# What Is a Currency Worth?

Thummim Cho* Riccardo Colacito† Lukas Kremens‡ Mirela Sandulescu§

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**Abstract**

Introducing a new method to compute exchange rate levels implied by a given pricing model, we find that a two-factor model of the global equity market and a value factor generates the closest fit to observed market exchange rates. The associated measure of *misvaluation* predicts currency returns at short and long horizons, and skewness in carry trade portfolios. We apply the method to the Chinese yuan and find substantial undervaluation between 2010 and 2015, and a sharp collapse of the model-implied exchange rate to the market exchange rate with the start of tightening U.S. monetary policy in 2022.

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*Korea University Business School. Email: thummim@korea.ac.kr.

†Kenan-Flagler Business School, University of North Carolina at Chapel Hill; and NBER. Email: ric@unc.edu.

‡Foster School of Business, University of Washington. Email: lkremens@uw.edu.

§Kenan-Flagler Business School, University of North Carolina at Chapel Hill. Email: mirela_sandulescu@kenan-flagler.unc.edu.

*"Money often costs too much." — Emerson (1860)*

What determines the cross-section of currency returns? This is one of the most studied questions in international finance. By contrast, there is little direct research on what determines currency *prices*, that is, exchange-rate levels. The distinction is important. A risk model can appear to explain returns well—delivering small average alphas—yet imply large errors in exchange-rate levels if those alphas are persistent. Exchange-rate levels are economically central: they are targets of monetary intervention and currency pegs, and they shape hedging, long-horizon investment, and trade decisions.

In this paper, we develop a model-implied measure of mispricing in exchange-rate levels. Building on the discounted-alpha framework in Cho and Polk (2024), we estimate a currency's long-horizon value by correcting the current spot rate with anticipated future currency abnormal returns (alphas). Because these alphas are typically short-lived and can be guided by the extensive currency-characteristics literature, the method turns an elusive infinite-horizon valuation problem into a tractable empirical exercise. We call this object the "model-implied exchange rate," noting that the respective model takes the perspective of a long-term buy-and-hold investor. We refer to the relative gap between the model-implied exchange rate and the observed market exchange rate as "misvaluation."

Applying our method, we document three novel empirical findings on the cross-section of exchange-rate levels. First, we find that a single-factor model using the global equity market (hereafter, the "Mkt" model) generates smaller misvaluations in the cross-section of currencies than the conditional Dollar-Carry ("Dol+Car") model that has been found to do well in pricing the cross-section of short-horizon returns. The Mkt model is only beaten in terms of average misvaluations by one that further adds the value factor ("Mkt+Val"). In fact, adding the Dollar and Carry factors *raises* misvaluations relative to a model of the market plus a value factor. Further adding a momentum factor does not lead to a meaningful change. These conclusions hold broadly for individual currencies as well as for characteristic-sorted long-short portfolios. We find that our mispricing measure predicts currency returns at both short and long horizons, with the mispricing measure relative to the Mkt+Val model outperforming other models in terms of predictive $R^2$.

Second, we apply the method to the time series of misvaluation in the most famous cross-sectional currency portfolio—the carry trade. We find that the carry trade is more prone to crash risk when its valuation is overstretched. That is, when high-interest currencies like the Australian dollar and New Zealand dollar are particularly overvalued relative to their sample mean, a portfolio that combines them has more negatively skewed returns. Similarly, a portfolio of low-interest, safe-haven currencies like the Japanese yen and Swiss franc has more positively skewed returns when it is particularly undervalued.

Third, we provide a novel empirical benchmark to assess instances of potential currency manipulation, a question of central importance for policymakers. Existing assessments typically rely on indirect proxies such as bilateral trade balances, current account surpluses, or foreign exchange intervention, and policy discussions often emphasize the difficulty of determining whether a currency is "too strong" or "too weak." We address this gap by delivering a transparent and systematic measure of exchange rate mispricing that can be implemented in real time, turning an elusive policy question into a tractable empirical exercise disciplined by the data.

We illustrate the usefulness of this framework across several prominent currencies. As a benchmark, the Canadian dollar exhibits little evidence of persistent misvaluation, with spot and model-implied exchange rates closely aligned. In contrast, the Chinese yuan displays a substantial and statistically significant undervaluation following the Global Financial Crisis, reflecting a sustained disconnect between a rising model-implied value and a tightly managed exchange rate, a period marked by intense international policy debate. This gap gradually narrows and ultimately disappears with the onset of U.S. monetary tightening in 2022.

Finally, we document persistent overvaluation for major European currencies. The euro appears substantially overvalued between 2015 and 2022, with a pronounced disconnect in 2020: following the announcement of the European recovery fund, the euro appreciated sharply in spot markets, while the model-implied exchange rate remained close to the pre-announcement spot rate, suggesting overvaluation. Similarly, the Swiss franc is chronically overvalued, consistent with repeated statements by the Swiss National Bank and its sustained reliance on negative interest rates and foreign exchange intervention.

*Related literature.* An extensive literature on currency factor models has focused on identifying the systematic risks that drive short-horizon excess returns (see, inter alia, Lustig, Roussanov, and Verdelhan (2011, 2014) and Liu, Maurer, Vedolin, and Zhang (2025)). Our paper departs from this objective by shifting the focus from explaining return variation to the structurally distinct challenge of pricing exchange rate levels. As emphasized in our analysis, success in return pricing does not automatically translate into accuracy in pricing currency levels, as even small but persistent alphas can cumulate into economically large deviations in exchange rates. This perspective complements recent work by Chernov, Dahlquist, and Lochstoer (2023, 2024), who show that a large fraction of currency return variation reflects unpriced risks that do not command a risk premium. While their approach isolates priced components of returns using mean-variance techniques, our discounted-alpha methodology highlights how persistent pricing errors in returns map directly into mispricing in exchange rate levels. By explicitly linking short-horizon alphas to long-horizon valuation, we provide a framework that disciplines asset pricing models along a dimension that is central for policy and macro-finance applications.

Our analysis is also closely related to the literature that studies exchange rate determination within consumption-based asset pricing frameworks. Seminal work by Lustig and Verdelhan (2007) shows that aggregate consumption growth risk explains the cross-section of currency risk premia, while Verdelhan (2010) introduces habit formation to generate countercyclical risk premia consistent with the UIP puzzle. Additional work based on recursive preferences, such as Colacito and Croce (2011) and Colacito, Croce, Gavazzoni, and Ready (2018), link exchange rate dynamics to long-run growth risks and heterogeneous exposure to global shocks. While we do not explicitly model investors' consumption and saving decisions, our framework provides an empirical discipline for these structural models. Specifically, by delivering a tractable and forward-looking measure of exchange rate levels, our approach offers a benchmark against which equilibrium models can be evaluated. In this sense, we complement this literature by shifting attention from matching short-horizon returns to matching long-run valuation objects, thereby helping bridge the gap between international asset prices and macroeconomic fundamentals.

Our analysis also contributes to the work on currency manipulation and policy inter-

ventions. Hassan, Mertens, and Zhang (2023) develop a theory in which countries manage exchange rate risk premia by stabilizing their currencies relative to a dominant anchor, thus influencing capital flows and international risk sharing. We complement this line of research by providing a tractable empirical framework to assess exchange rate misvaluation in real time.[1] By focusing on exchange rate levels rather than returns, our methodology delivers a transparent benchmark that can be used to evaluate whether observed exchange rates deviate persistently from model-implied fundamentals. This feature is particularly relevant for policy discussions, where existing approaches rely on indirect indicators such as trade imbalances or intervention patterns rather than a direct measure of misvaluation.

Finally, our work connects to a large empirical literature on exchange rate predictability and volatility dynamics (Della Corte, Sarno, and Tsiakas (2011); Della Corte, Sarno, and Tsiakas (2009) and Della Corte, Ramadorai, and Sarno (2016)). We contribute to this literature by introducing a valuation-based measure of currency mispricing that captures deviations from fundamental exchange rate levels. Our approach is also closely related to advances in long-horizon currency forecasting (Kremens and Martin (2019), Kremens, Martin, and Varela (2025)). We complement this literature by documenting that a discounted-alpha-based mispricing measure not only predicts returns at horizons ranging from 3 to 60 months, but also delivers strong predictive performance across models. This predictive power arises from a valuation object grounded in asset pricing theory.

# 1 The Model-Implied Exchange Rate

## 1.1 Definition

Let $S_{i,t}$ be the nominal spot exchange rate in U.S. dollars per unit of the foreign currency $i$ at time $t$, $R^i_{t\to t+h}$ the cumulative one-period foreign interest rates from time $t$ to $t+h$, and $\widetilde{M}_{t\to t+h}$ the cumulative stochastic discount factor ("candidate SDF") implied by a currency pricing model, expressed from the perspective of a dollar investor. Then, define the *model-*

[1] Note, however, that the risk-based form of stabilization considered in Hassan, Mertens, and Zhang (2023) is not captured by our measure. We take the estimated risk loadings as given and, instead, misvaluation reflects the impact of more conventional interventions likely operating through quantity-based measures like open-market transactions and/or capital controls.

*implied exchange rate* as the present value of investing $S_{i,t}$ U.S. dollars in foreign currency and converting the proceeds back into U.S. dollars at an infinite horizon. This measure therefore takes a fair-value perspective of a buy-and-hold investor. This is the relevant perspective to take for long-horizon investors in foreign equity and bond markets, for governments and central banks, as well as for firms in long-horizon cross-border investment.

**Definition 1** (**Model-implied exchange rate**)**.** The value of currency $i$ at time $t$, denoted $V_{i,t}$, is the expected long-run value of the foreign currency with respect to a currency pricing model:

$$V_{i,t} \equiv \lim_{h\to\infty} E_t \left[ \widetilde{M}_{t\to t+h}(1 + R^i_{t\to t+h}) S_{i,t+h} \right]. \tag{1}$$

Here, the candidate SDF is a currency pricing model an econometrician uses to evaluate exchange rates in the sense of Hansen and Jagannathan (1991, 1997) and may not be the "correct" SDF. Throughout the paper, we assume that the limit in equation (1) exists.

