrial Production Growth

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and US industrial production growth (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	20	2	16	0	3
Frac. of Asy. $p < 0.05$	0.51	0.05	0.41	0.00	0.08
No. of Boot. $p < 0.05$	5	1	10	0	0
Frac. of Boot. $p < 0.05$	0.13	0.03	0.26	0.00	0.00
No. of Assets: 39					
Avg. Adj-R^2: 0.04					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	38	35	34	20	28
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51	0.72
No. of Boot. $p < 0.05$	37	35	32	18	22
Frac. of Boot. $p < 0.05$	0.95	0.90	0.82	0.46	0.56
No. of Assets: 39					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	25	39	39	39	34	37	19	28
Frac. of Asy. $p < 0.05$	0.64	1.00	1.00	1.00	0.87	0.95	0.49	0.72
No. of Boot. $p < 0.05$	7	38	38	36	33	33	16	15
Frac. of Boot. $p < 0.05$	0.18	0.97	0.97	0.92	0.85	0.85	0.41	0.38
No. of Assets: 39								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	25	4	7	4	0	30	24	0
Frac. of Asy. $p < 0.05$	0.71	0.11	0.20	0.11	0.00	0.86	0.69	0.00
No. of Boot. $p < 0.05$	14	1	11	5	0	16	14	9
Frac. of Boot. $p < 0.05$	0.40	0.03	0.31	0.14	0.00	0.46	0.40	0.26
No. of Assets: 35								

Table IA.13: Testing UIP with Real Exchange Rate Appreciation

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and real exchange rate appreciation (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	23	6	11	2	3
Frac. of Asy. $p < 0.05$	0.59	0.15	0.28	0.05	0.08
No. of Boot. $p < 0.05$	8	3	9	2	3
Frac. of Boot. $p < 0.05$	0.21	0.08	0.23	0.05	0.08
No. of Assets: 39					
Avg. Adj-R^2: 0.05					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	39	20	28	16	17
Frac. of Asy. $p < 0.05$	1.00	0.51	0.72	0.41	0.44
No. of Boot. $p < 0.05$	36	17	25	13	14
Frac. of Boot. $p < 0.05$	0.92	0.44	0.64	0.33	0.36
No. of Assets: 39					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	24	39	39	39	18	27	14	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.46	0.69	0.36	0.46
No. of Boot. $p < 0.05$	10	38	37	36	15	25	13	13
Frac. of Boot. $p < 0.05$	0.26	0.97	0.95	0.92	0.38	0.64	0.33	0.33
No. of Assets: 39								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	7	2	7	1	2	30	8	2
Frac. of Asy. $p < 0.05$	0.20	0.06	0.20	0.03	0.06	0.86	0.23	0.06
No. of Boot. $p < 0.05$	7	3	8	1	3	13	8	4
Frac. of Boot. $p < 0.05$	0.20	0.09	0.23	0.03	0.09	0.37	0.23	0.11
No. of Assets: 35								

Table IA.14: Testing UIP with Yield Curve Level Differential

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and the yield curve level differential (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	16	2	8	0	10
Frac. of Asy. $p < 0.05$	0.44	0.06	0.22	0.00	0.28
No. of Boot. $p < 0.05$	6	0	4	0	5
Frac. of Boot. $p < 0.05$	0.17	0.00	0.11	0.00	0.14
No. of Assets: 36					
Avg. Adj-R^2: 0.06					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	35	33	18	14	28
Frac. of Asy. $p < 0.05$	0.97	0.92	0.50	0.39	0.78
No. of Boot. $p < 0.05$	35	33	15	12	24
Frac. of Boot. $p < 0.05$	0.97	0.92	0.42	0.33	0.67
No. of Assets: 36					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	25	36	36	36	33	20	12	30
Frac. of Asy. $p < 0.05$	0.69	1.00	1.00	1.00	0.92	0.56	0.33	0.83
No. of Boot. $p < 0.05$	10	36	36	33	31	14	11	25
Frac. of Boot. $p < 0.05$	0.28	1.00	1.00	0.92	0.86	0.39	0.31	0.69
No. of Assets: 36								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	24	1	1	3	0	28	20	2
Frac. of Asy. $p < 0.05$	0.75	0.03	0.03	0.09	0.00	0.88	0.63	0.06
No. of Boot. $p < 0.05$	15	1	4	4	2	13	11	8
Frac. of Boot. $p < 0.05$	0.47	0.03	0.13	0.13	0.06	0.41	0.34	0.25
No. of Assets: 32								

