Beyond Carry: Prospective Interest Rate Differential and Currency Returns

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Following Engel (2011), we model the exchange rate using a present-value relationship, and show that the transitory component of spot exchange rate is the sum of expected foreign currency excess returns and 'prospective interest rate differential' – the infinite sum of expected future interest rate differentials. We construct the prospective interest rate differential using information in the term structure of interest rates via a pricing kernel decomposition approach. We find that the prospective interest rate differential is a stronger predictor of currency excess returns than the conventional carry signal, thus further deepening the forward premium puzzle.

1 Introduction

The uncovered interest parity (UIP) hypothesizes that a high interest rate foreign currency is expected to depreciate by the interest rate differential between the foreign and domestic risk free rates. Numerous empirical studies strongly reject the UIP (Fama (1984), Hodrick and Srivastava (1984)) and find that the expected depreciation rate of a high interest rate currency is at best weakly related to the interest rate differential.[1] Moreover, foreign currency excess returns are known to be predicted by interest rate differentials (Burnside (2011), Bekaert and Hodrick (1992), and Verdelhan (2010)), and higher interest rate currencies usually appreciate, generating a profitable trading strategy (the so-called 'carry trade'). Diversification further boosts the risk return trade-off of such currency speculations (Burnside, Rebelo, and Eichenbaum 2008). All the evidence suggests that there is a significant expected excess return in the foreign exchange market.

In this paper, we follow Engel (2011) to decompose the exchange rate into permanent and transitory components, and propose a new currency market return predictor, '*prospective* interest rate differential'. The ' *prospective* interest rate differential' is defined as the sum of all expected future foreign and domestic interest rate differentials. When the sum of expected future foreign interest rate is higher than that of the domestic interest rate, it signals that either the expected currency return is high or the foreign currency is temporarily overvalued and expected to depreciate in the future. This reasoning relates the present value of all future interest rate differentials to the expected currency return and depreciation rate and motivates our use of the 'prospective interest rate differential' to predict currency excess returns.

Empirically, we model the prospective interest rate by separately estimating the infinite sum of expected future foreign short rates and domestic short rates. Different from the carry trade, which focuses on the current interest rate differential, our framework exploits the asymmetry in persistence and of the foreign and domestic short rates. Similar to van Binsbergen and Koijen (2010) and Lacerda and Santa-Clara (2011), which both utilize the estimate of state variables to better predict stock returns, in our setup the contributions of the foreign and domestic short rates depend on the relative persistence of these variables. All else equal, a more persistent short rate

[1] For a complete survey, see Engel (1996).

process contributes more to the multiple period differential.

Interest rates have been shown to exhibit I(1) behavior (see Campbell and Shiller (1991) and Mishkin (1992)), this near nonstationarity makes it difficult to empirically estimate the persistence of short rates. In addition, if we estimate a simple auto-regression of short rates, it is likely that we will suffer the well-known "Hurwicz bias" that occurs when the sample size is small. This issue constitutes another difficulty: that our point estimates will be severely downward biased in the early sample period, thereby contaminating the return predictability results. We overcome these two difficulties with the following empirical approach.

We start from the no-arbitrage relationship that the rate of depreciation between two currencies capture the difference between the pricing kernels in the two countries. Following Ang and Chen (2010), who find that term structures of interest rates between countries contain useful information on currency market returns, we use a parsimonious model to decompose the pricing kernel to price government bonds. In the model, the dynamics of the short rate and bond returns contain the same persistence parameter, thereby allowing us to exploit the panel of bond returns in addition to short rates to estimate the degree of the latter's persistence in respective countries.[2] We observe a lot of cross-country difference in the degree of persistence, which contributes asymmetrically to the future cross-country interest rate differentials. Therefore, measuring the dynamics of short rate provides us with additional information about expected currency returns and exchange rate movements.