One may ask why we do not define the expected long-run spot exchange rate,

$$S_{i,t,\infty} \equiv \lim_{h\to\infty} E_t \left[ S_{i,t+h} \right], \tag{2}$$

as the model-implied exchange rate. This object is problematic for two reasons. First, nominal exchange rates may be nonstationary, so the limit may be ill-defined or economically hard to interpret. Second, even when well defined, equation (2) does not properly discount future spot rates to present value and therefore does not represent "value" in the usual economic sense. For example, consider two currencies with the same expected long-run spot rate. All else equal, the currency expected to depreciate in more valuable future states (i.e., states with high $\widetilde{M}_{t\to t+h}$) should be worth less today. The same logic applies to a currency with a lower interest rate, since equation (2) does not account for the time value of money.

In contrast, by applying the standard asset-pricing valuation equation, the model-implied exchange rate in equation (1) has a natural interpretation as the present value of an exchange rate future expiring at an infinite horizon, having applied the model-implied risk- and time-discount on the long-run investment in a unit foreign currency.

We emphasize three additional aspects of the model-implied exchange rate. First, like

abnormal returns (alphas), it is subject to the joint-hypothesis problem (Fama, 1970): deviations from price may reflect misspecification of the pricing model or genuine currency misvaluation. Thus, the model-implied exchange rate, like alpha, differs across different currency pricing models. Second, it is particular to the rolled-over one-period interest rate strategy used to move money from $t$ to $t+\infty$.[2] Third, the model-implied exchange rate is specific to the econometrician's information set, which we assume to include all historical data on exchange rates, interest rates, and a chosen set of currency characteristics up to that point.

## 1.2 A short-horizon expression for model-implied exchange rates

An exact mathematical identity shows that one arrives at the (infinite-horizon) model-implied exchange rate by simply "correcting" the spot exchange rate with discounted future currency abnormal returns ($\alpha$s), which have a shorter horizon.

**Assumption 1** (**Candidate SDF explains the U.S. one-period interest rate**). From hereon, we assume that the candidate SDF explains the U.S. one-period interest rate:

$$E_{t+h}\left[\widetilde{M}_{t+h+1}\right] = \frac{1}{1+R^{\$}_{f,t+h}}, \tag{3}$$

for any $t+h$.

**Lemma 1** (**Currency valuation with discounted alphas**). *As a mathematical identity, the model-implied exchange rate is the spot rate plus the discounted sum of subsequent abnormal currency returns ($\alpha$s):*

$$V_{i,t} = S_{i,t} + \sum_{h=0}^{\infty} E_t\left[\widetilde{M}_{t\to t+h+1}(1+R^{i}_{t\to t+h})S_{i,t+h}\alpha_{i,t+h}\right], \tag{4}$$

$$\alpha_{i,t+h} \equiv E_{t+h}\left[\frac{\widetilde{M}_{t+h+1}}{E_{t+h}\widetilde{M}_{t+h+1}}R^{e}_{i,t+h+1}\right], \tag{5}$$

[2]This strategy allows us to relate the model-implied exchange rate directly to findings in the currency pricing literature, which computes currency excess returns using one-period interest rates. It also avoids having to work with the notion of risk-free interest over an infinite horizon, which would likely be infinite. Our identity below requires that we use one-period interest rates, although a related identity might exist for model-implied exchange rate definitions that use longer-term interest rates.

$$R^e_{i,t+h+1} \equiv (1 + R^i_{f,t+h})\frac{S_{i,t+h+1}}{S_{i,t+h}} - (1 + R^{\$}_{f,t+h}), \tag{6}$$

*where* $\widetilde{M}_{t+h+1}$ *is the one-period candidate SDF implied by the currency pricing model,* $R^e_{i,t+h+1}$ *is the currency excess return from* $t+h$ *to* $t+h+1$*, and* $R^i_{f,t+h}$ *and* $R^{\$}_{f,t+h}$ *are, respectively, the one-year foreign and U.S. interest rates. Here, the model-implied exchange rate and the conditional* $\alpha$*s are relative to the same* $\widetilde{M}$*, which is assumed to satisfy the mild condition of pricing one-period U.S. interest rates.*

To prove this lemma, use the fact that $\widetilde{M}_{t\to t+h} = \widetilde{M}_{t\to t+h-1}\widetilde{M}_{t+h}$ and $1 + R^i_{f,t\to t+h} = (1 + R^i_{f,t\to t+h-1})(1 + R^i_{f,t+h-1})$ to rewrite the model-implied exchange rate in equation (1) as

$$\begin{aligned} V_{i,t} &= \lim_{h\to\infty} PV_t\{\left(1 + R^i_{f,t\to t+h}\right) S_{i,t+h}\} \\ &= \lim_{h\to\infty} E_t\left[\widetilde{M}_{t\to t+h-1}(1 + R^i_{f,t\to t+h-1})E_{t+h-1}\left[\widetilde{M}_{t+h}(1 + R^i_{f,t+h-1})S_{i,t+h}\right]\right]. \end{aligned} \tag{7}$$

Using the definition of $\alpha$ and excess return in equations (5) and (6) as well as the condition that $E_{t+h-1}\left[\widetilde{M}_{t+h}\right] = 1/(1 + R^{\$}_{f,t+h-1})$, write this as

$$\begin{aligned} V_{i,t} &= \lim_{h\to\infty}\{E_t[\widetilde{M}_{t\to t+h}(1 + R^i_{f,t\to t+h-1})S_{i,t+h-1}\alpha_{i,t+h-1}] \\ &\quad + PV_t\{(1 + R^i_{f,t\to t+h-1})S_{i,t+h-1}\}\}. \end{aligned} \tag{8}$$

Iterating backward and setting $R^i_{t\to t} = 0$ leads to the discounted-$\alpha$ expression in equation (4).

The core insight of Lemma 1 is that the infinite-horizon object in equation (1) can be rewritten as the much more tractable short-horizon object in equation (4). This short-horizon formulation makes estimation far easier for two reasons. First, equation (4) shows that most of the model-implied exchange rate $V_{i,t}$ is simply today's observed spot exchange rate $S_{i,t}$, which does not require estimation. Second, the discounted-$\alpha$ component of $V_{i,t}$ is also likely to be a short-horizon object, because abnormal currency returns relative to a sensible pricing model tend to be short-lived.

Thus, our methodology reframes the estimation of a seemingly elusive infinite-horizon quantity as the estimation of a far more tangible short-horizon component that can be

disciplined by the data.

Suppose a consol paying \$1 perpetually has a constant market price of $P = \$25$ (implying a constant, infinite-horizon risk-free rate in dollars of 4%). Suppose, similarly, that an otherwise equivalent consol denominated in currency $i$ has a price of 20 (implying a risk-free rate of 5%). Further, suppose that the exchange rate is pegged to the dollar at $s$ dollars per unit of local currency and, by assumption, that peg is permanent and riskless. That is, the dollar spot price of the foreign consol is $20s$. But, by standard DCF arguments, its fundamental value (in dollars) is

$$V_0^{DCF} = \frac{s}{1.04} + \frac{s}{1.04^2} + ... = \frac{s}{0.04} = \$25s.$$

To instead apply discounted alpha, note that $\alpha = (0.05 - R_f) \times 20s = 0.2s$. Then,

$$\begin{aligned} V_0 &= 20s + \widetilde{M}_{0\to 1}\,\alpha + \widetilde{M}_{0\to 2}\,\alpha + ... \\ &= s\left(20 + \frac{1}{1.04}0.2 + \frac{1}{1.04^2}0.2 + ...\right) = s\left(20 + \frac{0.2}{0.04}\right) = \$25s. \end{aligned}$$

## 1.3 Currency valuation with currency alphas

Applying the identity in equation (4) directly to value currencies requires specifying multi-horizon discount factors implied by a currency pricing model. Instead, we use an equivalent one-period iteration of the identity, reducing valuation to a one-period problem (Cho, Polk, and Rogers, 2025).

To see this, equation (4) roughly says that model-implied misvaluation at times $t$ and $t+1$ follow, respectively,

$$\begin{aligned} \nu_{i,t} &= \alpha_{i,t} + E_t\left[X_{i,t+1}\alpha_{i,t+1}\right] + ... \\ \nu_{i,t+1} &= \alpha_{i,t+1} + E_{t+1}\left[X_{i,t+2}\alpha_{i,t+2}\right] + ... \end{aligned}$$

where $\nu$ (called "model-implied misvaluation" or simply "undervaluation") is the percentage difference between the model-implied exchange rate and the spot rate, and $X$ represents the discount applied to alphas. Hence, time-$t$ alpha is the duration-adjusted *decay* in misvalua-

tion:

$$\alpha_{i,t} = \nu_{i,t} - E_t \left[ X_{i,t+1} \nu_{i,t+1} \right]. \tag{9}$$

To see why this simplifies valuation, suppose $X_{i,t+1} \approx 1$ and $\phi_{i,t}$ is the time-$t$ misvaluation decay rate. Then, equation (9) becomes

$$\begin{aligned} \alpha_{i,t} &= (1 - \phi_{i,t}) \times \nu_{i,t} \\ \implies \nu_{i,t} &= \frac{1}{1 - \phi_{i,t}} \alpha_{i,t}, \end{aligned}$$

allowing us to back out the "stock" of misvaluation at $t$ from the "flow" of one-period alpha at $t$. Adjusting the spot rate by estimated misvaluation ($\hat{\nu}$) allows us to estimate model-implied exchange rate in equation (1). In reality, $\phi_{i,t}$ is not observed and $X$ is not fixed, but we can model them using currency characteristics.