Table IA.15: Testing UIP with Yield Curve Slope Differential

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and the yield curve slope differential (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	16	2	13	0	10
Frac. of Asy. $p < 0.05$	0.44	0.06	0.36	0.00	0.28
No. of Boot. $p < 0.05$	6	0	7	0	5
Frac. of Boot. $p < 0.05$	0.17	0.00	0.19	0.00	0.14
No. of Assets: 36					
Avg. Adj-R^2: 0.06					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	35	33	33	14	28
Frac. of Asy. $p < 0.05$	0.97	0.92	0.92	0.39	0.78
No. of Boot. $p < 0.05$	35	33	27	12	24
Frac. of Boot. $p < 0.05$	0.97	0.92	0.75	0.33	0.67
No. of Assets: 36					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
			$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	25	36	36	36	33	35	12	30
Frac. of Asy. $p < 0.05$	0.69	1.00	1.00	1.00	0.92	0.97	0.33	0.83
No. of Boot. $p < 0.05$	10	36	36	33	31	29	11	25
Frac. of Boot. $p < 0.05$	0.28	1.00	1.00	0.92	0.86	0.81	0.31	0.69
No. of Assets: 36								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	24	1	2	3	0	28	20	2
Frac. of Asy. $p < 0.05$	0.75	0.03	0.06	0.09	0.00	0.88	0.63	0.06
No. of Boot. $p < 0.05$	15	1	3	4	2	13	11	8
Frac. of Boot. $p < 0.05$	0.47	0.03	0.09	0.13	0.06	0.41	0.34	0.25
No. of Assets: 32								

Table IA.16: Testing UIP with Change of Yield Curve Level Differential

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and the change in the yield curve level differential (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	16	3	12	0	2
Frac. of Asy. $p < 0.05$	0.44	0.08	0.33	0.00	0.06
No. of Boot. $p < 0.05$	8	0	7	0	1
Frac. of Boot. $p < 0.05$	0.22	0.00	0.19	0.00	0.03
No. of Assets: 36					
Avg. Adj-R^2: 0.05					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	35	33	36	12	12
Frac. of Asy. $p < 0.05$	0.97	0.92	1.00	0.33	0.33
No. of Boot. $p < 0.05$	34	33	33	11	11
Frac. of Boot. $p < 0.05$	0.94	0.92	0.92	0.31	0.31
No. of Assets: 36					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	24	36	36	36	32	36	12	12
Frac. of Asy. $p < 0.05$	0.67	1.00	1.00	1.00	0.89	1.00	0.33	0.33
No. of Boot. $p < 0.05$	9	36	36	33	31	33	12	9
Frac. of Boot. $p < 0.05$	0.25	1.00	1.00	0.92	0.86	0.92	0.33	0.25
No. of Assets: 36								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	22	4	8	2	2	29	22	1
Frac. of Asy. $p < 0.05$	0.71	0.13	0.26	0.06	0.06	0.94	0.71	0.03
No. of Boot. $p < 0.05$	12	2	9	2	2	12	10	8
Frac. of Boot. $p < 0.05$	0.39	0.06	0.29	0.06	0.06	0.39	0.32	0.26
No. of Assets: 31								