To demonstrate the forecasting power of our new predictor, we long (short) currencies when the sum of expected future interest rates is higher (lower) than the domestic counterpart. We explore several alternative portfolio constructions. First, the equally weighted portfolio based on our new predictor achieves a 43% higher Sharpe ratio than that of the equally-weighted carry portfolio.

[2]Following Alvarez and Jermann (2005) and Bakshi and Chabi-Yo (2012), we decompose the pricing kernel into the permanent and transitory components. Under this decomposition, the temporary component follows an exogenous autocorrelated time-series process, which simultaneously determines the dynamics of short rate, as well as the cross-section of long-term government bond returns. A salient feature of the model is that the temporary component of the pricing kernel and the term structure of interest rates share the same persistence parameter, which can be subsequently recovered using a Kalman filter by matching the cross-section of government bonds returns. To avoid the look-ahead bias and facilitate a fair comparison with other strategies, we estimate our model every month, using information available up to that month only. We then compute the infinite sum of expected future interest rate differentials using different countries' estimated persistence parameters.

More significantly, the carry portfolio displays a big negative skewness while our portfolio skewness is positive. This suggests that our portfolio is less exposed to currency crashes (Brunnermeier, Nagel, and Pedersen (2008)). Secondly, our Portfolio constructed using the high-minus-low method (Lustig, Roussanov, and Verdelhan (2011)) offers even larger improvement of 84% in Sharpe ratio over the similarly constructed carry portfolio. Third, the spread weighted portfolio enjoys a 60% increase in Sharpe ratio.

Are common risk factors able to explain the high excess returns of the portfolios sorted based on prospective interest rate differential? Lustig and Verdelhan (2007) and Lustig, Roussanov, and Verdelhan (2011) suggest that the consumption risk and a slope factor in the currency market go a long way in explaining the excess returns of carry portfolios. We regress our equally-weighted, high-minus-low, and spread weighted portfolio returns on various stock market and currency market factors. We find that these common factors cannot explain away our portfolio excess returns and the intercepts are all positive and significant. Another important source of currency risk lies in currency crashes and rare disaster risk accounts for a significant portion of carry trades returns (Jurek (2013), Farhi et al. (2009)). We explore this explanation for our equally-weighted portfolio and find that the realized return of our equally-weighted portfolio shows a positive skewness.

The paper is organized as follows. In section 2, we detail our present-value model and present the pricing kernel decomposition. In section 3 we introduce the data. In section 4, we present predictive regressions of both expected returns and currency depreciation rates and compare out-of-sample portfolio performance. We also explore various risk based explanations and conduct robustness checks. Section 5 concludes. We also provide more details on the model estimation in the Appendix.

2 Model

We start from the nominal foreign exchange rate and take USD as the base currency throughout our paper. Let the direct rate between the USD and foreign currency unit (FCU) be $s_t = \log S_t$

(i.e., S_t=1.5USD/£or 1£=1.5USD), and the domestic and foreign interest rate be i_t and i_t^*. We follow the literature and add asterisks to denote the corresponding foreign variables, using ∇ as the cross country difference (i.e., $\nabla i_t = i_t^* - i_t$), and Δ as the time series first difference (i.e., $\Delta s_{t+1} = s_{t+1} - s_t$). The currency excess return λ_{t+1} is:

$$\lambda_{t+1} = s_{t+1} - s_t + \nabla i_t.$$

We assume the currency market return λ_{t+1} is the sum of an expected component l_t (the risk premium) and an unexpected component. Thus

$$E_t s_{t+1} - s_t = E_t \lambda_{t+1} - \nabla i_t = l_t - \nabla i_t \tag{1}$$

or $s_t - E_t s_{t+1} = \nabla i_t - l_t$. Iterating forward and summing up we have

$$s_t - E_t s_{t+k} = \sum\nolimits_{j=0}^{k} E_t \nabla i_{t+j} - \sum\nolimits_{j=0}^{k} E_t l_{t+j}$$