To estimate model-implied exchange rate for individual currencies, we model currency misvaluation as a function of currency characteristics $z$:

$$\nu_{i,t} = \gamma_V z_{i,t} + u_{i,t}. \tag{10}$$

Then, equation (9) says that time-$t$ alpha is the mapping from characteristics to misvaluation ($\gamma_V$) times the duration-adjusted decay in *characteristics*:

$$\underbrace{\alpha_{i,t}}_{\text{(i) alpha}} = \gamma_V \underbrace{\left( z_{i,t} - E_t \left[ X_{i,t+1} z_{i,t+1} \right] \right)}_{\text{(ii) duration-adj characteristic decay}} + u_{i,t}, \tag{11}$$

where both (i) and (ii) can be estimated for each currency and time: (i) can be estimated by harnessing the extensive research on currency alphas, while (ii) can be estimated based on how currency characteristics decay in the data. We then simply regress (i) on (ii) in a currency-time panel to estimate $\gamma_V$, the mapping from characteristics to currency misvaluation. Finally, the model-implied exchange rate is simply $1 + \hat{\gamma}_V$ times the spot exchange rate:

$$\hat{V}_{i,t} = (1 + \hat{\gamma}_V z_{i,t}) S_{i,t}. \tag{12}$$

Appendix A uses simple asset-pricing algebra to show that the correct approximate expression for equation (11) upon specifying linear processes for excess returns, characteristic evolution, and their conditional covariance is

$$\underbrace{\frac{\alpha_{i,t}}{1+R^{\$}_{f,t}}}_{\text{(i) alpha}} = \quad \gamma_V \quad \underbrace{(I-\phi_z-\frac{\Gamma_{R,z}}{1+R^{\$}_{f,t}})z_{i,t}}_{\text{(ii) duration-adj characteristic decay}} \quad + \tilde{u}_{i,t}, \tag{13}$$

where $\widetilde{u}_{i,t}$ is an error term, and the quantities $\alpha_{i,t}$, $\phi_z$, and $\Gamma_{R,z}$ can be estimated with linear panel regressions that, in the spirit of Fama and MacBeth (1973) and Shanken (1990), specify the intercepts and factor exposures to depend on currency characteristics:

$$\begin{aligned} R^{e}_{i,t+1} &= \alpha_{i,t} + \beta_{R,i,t} f_{t+1} + \epsilon_{R,i,t+1}, & (14)\\ z_{i,t+1} &= \phi_z\, z_{i,t} + \beta_{z,i,t} f_{t+1} + \epsilon_{z,i,t+1}, & (15)\\ \epsilon_{R,i,t+1}\epsilon_{z,i,t+1} &= \Gamma_{R,z} z_{i,t} + \epsilon_{\sigma,i,t+1} & (16) \end{aligned}$$

with

$$\begin{aligned} \alpha_{i,t} &= \gamma_R\, z_{i,t}, & \beta'_{R,i,t} &= \Gamma_R\, z_{i,t}, \\ \beta'_{z,i,t} &= \begin{pmatrix} \beta'_{z,1,i,t} & \dots & \beta'_{z,L,i,t} \end{pmatrix}, & \beta'_{z,l,i,t} &= \Gamma_{z,l}\, z_{i,t}. \end{aligned} \tag{17}$$

To summarize, we estimate $\gamma_V$, the mapping from currency characteristics to model-implied currency misvaluation, in two steps:

1. Estimate equations (14) and (15) by regressing the left-hand side on the intercept, characteristics, and factors interacted with characteristics, as specified in equation (17), in a currency-time panel. Based on the residuals from these regressions, regress $\widehat{\epsilon}_{R,i,t+1}\widehat{\epsilon}_{z,l,i,t+1}$ on $z_{i,t}$ for each characteristic $l = 1, ..., L$ to estimate $\Gamma_{R,z}$ in equation (16).

2. As the second-step panel regression, regress $\hat{\gamma}_R z_{i,t}/(1+R^{\$}_{f,t})$ on time fixed effects and

the $L$-vector of regressors,

$$\left[ I - \hat{\phi}_z - \frac{1}{1 + R^{\$}_{f,t}} \hat{\Gamma}_{R,z} \right] z_{i,t}, \tag{18}$$

to estimate $\gamma_V$, where $\hat{\gamma}_R$, $\hat{\phi}_z$, and $\hat{\Gamma}_{R,z}$ are from the first step. Use the resulting $\hat{\gamma}_V$ to obtain the model-implied exchange rate in equation (1).

We use one year as the interval of time between $t$ and $t+1$ in equations (14), (15), and (16) but estimate all regressions using overlapping monthly observations.[3] We provide bootstrap $t$-statistics and confidence intervals that correct for cross-sectional and time-series correlation in the residuals as well as the two-stage nature of our estimation approach.

# 2 Data and Variables

Our empirical analysis combines exchange rates, interest rates, equity market returns, macroeconomic variables, and standardized currency risk factors to construct a panel of currency excess returns and characteristics consistent with the valuation framework developed in Section 1.

## 2.1 Currencies and sample period

Let $S_{i,t}$ denote the nominal spot exchange rate, expressed as U.S. dollars per unit of foreign currency $i$ at time $t$. The U.S. dollar is treated as the domestic currency throughout. Our baseline sample consists of the G10 currencies: the United Kingdom, Switzerland, the euro area,[4] Japan, Canada, Australia, New Zealand, Denmark, Norway, and Sweden. Section 4 extends the analysis to the Chinese yuan.

The sample spans January 1983 through June 2024 at a monthly frequency. The start-

[3] There is some discretion over what time interval one uses as one period ($t$). Monthly is too short to capture how accounting-based characteristics evolve over time, but using a time interval that is too long results in an inaccurate estimation of alpha, since over such a long period, a significant part of the return comes from dividends that are paid out at different points in time. We measure one period to be a year and use annual data to estimate the first- and second-stage coefficients. Two-year or three-year intervals could also be reasonable alternatives if one wants to capture longer-horizon dynamics of characteristics.

[4] We use Germany as a proxy for the euro area prior to the introduction of the euro.

ing date is determined by the availability of lagged data required to construct the value characteristic and aligns the empirical design with recent work in the currency asset pricing literature (see, e.g., Liu et al. (2025), among others). Spot exchange rates, one-month and twelve-months deposit rates, consumer price indices, and equity index returns are obtained from Refinitiv Datastream. Aggregate equity returns are computed using the prices of MSCI country indices and the MSCI World Index. Currency factor returns are taken from the database of Della Corte and Riddiough (2025)[5].

## 2.2 Currency returns

Let $R^i_{f,t}$ denote the gross one-period foreign risk-free return between $t$ and $t+1$, and let $R^{\$}_{f,t}$ denote the corresponding U.S. risk-free return. Currency excess returns follow standard international asset pricing conventions and are defined as

$$R^e_{i,t+1} = \left(1 + R^i_{f,t}\right) \frac{S_{i,t+1}}{S_{i,t}} - (1 + R^{\$}_{f,t}),$$

which corresponds to borrowing in U.S. dollars, investing in the foreign risk-free asset, and converting proceeds back into dollars at the subsequent period.

All returns are observed at the monthly frequency but mapped into annual horizons using overlapping observations, consistent with the estimation of currency alphas and characteristic dynamics described in Section 1.

## 2.3 Risk factors

Asset pricing tests employ five traded risk factors spanning global equity and currency markets. The five factors we consider throughout are:

(i) Market: Dollar-denominated excess return on the MSCI World stock index,

(ii) Dollar: Equal-weighted excess return on a portfolio of all G10 currencies,

(iii) Carry: Equal-weighted excess return on a long-short quintile portfolio of G10 currencies, sorted on one-month interest rate differentials vis-à-vis the dollar,

[5] https://www.currencyfactors.com/currency-data

(iv) Value: Equal-weighted excess return on a long-short quintile portfolio of G10 currencies sorted by the 5-year change in the real exchange rate,

(v) Momentum: Equal-weighted excess return on a long-short quintile portfolio of G10 currencies sorted by the trailing 12-month return.

These factors are used to estimate a sequence of nested pricing models that progressively incorporate global equity risk and currency risk components. From these five factors, we construct five factor models: (i) Market ("Mkt"), (ii) Market + Value ("Mkt+Val"), (iii) Dollar + Carry ("Dol+Car"), (iv) Market + Value + Dollar + Carry ("4-Factor"), (v) Market + Value + Dollar + Carry + Momentum ("5-Factor").

## 2.4 Currency characteristics

We consider several characteristics for the vector $z_{i,t}$ used to explain time-varying alphas and model-implied currency misvaluation, as outlined in Section 1. The first characteristic is the 1-month interest rate differential,

$$z_{i,t}^{\text{carry}} = R_{f,t}^{i} - R_{f,t}^{\$},$$

which is used to sort currencies for the carry factor and, empirically, also captures a currency's exposure to that factor.

Momentum characteristics are constructed from cumulative exchange-rate returns measured over the previous twelve and three months, respectively. The value characteristic is measured using the real exchange rate, defined as

$$Q_{i,t} = S_{i,t} \times P_{i,t}^{*}/P_t,$$

where $P_t$ and $P_{i,t}^{*}$ denote domestic and foreign price levels derived from consumer price indices. The value characteristic equals the negative five-year change in the real exchange rate, meaning currencies with relatively low real exchange rates receive higher scores.

We additionally include exposure-based characteristics obtained from rolling time-series regressions of currency excess returns on traded risk factors. The resulting coefficients define

the conditional market beta and dollar beta. Macroeconomic conditions are captured by the monthly inflation rate computed as the change in CPI.

Higher-moment risk characteristics are constructed using daily exchange rate data within each month. Realized volatility equals the square root of the sum of squared daily returns, while realized skewness corresponds to the standardized third central moment of daily returns.

We use annual horizons for returns and alphas from overlapping monthly samples, and our baseline estimation is based on five characteristics: carry, value, 12-month momentum, market beta, and dollar beta. In an augmented specification, we further use inflation, volatility, skewness, and 3-month momentum. We note, however, that these additional characteristics do not significantly predict alphas relative to any of the models under consideration, nor do they meaningfully predict the baseline characteristics (see $R^2$ in Table B.1 compared to Table 2).