Table IA.17: Testing UIP with Momentum Factor

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and the momentum factor (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	22	0	14	0	0
Frac. of Asy. $p < 0.05$	0.56	0.00	0.36	0.00	0.00
No. of Boot. $p < 0.05$	9	0	10	0	0
Frac. of Boot. $p < 0.05$	0.23	0.00	0.26	0.00	0.00
No. of Assets: 39					
Avg. Adj-R^2: 0.04					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	39	32	34	23	30
Frac. of Asy. $p < 0.05$	1.00	0.82	0.87	0.59	0.77
No. of Boot. $p < 0.05$	37	29	33	21	20
Frac. of Boot. $p < 0.05$	0.95	0.74	0.85	0.54	0.51
No. of Assets: 39					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	23	39	39	39	32	37	22	28
Frac. of Asy. $p < 0.05$	0.59	1.00	1.00	1.00	0.82	0.95	0.56	0.72
No. of Boot. $p < 0.05$	9	39	38	37	29	33	20	18
Frac. of Boot. $p < 0.05$	0.23	1.00	0.97	0.95	0.74	0.85	0.51	0.46
No. of Assets: 39								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	24	0	8	4	2	30	23	0
Frac. of Asy. $p < 0.05$	0.67	0.00	0.22	0.11	0.06	0.83	0.64	0.00
No. of Boot. $p < 0.05$	16	0	11	3	2	14	14	13
Frac. of Boot. $p < 0.05$	0.44	0.00	0.31	0.08	0.06	0.39	0.39	0.36
No. of Assets: 36								

Table IA.18: Testing UIP with Value Factor

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D). The five instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), the inflation differential ($d\pi$), and the value factor (x); see Section IA.5.

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	28	2	13	0	14
Frac. of Asy. $p < 0.05$	0.74	0.05	0.34	0.00	0.37
No. of Boot. $p < 0.05$	16	2	11	0	5
Frac. of Boot. $p < 0.05$	0.42	0.05	0.29	0.00	0.13
No. of Assets: 38					
Avg. Adj-R^2: 0.05					

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
	$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	38	35	34	22	22
Frac. of Asy. $p < 0.05$	1.00	0.92	0.89	0.58	0.58
No. of Boot. $p < 0.05$	38	34	33	21	4
Frac. of Boot. $p < 0.05$	1.00	0.89	0.87	0.55	0.11
No. of Assets: 38					

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$				
				$\tilde{s}$	ξ	dr	$d\pi$	x
No. of Asy. $p < 0.05$	29	38	38	38	34	36	23	28
Frac. of Asy. $p < 0.05$	0.76	1.00	1.00	1.00	0.89	0.95	0.61	0.74
No. of Boot. $p < 0.05$	12	37	37	37	34	33	20	5
Frac. of Boot. $p < 0.05$	0.32	0.97	0.97	0.97	0.89	0.87	0.53	0.13
No. of Assets: 38								

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables					$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	x	Wald	Share	Share
No. of Asy. $p < 0.05$	21	2	8	1	7	29	21	2
Frac. of Asy. $p < 0.05$	0.68	0.06	0.26	0.03	0.23	0.94	0.68	0.06
No. of Boot. $p < 0.05$	3	5	4	2	0	5	3	11
Frac. of Boot. $p < 0.05$	0.10	0.16	0.13	0.06	0.00	0.16	0.10	0.35
No. of Assets: 31								

Table IA.19: Testing UIP, Block Bootstrap (1)

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the VAR residuals are resampled using block bootstrap with block length determined by autocorrelation in the VAR residuals; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	3	0	3	0
Frac. of Boot. $p < 0.05$	0.08	0.00	0.08	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.02				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	38	29	25	11
Frac. of Boot. $p < 0.05$	0.97	0.74	0.64	0.28
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	2	38	36	36	26	24	10
Frac. of Boot. $p < 0.05$	0.05	0.97	0.92	0.92	0.67	0.62	0.26
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	14	2	7	1	11	11	4
Frac. of Boot. $p < 0.05$	0.41	0.06	0.21	0.03	0.32	0.32	0.12
No. of Assets: 34							

Table IA.20: Testing UIP, Block Bootstrap (2)

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the VAR residuals are resampled using block bootstrap with block length determined by autocorrelation in squared VAR residuals; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	5	0	4	0
Frac. of Boot. $p < 0.05$	0.13	0.00	0.10	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.03				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	37	29	26	12
Frac. of Boot. $p < 0.05$	0.95	0.74	0.67	0.31
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	3	38	37	36	27	24	11
Frac. of Boot. $p < 0.05$	0.08	0.97	0.95	0.92	0.69	0.62	0.28
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	13	4	9	1	12	10	4
Frac. of Boot. $p < 0.05$	0.38	0.12	0.26	0.03	0.35	0.29	0.12
No. of Assets: 34							