Letting $k \to \infty$, we define $\bar{\imath}^* = \lim_{j\to\infty} i_{t+j}^*$, $\bar{\imath} = \lim_{j\to\infty} i_{t+j}$, and $\bar{l} = \lim_{j\to\infty} l_{t+j}$. Also, we define $\tau = \bar{l} - (\bar{\imath}^* - \bar{\imath})$, and we generate

$$s_t - \lim_{j\to\infty} E_t s_{t+j} + j\tau = \sum_{j=0}^{\infty} \left(E_t \left[i_{t+j}^* - \bar{\imath}^* \right] - E_t \left[i_{t+j} - \bar{\imath} \right] \right) - \sum_{j=0}^{\infty} E_t \left(l_{t+j} - \bar{l} \right) \tag{2}$$

In Engel (2011), the term $\sum_{j=0}^{\infty} \left(E_t [i_{t+j}^* - \bar{\imath}^*] - E_t \left[i_{t+j} - \bar{\imath} \right] \right)$ is the prospective interest rate differential. According to the Beveridge and Nelson decomposition, we eliminate the permanent components, and both sides are stationary. We can write $s_t - \lim_{j\to\infty} E_t s_{t+j} + j\tau$, the transitory part of s_t, as s_t^T. This equation thus tells us that the transitory component of exchange rate is the sum of the prospective interest rate differential and expected future currency returns.

We find this multiple periods relationship among the rate of depreciation, interest rates, and currency return very useful. As the prospective interest rate differential contains even more information than carry (current period interest rate differential) about the next period currency return, therefore it may be more useful to predict currency return.[3] We then exploit this identity and build empirical proxies for the terms involving infinite sums, so we may study the dynamics of currency return against interest rates over time.

If we further assume that the interest rates follow a simple AR(1) process such that $i_{t+1}^{*} - \bar{\imath}^{*} = \phi^{*}\left(i_t^{*} - \bar{\imath}^{*}\right) + \varepsilon_{t+1}^{*}$ and $i_{t+1} - \bar{\imath} = \phi\left(i_t - \bar{\imath}\right) + \varepsilon_{t+1}$ for the foreign country and the U.S., then we can rewrite the above equation as

$$s_t^T = \left(\frac{i_t^{*} - \bar{\imath}^{*}}{1-\phi^{*}} - \frac{i_t - \bar{\imath}}{1-\phi}\right) - \sum_{j=0}^{\infty} E_t\left(l_{t+j} - \bar{l}\right) \tag{3}$$

If we similarly model the risk premium as an AR(1) process, such that $l_{t+1} - \bar{l} = \gamma\left(l_t - \bar{l}\right) + \epsilon_{t+1}$ then the preceding formula can be further reduced to

$$\frac{l_t - \bar{i}}{1-\gamma} = \left[\frac{i_t^{*} - \bar{\imath}^{*}}{1-\phi^{*}} - \frac{i_t - \bar{\imath}}{1-\phi}\right] - s_t^T.$$

If investor expects no time variation of interest rates, then currency return can be predicted in the conventional regression where the carry (interest rate differential) is the predictor. However, investor updates the belief every time when she received new information about interest rates, thus both interest rates will be expected to fluctuate around their own average. Therefore, instead of running the conventional predictive regression, we develop a new currency return predictor $\chi = \frac{i_t^{*} - \bar{\imath}^{*}}{1-\phi^{*}} - \frac{i_t - \bar{\imath}}{1-\phi}$. By taking into consideration of the persistence and long run trend of each interest rate, the prospective interest rate differential is much more volatile than the carry.