All characteristics are standardized cross-sectionally each month prior to estimation, ensuring comparability across currencies and consistency with the panel valuation regressions. This reduces noise in the estimation procedure and implies that the resulting misvaluation measures should be interpreted as cross-sectional objects. That is, by construction, the misvaluation of the dollar against the average G10 currency is zero in every month. This is consistent with the focus of Section 3 on cross-sectional characteristic-sorted portfolios. In Section 4, we instead study the time series of misvaluation for individual currencies, including the Chinese yuan, the Canadian dollar, the euro, and the Swiss franc, each against the dollar. This implies that we measure their respective misvaluation against the dollar relative to that of the average G10 currency.

# 3 Model-Implied Exchange Rates

In this section, we assess the model fit of different risk models for exchange rate levels. We first compare misvaluation across models (Section 3.1), before we discuss the empirical determinants of misvaluation (Section 3.2). We then turn to return predictability by misvaluations across models and horizons (Section 3.3). Lastly, we assess the nexus between

misvaluation in carry trade currencies and carry trade crash risk (Section 3.4).

## 3.1 Fundamental exchange rates and misvaluation

How well do different risk models price observed exchange rates? In this section, we compute model-implied exchange rates for five different factor models, and compare them to market exchange rates. As a first exercise, we compute the average absolute misvaluation, that is the monthly deviation of the respective model-implied exchange rate from the observed market exchange rate. Table 1 reports the results. The Mkt+Val model has the smallest misvaluations, with an average misvaluation of 5.7%. The Dol+Car model has the largest, with an average of 9.7%.

The strong performance of the Mkt+Val is consistent with results in Kremens, Martin, and Varela (2025). They find that the real exchange rate—the value characteristic—and the quanto-implied risk premium—a variable closely related to a currency's equity-market beta (Kremens and Martin (2019))—combine to form a successful bivariate forecasting model of long-horizon currency returns. They also find that these two variables explain around half of the variation in long-horizon currency return expectations articulated by professional forecasters. The relatively strong performance of the Mkt factor on its own is further reminiscent of findings by Chernov, Dahlquist, and Lochstoer (2023) that the best single-factor that prices monthly currency returns correlates with consumption risk.

The relatively poor performance of Dol+Car in misvaluations is a surprise relative to short-horizon abnormal returns, where this model has been shown to do well (Lustig, Roussanov, and Verdelhan (2011); Liu et al. (2025)). However, as outlined in Section 1, a close fit in short-horizon returns does not necessarily translate into a close fit for longer-horizon objects like prices.

The 4-Factor model lowers average monthly misvaluation relative to Dol+Car but not relative to Mkt and Mkt+Val. That is, the market and value factors improve pricing in price levels relative to dollar and carry, but not vice versa. Further adding momentum provides no marginal benefit.

Reconciling this with familiar results from short-horizon returns, Panel B of Table 1 shows

that, indeed, the Dol+Car model outperforms the Mkt model in monthly alphas. It does not, however, outperform Mkt+Val. The carry characteristic does significant alphas relative to models that don't include the carry factor but, similarly, the value characteristic predicts significant alpha relative to Dol+Car. That is, the relative short-horizon performance of Dol+Car and Mkt+Val comes down to the relative importance of the carry and value characteristics. Consequently, the 4-Factor model beats both. Further, at short-horizons, adding momentum *does* help and the 5-Factor model has the smallest average monthly alphas, consistent with the momentum characteristic predicting positive alphas (in the margins of statistical significance) relative to models based on the other four factors.

## 3.2 Misvaluation: alphas, characteristics, and persistence

Figure 1 plots misvaluation at the portfolio level for long-short portfolios sorted on market beta, value, carry, and momentum characteristics. Here, we go long (short) the three currencies with the highest (lowest) characteristic. We omit the 4-Factor model for better readability. The beta-sorted portfolio is consistently undervalued relative to the models that include the carry and dollar factors, and including the 5-Factor model that includes the market factor. On the contrary, the carry-sorted portfolio is consistently undervalued relative to the models that do not include the dollar and carry factors. The value-sorted portfolio, in turn, is priced better by models that include the value factor, but the differences appear smaller and revert more quickly. Lastly, the momentum-sorted portfolio, appears to be priced similarly well on average by all models, with marginally narrower misvaluation for the 5-Factor model that includes momentum. Also, misvaluation in the momentum-sorted portfolio appears the least persistent.

Persistence is the key observation in mapping characteristics to misvaluation and, thus, explain misvaluation in characteristic-sorted portfolios. As a first approximation, misvaluation is the product of the alpha that a given characteristic predicts relative to a given model and the persistence of the characteristic.

As an illustration of which characteristics are associated with undervaluation implied by which models, Panel A of Table 2 projects 12-month alphas on characteristics, Panel B reports the transition matrix of the characteristic VAR, and Table 3 projects model-implied

undervaluation on the characteristics.

Carry, that is, a large interest differential, is associated with 12-month alphas relative to the Mkt and Mkt+Val models (Table 2, Panel A). It is also a relatively persistent characteristic (Panel B), consistent with a large and positive association with undervaluation (Table 3), as well as large and persistent undervaluation for the models in the bottom-left panel of Figure 1. Similarly, market beta predicts alphas relative to Dol+Car, which, given its persistence, leads to undervaluation by that model for the beta sorted portfolio. The same holds for value; the value characteristic is slightly less persistent than market beta but predicts a larger 12-month alpha relative to the Dol+Car model.

But the mapping from characteristics to undervaluation is slightly more subtle than just alpha times characteristic persistence. The dollar beta, for instance, is the most persistent characteristic in the baseline set. It predicts (without statistical significance) positive alphas relative to all five models, the alpha with respect to Dol+Car being the smallest (Table 2, Panel A). Yet, the dollar beta is associated with the largest (and only significant) undervaluation for Dol+Car (Table 3). The resolution to this apparent puzzle lies in the cross-predictions of the characteristic matrix. The dollar beta strongly predicts other characteristics that are associated with Dol+Car alphas, specifically the persistent market beta.

The results in this subsection highlight how factor models that are successful in the short-term can nonetheless fail to price exchange rate levels: First, small alphas missed by such a model compound if they and the characteristics they are associated with are persistent. Second, if factor loadings are time-varying, a given characteristic may predict large alphas at some point in the future even if near-term abnormal returns are unpredictable.

## 3.3 Predicting currency returns

Next, we take our misvaluation measure to return prediction. To preface this exercise, misvaluation is mechanically tied to abnormal returns, as outlined above. However correct specification of abnormal returns does not imply strong predictability in total returns, nor does misspecification imply lack of predictability. On the contrary, a model that misses

an important risk premium will deem currencies that are particularly exposed to that risk premium undervalued, and those currencies will tend to have high subsequent returns as compensation for that exposure. But such a model will also generate large average misvaluations. Predictability results should therefore be viewed in combination with the results on average misvaluations presented in Table 1: a successful measure of true misvaluation will generate relatively small misvaluations *and* predictability of overall returns.

That said, Table 4 reports currency return prediction using our misvaluation measures for the five different models at 3-, 12-, 24-, and 60-month horizons. The goal of this exercise is to provide a sanity check on the misvaluation measures—true misvaluation should be associated with subsequent returns—not to position these measures as novel return predictors detached from the characteristics used to construct them. For all models, we find that undervaluation strongly predicts returns. The coefficients increase with the horizon, indicating that prices—and thus measures of undervaluation—reflect long-term returns.

Predictive power is particularly strong statistically—both in terms of significance and $R^2$—in the cross-section. This is a consequence of our cross-sectional standardization of characteristics in estimating misvaluations, which renders the misvaluation measure an essentially cross-sectional object.

Comparing across models, we note that Mkt+Val generates the largest $R^2$ (both total and cross-sectional) at all horizons, ranging from 0.9% total $R^2$ at 3 months (Panel A, column 3) to 17.8% cross-sectional $R^2$ at 60 months (Panel D, column 4). This is particularly noteworthy given the result in Table 1 that this model generates the smallest misvaluations, on average. This suggests that the success of its associated misvaluation measure in predicting returns is likely less prone to model misspecification than that of other models. In other words, the predicted variation is less likely to reflect systematic and predictably variation in risk premia, and more likely to reflect variation in true abnormal returns—a much harder-to-predict object.

### 3.4 Currency misvaluations and carry trade crashes

Having constructed a measure of misvaluation for each currency, we now turn to the most famous, and notoriously crash-prone, currency portfolio—the carry trade. Our measure lets us address questions such as: is the carry trade more crash prone when valuation levels are stretched, that is, when the long leg is over- and the short leg is undervalued? We construct a prototypical carry portfolio that is long the two highest-interest rate currencies in our sample, AUD and NZD, and short the two lowest-interest rate currencies, JPY and CHF. We then compute the average misvaluation of each leg (equal-weighted) using the Mkt+Val model, and its skewness over the next 3-, 6, and 12 months. Skewness is computed at the portfolio level, that is, for the equal-weighted return, at daily frequency. We then predict skewness using undervaluation.

Table 5 reports the results. The first three columns report results from a pooled time-series regression of both, long and short, portfolios with a portfolio fixed effect. We control for the portfolio-level carry characteristic in all regressions, meaning we test for predictive power of our valuation measure over and above the information in interest differentials. For all horizons, larger undervaluation is associated with more positive skewness, that is, a leg of the carry trade that is cheap relative to its sample mean is more likely to experience sharp currency appreciation and, vice versa, a leg that is expensive is more likely to crash.

Columns 4–6 and 7–9 repeat the analysis separately for the long (AUD+NZD) and short (JPY+CHF) portfolios. Undervaluation positively predicts skewness for all horizons and both legs, meaning both crash risk in investment currencies and appreciation risk in funding currencies contribute to valuation-indicated crash risk in the carry trade. In comparison, interest differentials (the carry characteristic) only significantly predict skewness at short horizons and only for the low-interest currencies.