Table IA.21: Testing UIP, Monte Carlo Simulation under Joint Normality

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the VAR residuals are simulated using a joint normal distribution; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	7	1	11	0
Frac. of Boot. $p < 0.05$	0.18	0.03	0.28	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.05				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	37	34	32	18
Frac. of Boot. $p < 0.05$	0.95	0.87	0.82	0.46
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	11	39	38	36	34	33	16
Frac. of Boot. $p < 0.05$	0.28	1.00	0.97	0.92	0.87	0.85	0.41
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	13	0	11	4	13	9	7
Frac. of Boot. $p < 0.05$	0.38	0.00	0.32	0.12	0.38	0.26	0.21
No. of Assets: 34							

Table IA.22: Testing UIP, 600 Months of Warm-up Period

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the warm-up period for simulating instruments is 600 months; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	7	1	11	0
Frac. of Boot. $p < 0.05$	0.18	0.03	0.28	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.05				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	37	34	32	18
Frac. of Boot. $p < 0.05$	0.95	0.87	0.82	0.46
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	11	39	38	36	34	33	16
Frac. of Boot. $p < 0.05$	0.28	1.00	0.97	0.92	0.87	0.85	0.41
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	13	0	10	4	13	9	7
Frac. of Boot. $p < 0.05$	0.38	0.00	0.29	0.12	0.38	0.26	0.21
No. of Assets: 34							

Table IA.23: Testing UIP, 50,000 Bootstrap Repetitions

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the number of bootstrap repetitions is 50,000; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	22	3	15	0
Frac. of Asy. $p < 0.05$	0.56	0.08	0.38	0.00
No. of Boot. $p < 0.05$	7	0	11	0
Frac. of Boot. $p < 0.05$	0.18	0.00	0.28	0.00
No. of Assets: 39				
Avg. Adj-R^2: 0.05				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	35	34	20
Frac. of Asy. $p < 0.05$	0.97	0.90	0.87	0.51
No. of Boot. $p < 0.05$	37	34	32	17
Frac. of Boot. $p < 0.05$	0.95	0.87	0.82	0.44
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	24	39	39	39	34	37	18
Frac. of Asy. $p < 0.05$	0.62	1.00	1.00	1.00	0.87	0.95	0.46
No. of Boot. $p < 0.05$	11	39	38	36	34	33	16
Frac. of Boot. $p < 0.05$	0.28	1.00	0.97	0.92	0.87	0.85	0.41
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	25	2	7	4	30	22	0
Frac. of Asy. $p < 0.05$	0.74	0.06	0.21	0.12	0.88	0.65	0.00
No. of Boot. $p < 0.05$	13	1	10	3	13	10	7
Frac. of Boot. $p < 0.05$	0.38	0.03	0.29	0.09	0.38	0.29	0.21
No. of Assets: 34							

Table IA.24: Testing UIP, Deutsche Mark as Reference Currency

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the reference currency is the Deutsche Mark; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	16	0	5	1
Frac. of Asy. $p < 0.05$	0.59	0.00	0.19	0.04
No. of Boot. $p < 0.05$	6	0	3	1
Frac. of Boot. $p < 0.05$	0.22	0.00	0.11	0.04
No. of Assets: 27				
Avg. Adj-R^2: 0.04				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	26	25	25	8
Frac. of Asy. $p < 0.05$	0.96	0.93	0.93	0.30
No. of Boot. $p < 0.05$	25	24	24	8
Frac. of Boot. $p < 0.05$	0.93	0.89	0.89	0.30
No. of Assets: 27				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	13	27	27	26	22	25	9
Frac. of Asy. $p < 0.05$	0.48	1.00	1.00	0.96	0.81	0.93	0.33
No. of Boot. $p < 0.05$	5	26	26	25	22	22	8
Frac. of Boot. $p < 0.05$	0.19	0.96	0.96	0.93	0.81	0.81	0.30
No. of Assets: 27							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	23	1	7	1	25	22	1
Frac. of Asy. $p < 0.05$	0.85	0.04	0.26	0.04	0.93	0.81	0.04
No. of Boot. $p < 0.05$	11	1	9	2	14	13	8
Frac. of Boot. $p < 0.05$	0.41	0.04	0.33	0.07	0.52	0.48	0.30
No. of Assets: 27							