We estimate the persistence of nominal short interest rates ϕ and ϕ^{*} from data. However, there are some potential concerns as the persistence of interest rate is known to be hard to estimate precisely. There are some empirical observations that interest rates exhibit I(1) behavior (see

[3] Jordà and Taylor (2012) find empirically that the reversion to the "FEER" (fundamental equilibrium exchange rate) can forecast currency excess returns strongly. Although the ideas are similar, conceptually, the FEER is the long-run mean of the log real exchange rate or the PPP implied exchange rate, instead of the permanent component of the nominal exchange rate as we are studying. Still, their result is largely consistent with our line of argument: when the infinite sum of expected interest rate differential is high, or when the temporary component of exchange rate is low, then the excess return is expected to be higher.

Campbell and Shiller (1991) and Mishkin (1992)). In that case the construction of prospective interest rate will be difficult. On the other hand, if we conduct a simple auto-regression, it is likely we will suffer more from the well-known Hurwicz bias when the sample size is very small in the early sample period.

We overcome this difficulty through building a parsimonious model. Motivated by Ang and Chen (2010) who find that term structures of interest rate between countries contain useful information on currency market returns, we decompose the pricing kernel then to price each country's government bonds, thereby allowing us to exploit government bond returns in addition to short rates, in order to estimate the degree of the short rates' persistence in each country. We label this alternative method to measure prospective interest rate differential as χ'.

To focus our attention on the currency return predictability, we only give out details of this simple model in the Supplementary appendix 6.1, and also include the model estimation through Kalman filter in the Supplementary appendix 6.2.

3 Data

We obtain data on default-free zero coupon bonds, and foreign exchange rates from Datastream, the sample period is 1979:12$\sim$2011:08, totally 381 months. Our entire sample includes 25 countries/regions, including Australia, Germany, Belgium, Canada, Czech, Denmark, EMU, Spain, Finland, France, Greece, Hungry, Ireland, Italy, Japan, Netherlands, Norway, New Zealand, Austria, Poland, Portugal, South Africa, Sweden, Switzerland, United Kingdom, and United States as the home currency. The majority are developed countries, while EMU is a group of countries.[4]

For Datastream's default-free zero coupon bonds, we search all the available maturity for every country. Table A.1 reports the maturity and the earliest month when a country's bond index becomes available. As can be seen, France and U.K. have bond data with all the 2, 3, 5,

[4]The number of test currencies is close to Burnside (2011). Due to bond data limitations, our number of currencies is smaller than those considered in carry trade strategies such as Lustig and Verdelhan (2007) and Lustig, Roussanov, and Verdelhan (2011).

7, 10, 15, 20, 30, and 50 years maturities, while Germany, Netherlands, U.K. and U.S. have the earliest available data to be included in our final sample.

For spot and forward exchange rates, we sample the data with the frequency of one month. Most of our spot and forward rates are from WMR, and depending on the availability of bond data, we also use BBI when WMR is not available. Risk-free rates are one month Eurocurrency deposit rate. Following Burnside (2011), we augment the spot rates taking the advantage of longer history of pound rates. That is, Reuter/WMR many times have quotes for a FCU/£ long way back. We first augment the current Barclays (BBI) \$/£ this way, then assume no triangular arbitrage and back out the FCU/\$ as (FCU/£)/(\$/£). For missing interest rates, we assume covered interest rate parity and rely on the known British interest rate, and both spot and forward pounds exchange rate to invert. When 1-month forward rates are missing for some countries, we again take advantage of the pound and dollar forward rates, and use the implied cross forward rate as above, assuming no triangular arbitrage.

Our final sample thus comprises of an unbalanced panel of bond returns, spot rates, and interest rates for each country. In order to balance the number of currencies and the availability of bond returns data, our main results are based on a set of currencies, which excludes Euro countries after the birth of Euro in 1999. They involve all the available currencies before 1999 but only 14 currencies after 1999, and they also largely represent the most actively traded currencies available to investors today. To make our results comparable to extant literature, we also follow Burnside (2011) where he studies a set of 19 currencies, including those of European countries even though after 1999 Euro is being used. We call this alternative set '19 currencies'.