## 4 Currency Manipulators and Misvaluation

The question of whether exchange rates are mispriced is of central importance for policymakers. In the United States, for example, the U.S. Treasury regularly publishes a monitoring list of trading partners that warrant close attention for potential currency manipulation, relying

on a set of observable criteria such as bilateral trade balances, current account surpluses, and patterns of foreign exchange intervention. While these indicators are informative, they remain indirect proxies for the underlying concept of currency mispricing. More broadly, both policy discussions and the financial press frequently emphasize the difficulty of assessing whether a currency is "too strong" or "too weak," reflecting the absence of a widely accepted empirical measure of exchange rate mispricing.[6] Against this background, this section applies our methodology to four major currencies providing a set of case studies across different economic environments.

The results are presented in Figure 2. While the evidence presented in this section broadly confirms the historical narrative surrounding episodes of currency mispricing, the key contribution of our approach is forward-looking: it delivers a transparent and systematic benchmark that policymakers can use to assess exchange rate mispricing in real time. Recall that our estimation standardizes G10 currency characteristics each period to facilitate the multi-step estimation. Thus, the resulting misvaluation measure should not be viewed as an absolute object but relative to the average G10 currency at a given time.

**Canadian Dollar.** The Canadian dollar provides a useful benchmark case for our analysis. The spot and model-implied exchange rates for the Canadian dollar track each other closely over the entire sample period, indicating little evidence of persistent over- or undervaluation. This pattern is consistent with the characterization of the Canadian dollar in policy discussions, where it is typically viewed as a commodity-linked currency whose fluctuations largely reflect movements in oil prices, terms of trade, and relative macroeconomic conditions. As such, the Canadian dollar serves as a natural benchmark for our methodology, illustrating that, in the absence of strong distortive forces, spot exchange rates remain close to their model-implied counterparts.

**Chinese Yuan.** Ever since China's accession to the World Trade Organization in December 2001, the Chinese government has faced accusations of currency manipulation by trading partners. Our method allows us to speak directly to the question of under- or overvaluation.

We use the best-performing model, Mkt+Val, estimated on the sample of G10 currencies,

[6] See, for example, Reuters, "Euro may be too weak for Germany but too strong for others," 2017.

but applied to Chinese currency characteristics between January 2000 and June 2024. In that sense, the resulting misvaluation measure for the yuan is an out-of-sample object. As before, we standardize characteristics to aid estimation. G10 characteristics are standardized in the full panel and month-by-month, and we similarly standardize the yuan's characteristics relative to the G10 cross-section. That is, we impose that the U.S. dollar is valued fairly against the average G10 currency, but we do not impose an absolute benchmark on the yuan's valuation.

Figure 2 plots the dollar-yuan exchange rate (red) against its model-implied fundamental value (blue, with 95% confidence band). The yuan is firmly pegged to the dollar close to 1-to-8 until early 2005. The subsequent two decades play out in three distinct phases. First, under international pressure, the PBC then slowly adopts a crawling peg that sticks remarkably close to the model-implied value until the start of the Global Financial Crisis.

The second phase is one of substantial undervaluation. While the fundamental value keeps rising throughout and especially towards the end of the Great Recession, the PBC keeps the exchange rate steady close to 1-to-7, and continues to allow only marginal appreciation over the subsequent years. As a result, the yuan becomes significantly undervalued by our measure during the early 2010s, consistent with widespread international debate at the time. Following the taper tantrum and gradual normalization of U.S. monetary policy starting in 2013, the fundamental value and the exchange rate fall, such that undervaluation narrows slightly but remains steady (and in the margins of statistical significance) until the start of the Covid-19 pandemic (when confidence bands widen).

The third phase starts with the hiking cycle in U.S. monetary policy in 2022. The model-implied exchange rate plummets and undervaluation evaporates as Chinese rates remain low. Over the subsequent years, the exchange rate stays close to fundamental value with economically and statistically small *over*valuation by early 2024.

**Euro.** Regarding the euro–dollar exchange rate, our analysis indicates that the spot and model-implied exchange rates track each other closely until 2015–2016. From that point until the onset of the Fed hiking cycle in 2022, our model reveals a substantial and persistent overvaluation of the euro.

During 2017-2019, at a time when the European Central Bank was attempting to stimulate the economy and lift inflation from persistently low levels, the strength of the euro was often perceived as indicative of overvaluation. In particular, the currency's rapid appreciation and elevated real exchange rate were seen as raising concerns about potential side effects, including downward pressure on inflation and a deterioration in export competitiveness, as policymakers worried that a strong euro could complicate efforts to counter deflation and support the recovery.

Our measure further identifies a renewed episode of substantial euro overvaluation against the U.S. dollar in the immediate aftermath of the COVID-19 shock. This episode coincides with the sharp appreciation of the euro in the second half of 2020, which can be attributed not only to broad U.S. dollar weakness driven by aggressive monetary stimulus and abundant global liquidity, but also to euro-specific factors, including improved confidence in the euro area outlook and the policy response to the pandemic. In particular, the agreement on the joint European recovery fund was associated with an immediate appreciation of the euro. While the euro appreciated sharply in spot markets following this announcement, our model-implied exchange rate remains close to its early-2020 levels, indicating a disconnect between observed and model-implied exchange rates and suggesting that the market reaction largely reflects an episode of overvaluation.

**Swiss franc.** Our analysis points to a Swiss franc that is chronically overvalued. Even after the Swiss National Bank abandoned the exchange rate floor in January 2015 and allowed the franc to appreciate sharply, the currency has remained significantly overvalued according to our measure. On the day of the announcement, the franc appreciated by roughly 20% against the euro within minutes, reflecting a sudden repricing of its safe-haven status. This finding is consistent with policy discussions in which it has repeatedly been described by the Swiss National Bank as "significantly overvalued," a view that has guided the sustained use of negative interest rates and foreign exchange intervention.

# 5 Conclusion

By shifting the focus from explaining short-horizon excess returns to the distinct challenge of pricing exchange rate levels, we develop a tractable empirical framework to measure model-implied fundamental values. Our discounted-alpha approach shows that success in pricing returns does not necessarily translate into accurate pricing of levels, and highlights that a parsimonious specification often delivers the most precise long-run valuation estimates.

From a policy perspective, the framework provides a transparent and systematic benchmark to assess exchange rate misvaluation in real time, reducing reliance on indirect proxies such as bilateral trade balances or foreign exchange intervention. Our empirical results illustrate how the approach can identify episodes in which observed exchange rates diverge from model-implied values, as in the case of the Chinese yuan, the euro, and the Swiss franc.

While our analysis focuses on the cross-section of major currencies, the methodology can be extended more broadly to other assets whose valuation can be expressed in terms of expected abnormal returns, including reserve assets such as gold and silver. This suggests a natural avenue for future research in applying discounted-alpha valuation across asset classes.

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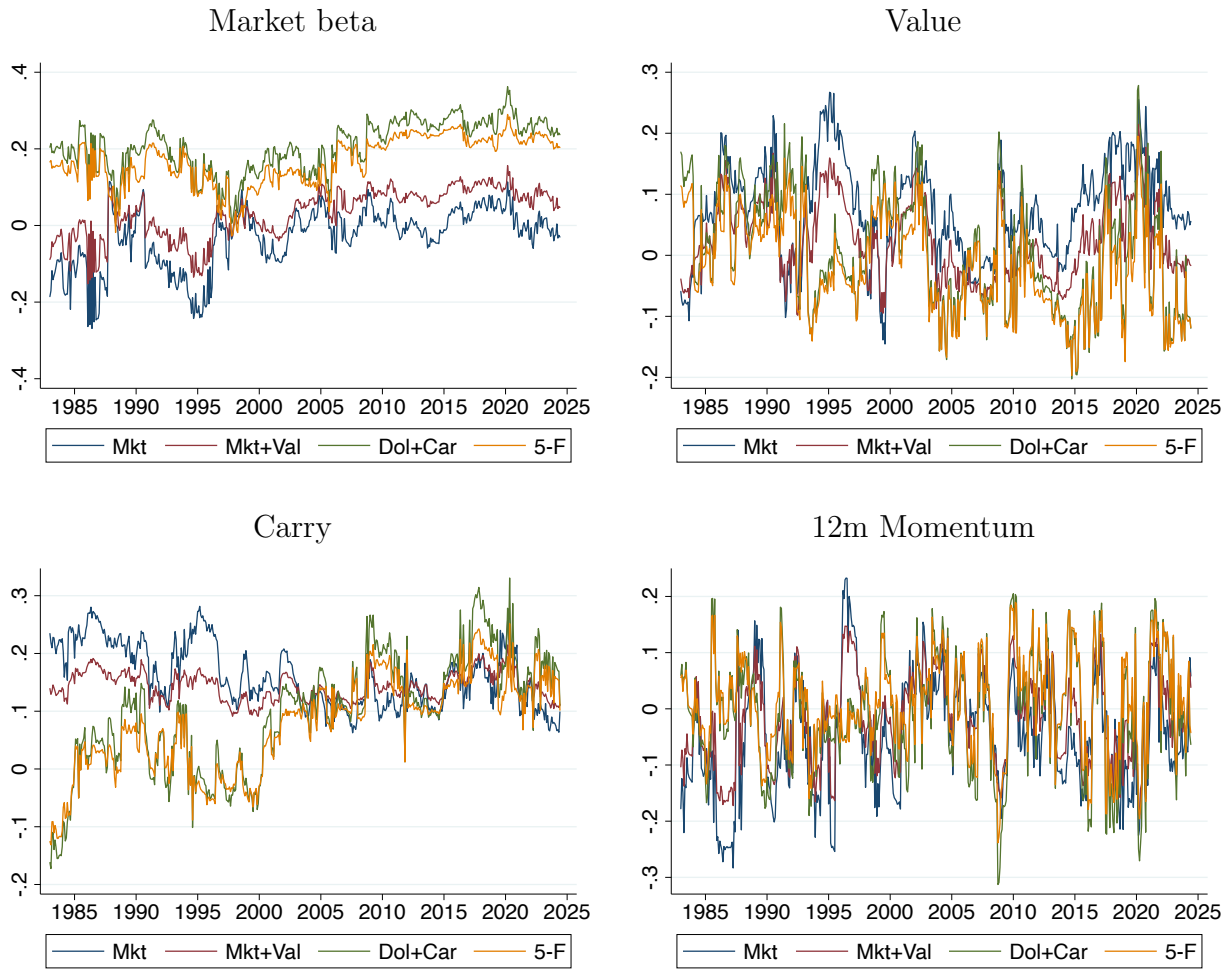



Figure 1: **Misvaluation in Long-Short Portfolios, by Factor Model**

We plot estimated misvaluation of the long-short characteristic portfolio that goes long the highest characteristic tercile and short the lowest tercile characteristic currencies. Positive misvaluation indicates that the portfolio is undervalued. This is based on the 5-characteristic model of misvaluation. The sample period is 1983m1–2024m6.