Table IA.25: Testing UIP, Japanese Yen as Reference Currency

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the reference currency is the Japanese Yen; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	26	0	7	4
Frac. of Asy. $p < 0.05$	0.67	0.00	0.18	0.10
No. of Boot. $p < 0.05$	6	0	4	3
Frac. of Boot. $p < 0.05$	0.15	0.00	0.10	0.08
No. of Assets: 39				
Avg. Adj-R^2: 0.05				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	39	31	26	35
Frac. of Asy. $p < 0.05$	1.00	0.79	0.67	0.90
No. of Boot. $p < 0.05$	38	31	22	34
Frac. of Boot. $p < 0.05$	0.97	0.79	0.56	0.87
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and $\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
				$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	20	39	39	39	31	26	36
Frac. of Asy. $p < 0.05$	0.51	1.00	1.00	1.00	0.79	0.67	0.92
No. of Boot. $p < 0.05$	6	39	38	38	28	22	34
Frac. of Boot. $p < 0.05$	0.15	1.00	0.97	0.97	0.72	0.56	0.87
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	36	1	14	1	37	35	1
Frac. of Asy. $p < 0.05$	0.95	0.03	0.37	0.03	0.97	0.92	0.03
No. of Boot. $p < 0.05$	25	1	14	1	24	25	8
Frac. of Boot. $p < 0.05$	0.66	0.03	0.37	0.03	0.63	0.66	0.21
No. of Assets: 38							

Table IA.26: Testing UIP, British Pound as Reference Currency

This table summarizes the results of direct tests (Panel A), indirect tests (Panel B), joint tests (Panel C), and infinite-horizon tests (Panel D), where the reference currency is the British Pound; see Section IA.5. The four instruments considered are the real exchange rate ($\tilde{s}$), the one-month excess return (ξ), the nominal interest rate differential (dr), and the inflation differential ($d\pi$).

Panel A: Three-month Horizon, Direct Tests

	Explanatory Variables			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	9	3	14	3
Frac. of Asy. $p < 0.05$	0.23	0.08	0.36	0.08
No. of Boot. $p < 0.05$	2	2	7	1
Frac. of Boot. $p < 0.05$	0.05	0.05	0.18	0.03
No. of Assets: 39				
Avg. Adj-R^2: 0.01				

Panel B: Three-month Horizon, Indirect Tests

	$\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	38	15	35	35
Frac. of Asy. $p < 0.05$	0.97	0.38	0.90	0.90
No. of Boot. $p < 0.05$	36	11	33	33
Frac. of Boot. $p < 0.05$	0.92	0.28	0.85	0.85
No. of Assets: 39				

Panel C: Three-month Horizon, Joint Tests

	$\hat{\beta}_{\xi,H} = 0$	$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\hat{\beta}_{\xi,H} = 0$ and	$\hat{\beta}_{\xi,H,k} = 0$ and $\hat{\beta}_{d\tilde{r},H,k} = -\beta_{\Delta\tilde{s},H,k}$			
			$\hat{\beta}_{d\tilde{r},H} = -\beta_{\Delta\tilde{s},H}$	$\tilde{s}$	ξ	dr	$d\pi$
No. of Asy. $p < 0.05$	14	39	39	39	12	37	35
Frac. of Asy. $p < 0.05$	0.36	1.00	1.00	1.00	0.31	0.95	0.90
No. of Boot. $p < 0.05$	7	38	37	32	8	30	35
Frac. of Boot. $p < 0.05$	0.18	0.97	0.95	0.82	0.21	0.77	0.90
No. of Assets: 39							

Panel D: Infinite-horizon Regression Statistics

	Explanatory Variables				$\hat{\beta}_{\xi,\infty} = 0$	Variance	Δ Variance
	$\tilde{s}$	ξ	dr	$d\pi$	Wald	Share	Share
No. of Asy. $p < 0.05$	21	1	6	2	27	17	0
Frac. of Asy. $p < 0.05$	0.60	0.03	0.17	0.06	0.77	0.49	0.00
No. of Boot. $p < 0.05$	3	3	8	3	4	2	4
Frac. of Boot. $p < 0.05$	0.09	0.09	0.23	0.09	0.11	0.06	0.11
No. of Assets: 35							