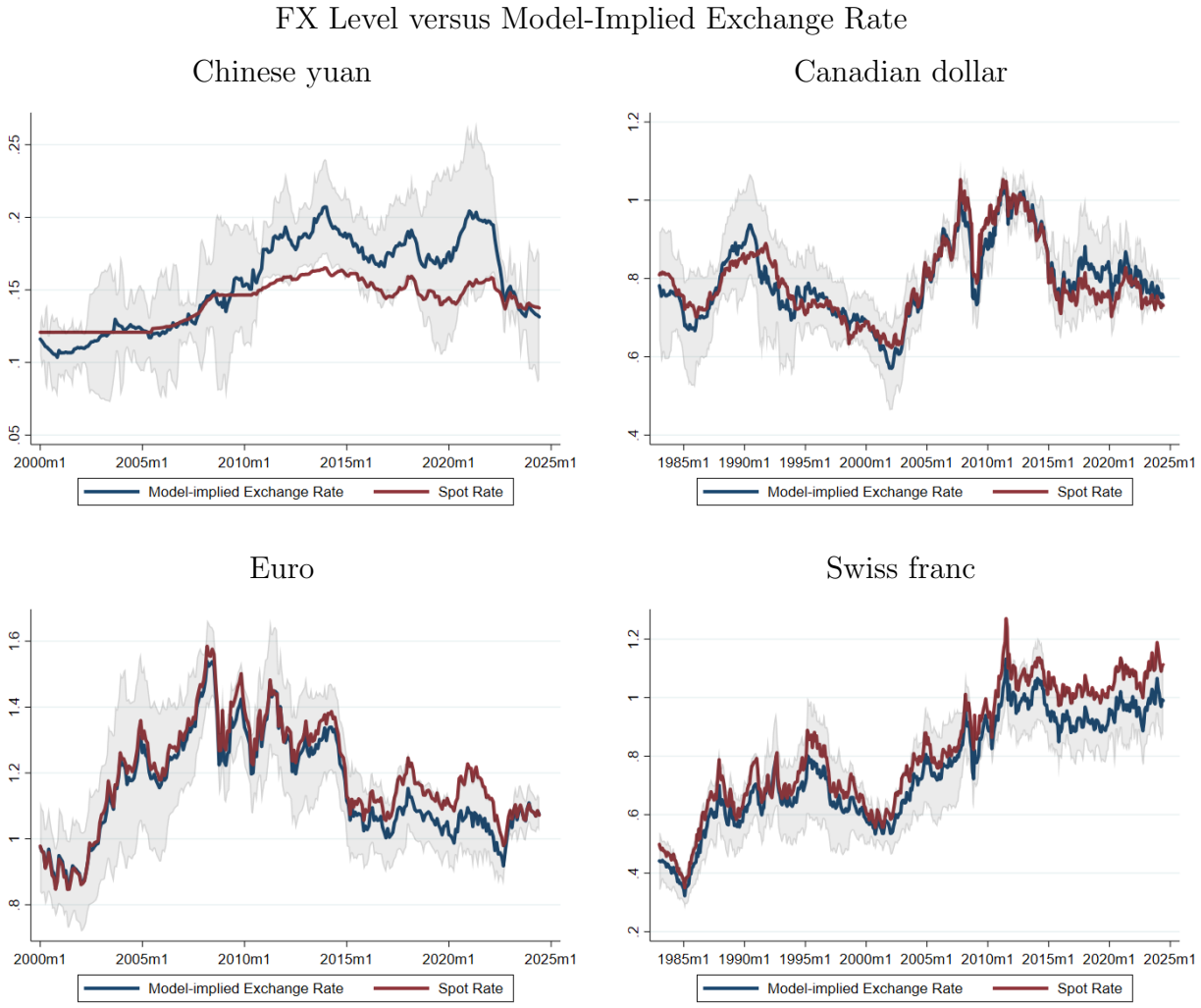



Figure 2: **Undervaluation Episodes in the Yuan and other major currencies**

We plot estimated model-implied exchange rate versus the spot rate for the Chinese yuan, Canadian dollar, euro, and Swiss franc. The estimation is based on the Market + Value model estimated on G10 currencies and applied to the respective characteristics, standardized cross-sectionally against the set of G10 currencies. It is based on the 5-characteristic model of misvaluation.

Table 1: **Average Absolute Currency Pricing Errors** ($\frac{1}{NT}\sum_{i,t}|\hat{\gamma}_x z_{i,t}|$)

The estimation applies discounted-alpha valuation to estimate currency-level model-implied misvaluation, defined as the percentage gap between the spot and a infinite-horizon model-implied exchange rate. The results are based on in-sample estimates for ten developed-market currencies from 1983m1 to 2024m6. Panel B reports average (annualized) 1-month alphas relative to the same models. Panel C regresses these annualized alphas on the characteristics and reports bootstrapped t-statistics in parentheses.

Panel A. Currency Misvaluation ($\frac{1}{NT}\sum_{i,t}|\hat{\gamma}_V z_{i,t}|$)

| Market | Mkt+Val | Dol+Car | 4-Factor | 5-Factor |
|---|---|---|---|---|
| 0.074 | 0.057 | 0.097 | 0.083 | 0.083 |

Panel B. Currency 1-month Alpha ($\frac{1}{NT}\sum_{i,t}|\hat{\gamma}_{1m} z_{i,t}|$)

| Market | Mkt+Val | Dol+Car | 4-Factor | 5-Factor |
|---|---|---|---|---|
| 0.0200 | 0.0162 | 0.0171 | 0.0159 | 0.0141 |

Panel C. Projection Coefficients for Currency 1-month Alpha ($\hat{\gamma}_{1m}$)

| Predictor | Market | Mkt+Val | Dol+Car | 4-Factor | 5-Factor |
|---|---|---|---|---|---|
| Carry | 1.65 | 1.16 | 0.60 | 0.66 | 0.75 |
| | (2.99) | (1.99) | (1.09) | (1.24) | (1.55) |
| Value | 1.53 | 0.61 | 0.98 | 0.55 | 0.44 |
| | (1.75) | (0.67) | (2.43) | (1.44) | (1.18) |
| Momentum | 1.85 | 1.77 | 2.23 | 2.02 | 1.72 |
| | (1.64) | (1.57) | (1.97) | (1.81) | (1.56) |
| Market Beta | 0.09 | -0.13 | 0.01 | -0.19 | -0.30 |
| | (0.13) | (-0.21) | (0.01) | (-0.27) | (-0.46) |
| Dollar Beta | -0.67 | -0.46 | -0.13 | -0.08 | 0.01 |
| | (-0.85) | (-0.59) | (-0.20) | (-0.12) | (0.02) |

Table 2: **1-Year Alpha Regression and Transition Matrix in the 1st Stage**

Panel A of this table reports regressions of model-implied misvaluations on currency characteristics for different models, with bootstrapped t-statistics in parentheses. Panel B reports the VAR transition matrix for the first-order characteristics VAR (after absorbing currency-specific factor exposures). The results are based on in-sample estimates for G10 currencies from 1983m1 to 2024m6. We report the baseline specification based on 12-month returns and factors.

Panel A. Multivariate 12-month Alpha Coefficients ($\gamma_R$)

| Predictor | Mkt | Mkt+Val | Dol+Car | 4-Factor | 5-Factor |
|---|---|---|---|---|---|
| Carry | 1.64 | 1.15 | -0.32 | -0.01 | 0.03 |
| | (3.26) | (2.01) | (-1.07) | (-0.08) | (0.12) |
| Value | 1.66 | 0.56 | 1.43 | 0.54 | 0.33 |
| | (1.96) | (0.68) | (3.42) | (1.42) | (0.80) |
| Momentum | -0.24 | -0.11 | 0.18 | 0.25 | 0.05 |
| | (-0.78) | (-0.47) | (0.44) | (0.68) | (0.14) |
| Mkt beta | -0.28 | -0.52 | 0.83 | -0.28 | -0.36 |
| | (-0.45) | (-0.75) | (2.41) | (-0.78) | (-1.08) |
| Dol beta | 0.70 | 0.78 | 0.47 | 0.94 | 0.92 |
| | (1.26) | (1.08) | (1.30) | (2.06) | (2.08) |

Panel B. Transition Matrix ($\phi_z$, net of Mkt+Val exposure)

| | $z_t$ | | | | | |
|---|---|---|---|---|---|---|
| $z_{t+1}$ | Carry | Value | Momentum | Mkt Beta | Dol Beta | $R^2$ |
| Carry | 0.88 | 0.02 | 0.01 | 0.03 | -0.05 | 0.79 |
| | (25.37) | (0.73) | (0.35) | (1.36) | (-1.48) | |
| Value | -0.01 | 0.60 | -0.12 | 0.01 | -0.06 | 0.44 |
| | (-0.17) | (14.86) | (-2.07) | (0.22) | (-1.05) | |
| Momentum | -0.10 | -0.01 | -0.02 | -0.06 | 0.17 | 0.20 |
| | (-2.02) | (-0.11) | (-0.23) | (-1.12) | (3.08) | |
| Market Beta | 0.07 | -0.01 | 0.02 | 0.71 | 0.17 | 0.73 |
| | (1.50) | (-0.24) | (0.78) | (13.70) | (3.35) | |
| Dollar Beta | 0.05 | -0.02 | -0.04 | -0.01 | 0.96 | 0.92 |
| | (2.60) | (-1.19) | (-2.10) | (-0.24) | (37.44) | |

Table 3: **Determinants of Misvaluation** ($\hat{\gamma}_V$, in %)

The table applies discounted-alpha valuation to estimate currency-level model-implied misvaluation as a projection on currency-level characteristics. The reported coefficients in percentage represent what the one-standard-deviation increase in the cross-sectional standardized rank of the characteristic predicts about the percentage of model-implied undervaluation. The results are based on in-sample estimates based on G10 currencies. The factor models are as follows: market; market + value; dollar + carry; mkt + dollar + carry + value (4-factor); mkt + dollar + carry + value + 12-month momentum (5-factor). The sample period is 1983m1–2024m6. We report the baseline specification based on 12-month returns and factors, with t-statistics in parentheses.

| Predictor | Mkt | | Mkt+Val | | Dol+Car | | 4-Factor | | 5-Factor | |
|---|---|---|---|---|---|---|---|---|---|---|
| Carry | 11.48 | 10.22 | 9.38 | 8.49 | 3.28 | 2.67 | 4.88 | 4.87 | 4.45 | 5.02 |
| | (3.04) | (3.05) | (2.36) | (2.34) | (1.05) | (0.91) | (1.51) | (1.72) | (1.48) | (1.71) |
| Value | 4.32 | 4.36 | 1.94 | 2.20 | 2.76 | 2.57 | 1.35 | 1.54 | 0.94 | 1.38 |
| | (2.47) | (2.50) | (0.93) | (1.00) | (3.16) | (3.22) | (1.22) | (1.49) | (0.89) | (1.33) |
| Momentum | -0.70 | -0.73 | -0.30 | -0.41 | -0.47 | -0.57 | -0.12 | -0.17 | -0.21 | -0.23 |
| | (-1.80) | (-1.67) | (-0.68) | (-0.83) | (-1.69) | (-1.78) | (-0.38) | (-0.50) | (-0.61) | (-0.65) |
| Market Beta | 0.22 | -0.38 | -0.37 | -1.04 | 3.99 | 3.91 | -0.05 | -0.04 | -0.27 | -0.12 |
| | (0.09) | (-0.18) | (-0.20) | (-0.54) | (1.95) | (1.95) | (-0.03) | (-0.03) | (-0.15) | (-0.08) |
| Dollar Beta | -0.11 | 0.20 | 0.23 | 0.89 | 10.96 | 9.53 | 9.03 | 7.65 | 8.31 | 7.57 |
| | (-0.01) | (0.02) | (0.03) | (0.12) | (2.01) | (1.84) | (1.20) | (1.19) | (1.06) | (1.06) |
| Inflation | | 2.60 | | 2.39 | | 0.66 | | 0.86 | | 0.92 |
| | | (1.75) | | (1.55) | | (1.03) | | (1.16) | | (1.20) |
| Volatility | | 0.54 | | 0.38 | | 0.98 | | 0.74 | | 0.59 |
| | | (0.64) | | (0.49) | | (2.15) | | (1.49) | | (1.31) |
| 3m Momentum | | -0.08 | | -0.05 | | 0.17 | | -0.01 | | -0.00 |
| | | (-0.18) | | (-0.10) | | (0.69) | | (-0.02) | | (-0.01) |
| Skewness | | -0.08 | | 0.01 | | -0.04 | | 0.02 | | 0.00 |
| | | (-0.22) | | (0.04) | | (-0.18) | | (0.12) | | (0.01) |

Table 4: **Predictive Regressions for 3-, 12-, 24- and 60-month Excess FX Returns**

The table regresses the times series of 3-, 12-, 24- and 60-month G10 currency excess returns on in-sample estimated undervaluation measure ($\nu_{i,t}$). We include specifications without and with time fixed effects and use $\nu_{i,t}$ estimated relative to the following models: Market, Market+Value, Dollar+Carry, and 5-factor (Market+Value+Dollar+Carry+Momentum). Estimated $\nu_{i,t}$ is based on in-sample estimates for G10 currencies from 1983m1 to 2024m6. We report Hansen-Hodrick t-statistics in parentheses to account for overlapping observations.

| | Mkt | | Mkt+Val | | Dol+Car | | 5-Factor | |
|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
| | Panel A: 3-month returns | | | | | | | |
| $\nu_{i,t}$ | 0.049 | 0.047 | 0.074 | 0.072 | 0.029 | 0.028 | 0.029 | 0.028 |
| | (3.236) | (4.721) | (3.709) | (5.475) | (2.377) | (3.487) | (2.008) | (2.965) |
| N | 4883 | 4883 | 4883 | 4883 | 4883 | 4883 | 4883 | 4883 |
| Within R2 | 0.007 | 0.013 | 0.009 | 0.018 | 0.004 | 0.007 | 0.003 | 0.005 |
| | Panel B: 12-month returns | | | | | | | |
| $\nu_{i,t}$ | 0.192 | 0.183 | 0.286 | 0.273 | 0.141 | 0.135 | 0.137 | 0.131 |
| | (2.990) | (4.756) | (3.364) | (5.456) | (2.675) | (4.302) | (2.192) | (3.526) |
| N | 4757 | 4757 | 4757 | 4757 | 4757 | 4757 | 4757 | 4757 |
| Within R2 | 0.021 | 0.054 | 0.027 | 0.069 | 0.017 | 0.045 | 0.012 | 0.031 |
| | Panel C: 24-month returns | | | | | | | |
| $\nu_{i,t}$ | 0.304 | 0.300 | 0.475 | 0.465 | 0.268 | 0.256 | 0.265 | 0.252 |
| | (2.430) | (4.221) | (2.872) | (5.097) | (2.604) | (4.421) | (2.156) | (3.633) |
| N | 4637 | 4637 | 4637 | 4637 | 4637 | 4637 | 4637 | 4637 |
| Within R2 | 0.025 | 0.074 | 0.034 | 0.101 | 0.029 | 0.082 | 0.020 | 0.057 |
| | Panel D: 60-month returns | | | | | | | |
| $\nu_{i,t}$ | 0.514 | 0.551 | 0.891 | 0.918 | 0.491 | 0.469 | 0.502 | 0.476 |
| | (1.929) | (3.880) | (2.567) | (5.509) | (2.194) | (3.875) | (1.871) | (3.263) |
| N | 4277 | 4277 | 4277 | 4277 | 4277 | 4277 | 4277 | 4277 |
| Within R2 | 0.031 | 0.115 | 0.051 | 0.178 | 0.041 | 0.122 | 0.031 | 0.092 |
| Time FE | No | Yes | No | Yes | No | Yes | No | Yes |

Table 5: **Predicting Skewness for Carry Portfolios**

The table regresses the average of 3-, 6-, and 12-month daily return skewness on in-sample estimated misvaluation ($\nu_{i,t}$) and portfolio-level carry characteristic (interest differentials) for the standard long (AUD + NZD) and short (CHF + JPY) legs of the carry trade. Columns 1–3 report pooled regressions of both carry legs with leg fixed effects, columns 4–6 and 7–9 report time-series regressions of the long and, respectively, short leg. Estimated $\nu_{i,t}$ is based on in-sample estimates of the Mkt+Value model for G10 currencies from 1983m1 to 2024m6. We report Hansen-Hodrick t-statistics in parentheses to account for overlapping observations in multi-period forecasts.

| Portfolio | Pooled | | | Long | | | Short | | |
|---|---|---|---|---|---|---|---|---|---|
| Horizon | 3m | 6m | 12m | 3m | 6m | 12m | 3m | 6m | 12m |
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| $\nu_{i,t}$ | 5.575 | 8.726 | 13.104 | 7.333 | 12.497 | 16.661 | 4.160 | 5.913 | 10.551 |
| | (2.755) | (2.642) | (2.321) | (2.062) | (2.048) | (1.551) | (1.880) | (1.843) | (2.188) |
| Carry | -0.276 | -0.379 | -0.639 | -0.314 | -0.521 | -0.800 | -0.466 | -0.543 | -0.682 |
| | (-1.950) | (-1.634) | (-1.582) | (-1.374) | (-1.323) | (-1.139) | (-2.341) | (-1.866) | (-1.529) |
| N | 994 | 994 | 994 | 497 | 497 | 497 | 497 | 497 | 497 |
| Within R2 | 0.021 | 0.035 | 0.049 | 0.027 | 0.044 | 0.042 | 0.032 | 0.046 | 0.089 |

# A Derivations

This appendix derives the approximate valuation regression in equation (13) from the one-period discounted-alpha identity in Section 1.3, using the FX notation in the paper ($S$ for the spot exchange rate and $\widetilde{M}$ for the candidate SDF).

## A.1 Derivation of equation (13)

Define model-implied currency undervaluation as

$$\nu_{i,t} \equiv \frac{V_{i,t}}{S_{i,t}} - 1. \tag{19}$$

Also define the one-period *gross* dollar return from holding foreign currency $i$ between $t$ and $t+1$ as

$$1 + R_{i,t+1} \equiv (1 + R^{i}_{f,t})\frac{S_{i,t+1}}{S_{i,t}} = (1 + R^{\$}_{f,t}) + R^{e}_{i,t+1}, \tag{20}$$

where $R^{e}_{i,t+1}$ is the currency excess return in equation (6).

The one-period version of the discounted-alpha identity implies

$$\frac{\alpha_{i,t}}{1 + R^{\$}_{f,t}} = \nu_{i,t} - E_t\left[\widetilde{M}_{t+1}(1 + R_{i,t+1})\,\nu_{i,t+1}\right]. \tag{21}$$

Now project undervaluation on the characteristic vector $z_{i,t}$:

$$\nu_{i,t} = \gamma_V z_{i,t} + u_{i,t}, \qquad \nu_{i,t+1} = \gamma_V z_{i,t+1} + u_{i,t+1}. \tag{22}$$

Substituting (22) into (21) gives

$$\frac{\alpha_{i,t}}{1 + R^{\$}_{f,t}} = \gamma_V z_{i,t} + u_{i,t} - \gamma_V E_t\left[\widetilde{M}_{t+1}(1 + R_{i,t+1})z_{i,t+1}\right] - E_t\left[\widetilde{M}_{t+1}(1 + R_{i,t+1})u_{i,t+1}\right]. \tag{23}$$

**Step 1: Expand the triple product term.** Applying the identity

$$E[XYZ] = E[XY]E[Z] + E[X]Cov(Y,Z) + E[Y]Cov(X,Z) + E[(X-EX)(Y-EY)(Z-EZ)]$$

(componentwise when $Z$ is a vector) with

$$X = \widetilde{M}_{t+1}, \qquad Y = 1 + R_{i,t+1}, \qquad Z = z_{i,t+1},$$

we obtain

$$E_t\Big[\widetilde{M}_{t+1}(1+R_{i,t+1})z_{i,t+1}\Big] = E_t\Big[\widetilde{M}_{t+1}(1+R_{i,t+1})\Big]\,E_t[z_{i,t+1}] + E_t[\widetilde{M}_{t+1}]\,Cov_t(R_{i,t+1}, z_{i,t+1}) + E_t[1+R_{i,t+1}]\,Cov_t(\widetilde{M}_{t+1}, z_{i,t+1}) + \sigma_{\widetilde{M},R,z,i,t}, \tag{24}$$

where

$$\sigma_{\widetilde{M},R,z,i,t} \equiv E_t\Big[\big(\widetilde{M}_{t+1} - E_t\widetilde{M}_{t+1}\big)\big(R_{i,t+1} - E_tR_{i,t+1}\big)\big(z_{i,t+1} - E_tz_{i,t+1}\big)\Big] \tag{25}$$

is the (vector) conditional coskewness term.

Because $R_{i,t+1} = R^{\$}_{f,t} + R^{e}_{i,t+1}$ and $R^{\$}_{f,t}$ is known at time $t$,

$$Cov_t(R_{i,t+1}, z_{i,t+1}) = Cov_t(R^{e}_{i,t+1}, z_{i,t+1}). \tag{26}$$

Also, by Assumption 1 (the candidate SDF prices the one-period U.S. risk-free return),

$$E_t[\widetilde{M}_{t+1}] = \frac{1}{1+R^{\$}_{f,t}}. \tag{27}$$

**Step 2: Use the linear laws of motion in equations (14)–(17).** From equation (15),

$$z_{i,t+1} = \phi_z z_{i,t} + \beta_{z,i,t} f_{t+1} + \epsilon^{z}_{i,t+1}, \tag{28}$$

so the projection error is mean zero conditional on $t$, and hence

$$E_t[z_{i,t+1}] = \phi_z z_{i,t}. \tag{29}$$

From equations (14)–(17), write

$$R^{e}_{i,t+1} = \alpha_{i,t} + \beta_{R,i,t} f_{t+1} + \epsilon^{R}_{i,t+1},$$

and therefore

$$Cov_t(R^e_{i,t+1}, z_{i,t+1}) = \underbrace{Cov_t(\beta_{R,i,t} f_{t+1},\ \beta_{z,i,t} f_{t+1})}_{\Delta^{(2)}_{Rz,i,t}} + \underbrace{Cov_t(\epsilon^R_{i,t+1}, \epsilon^z_{i,t+1})}_{\Gamma_{R,z} z_{i,t}} \tag{30}$$

where the second equality uses equation (16) (interpreted at the conditional-mean level) for the residual covariance term.[7]

Substituting (26)–(30) into (24) gives

$$\begin{aligned} E_t\left[\widetilde{M}_{t+1}(1+R_{i,t+1}) z_{i,t+1}\right] = E_t\left[\widetilde{M}_{t+1}(1+R_{i,t+1})\right] \phi_z z_{i,t} + \frac{1}{1+R^{\$}_{f,t}} \Gamma_{R,z} z_{i,t} + \frac{1}{1+R^{\$}_{f,t}} \Delta^{(2)}_{Rz,i,t} \\ + E_t[1+R_{i,t+1}]\, Cov_t(\widetilde{M}_{t+1}, z_{i,t+1}) + \sigma_{\widetilde{M},R,z,i,t}. \end{aligned} \tag{31}$$

**Step 3: FX approximation for discounting future alphas.** Define the approximation error

$$\delta_{i,t} \equiv E_t\left[\widetilde{M}_{t+1}(1+R_{i,t+1})\right] - 1. \tag{32}$$

In the FX implementation, we approximate $\delta_{i,t} \approx 0$, i.e.,

$$E_t\left[\widetilde{M}_{t+1}(1+R_{i,t+1})\right] \approx 1,$$

for the purpose of discounting future alphas. This is the additional FX approximation relative to the equity derivation, and it is exactly why no extra $\rho$-type term multiplies $\phi_z$ in equation (13).

Substituting (31) into (23) and collecting terms yields

$$\frac{\alpha_{i,t}}{1+R^{\$}_{f,t}} = \gamma_V \left( I - \phi_z - \frac{\Gamma_{R,z}}{1+R^{\$}_{f,t}} \right) z_{i,t} + \widetilde{u}_{i,t}, \tag{33}$$

which is equation (13) in the main text.

[7] Equivalently, equation (16) is the empirical regression used to estimate the predictable component $\Gamma_{R,z} z_{i,t}$ of the residual covariance. Any unpredictable component is absorbed into the error term below.

**Explicit expression for $\widetilde{u}_{i,t}$.** A convenient explicit representation is

$$\widetilde{u}_{i,t} \equiv u_{i,t} - E_t\Big[\widetilde{M}_{t+1}(1+R_{i,t+1})u_{i,t+1}\Big] - \gamma_V \delta_{i,t}\phi_z z_{i,t} - \frac{\gamma_V}{1+R^{\$}_{f,t}}\,\Delta^{(2)}_{Rz,i,t}$$
$$- \gamma_V E_t[1+R_{i,t+1}]\,Cov_t(\widetilde{M}_{t+1}, z_{i,t+1}) - \gamma_V \sigma_{\widetilde{M},R,z,i,t}. \tag{34}$$

Thus, $\widetilde{u}_{i,t}$ contains: (i) the projection error terms $u_{i,t}$ and discounted future $u_{i,t+1}$, (ii) the FX discounting approximation error $\delta_{i,t}\phi_z z_{i,t}$, (iii) omitted second-moment terms (e.g., $\Delta^{(2)}_{Rz,i,t} = \beta_{z,i,t}\big(\Sigma_{f,t} - \lambda_t\lambda_t'\big)\beta'_{R,i,t}$ and $E_t[1+R_{i,t+1}]\,Cov_t(\widetilde{M}_{t+1}, z_{i,t+1})$), and (iv) the third-moment (coskewness) term $\sigma_{\widetilde{M},R,z,i,t}$. In the baseline implementation we absorb these second- and third-moment terms into $\widetilde{u}_{i,t}$.[8]

[8] This is the same logic as in the appendix of Cho, Polk, and Rogers (2025), except that the FX derivation additionally imposes $E_t[\widetilde{M}_{t+1}(1+R_{i,t+1})] \approx 1$, which eliminates the extra multiplicative discount term on $\phi_z$.

# B Supplementary Tables

Table B.1: **Transition Matrix in the 1st Stage (augmented specification)**

The results are based on in-sample estimates for ten developed-market currencies from 1983m1 to 2024m6. We report the baseline specification based on 12-month returns and factors.

Transition Matrix ($\phi_z$, net of Mkt+Val exposure)

| | $z_t$ | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $z_{t+1}$ | Carry | Value | Mom (12m) | Mkt beta | Dol beta | Infl | Vol | Mom (3m) | Skew | $R^2$ |
| Carry | 0.814 | 0.015 | 0.022 | 0.009 | -0.037 | 0.121 | 0.006 | -0.009 | 0.000 | 0.79 |
| Value | -0.010 | 0.590 | -0.113 | 0.013 | -0.073 | -0.012 | 0.063 | -0.014 | -0.017 | 0.44 |
| Mom (12m) | -0.131 | -0.007 | -0.016 | -0.080 | 0.181 | 0.068 | -0.009 | 0.011 | 0.022 | 0.21 |
| Mkt beta | 0.080 | -0.001 | 0.009 | 0.714 | 0.169 | -0.009 | -0.024 | 0.011 | 0.009 | 0.73 |
| Dol beta | 0.051 | -0.020 | -0.041 | -0.001 | 0.952 | -0.015 | 0.010 | 0.009 | -0.004 | 0.92 |
| Infl | 0.328 | 0.096 | -0.059 | 0.062 | -0.029 | 0.317 | -0.005 | -0.049 | -0.012 | 0.40 |
| Vol | 0.105 | -0.032 | -0.073 | -0.013 | 0.081 | -0.028 | 0.412 | -0.019 | -0.014 | 0.21 |
| Mom (3m) | -0.050 | 0.017 | -0.052 | -0.038 | 0.097 | 0.060 | -0.028 | 0.003 | 0.022 | 0.05 |
| Skew | -0.099 | 0.008 | 0.015 | -0.086 | 0.061 | 0.020 | 0.005 | -0.042 | 0.001 | 0.02 |