4 Empirical results

4.1 Summary statistics and parameter estimates

Table 1 summarizes the currency excess returns of all 25 countries for the sample period from July 1982 to August 2011, subject to the data availability (detailed in Table A.1). The mean returns range from 2.04% (Switzerland) to 15.95% (South Africa) per annum and there is little serial correlation for most of the currency excess returns. A staggering 23 out of the 25 currencies exhibit negative skewness in their realized returns. Comparing the min and max monthly returns shows a similar pattern. The magnitude of the largest monthly loss exceeds that of the biggest monthly gain for 21 out of the 25 currencies. Both these features demonstrate the risk of currency crashes as highlighted in Brunnermeier, Nagel, and Pedersen (2008).

Table 1 about here.

Table 2 reports the estimated OLS AR(1)(ϕ) of the short interest rate of all countries. The ϕs are initially estimated with the first 30 monthly observations of each country, then each month one more observation is added and we update the ϕ estimate. In this way, we obtain a time-series of the ϕ estimates for each country. The bottom row presents the time-series averages of the cross-country statistics. The mean (time-series) cross-country average of the ϕs is 0.960, consistent with the fact that short rate is very persistent. Moreover, there is considerable cross-section variation in the persistence level. The smallest estimate of ϕ is only 0.001 (New Zealand) and the largest estimate is 1.165 (Denmark). The mean (time-series) cross-country standard deviation is 0.100.

Table 2 about here.

However, there are two concerns regarding these OLS AR(1) estimates. They are downward biased especially when the sample size is small, for example, the smallest estimate is 0.332, 0.313, 0.029, and 0.001 in Spain, Japan, Norway, and New Zealand. In the meantime, a larger than unit estimate of ϕ appears more than once in our country-month sample. For example, the largest estimate is 1.071, 1.165, 1.001, 1.004, 1.004, 1.134, 1.001 for Czech, Denmark, EMU, Greece, Hungary, Ireland, and South Africa. Though not necessarily a problem in building our return predictor, these larger-than-unity estimates contradict our model in decomposing the foreign exchange rates.

Our solution to these two problems is to enhance the sample by using the information on the term structure of interest rates. Motivated by (Ang and Chen 2010) that many variables from the term structure is useful in predicting currency returns, we specify the functional form of the pricing kernel then rely on all the government bond returns to improve the parameter estimation. Specifically, in our simple term structure model, the transitory component of the pricing kernel, the short rate, and government bond returns all share the same AR(1) parameter. This parsimonious model thus allows us to estimate a panel data of bond returns instead of relying on a single time series of short rate.

Table 3 documents the estimated persistence (to differentiate from OLS estimate, we denote this model estimate as ϕ') of the transitory component of the pricing kernel of all countries. Similarly, the ϕ's are initially estimated with the first 30 monthly observations of each country using a state-space approach (more details on the estimation process are in the appendix 6.2). We then expand the estimation window with every new observation. In this way, we obtain a time-series of the ϕ' estimates for each country. The bottom row presents the time-series averages of the cross-country statistics. In our model, the parameter ϕ' also represents the persistence of the short rate process. The mean (time-series) cross-country average of the ϕ's is 0.911. The lowest average ϕ' is 0.855 (Switzerland) and the highest average is 0.986 (Germany). The mean (time-series) cross-country standard deviation is 0.049. Relative to the simple OLS estimates, the Kalman filter estimates better capture the persistence of short rate and stay less than 1.

Table 3 about here.

4.2 Portfolio strategies

We next compare the portfolios formed by χ and χ' with those formed by carry. Carry trade dictates that when foreign interest is higher, we borrow a USD at i_t, change to FCU at S_t, deposit at i_t^*, then change back at S_{t+1}. When domestic interest is higher we do the opposite. The carry trade return is thus

$$sign\left[i_t^* - i_t\right]\left[\left(1+i_t^*\right)\frac{S_{t+1}}{S_t} - \left(1+i_t\right)\right]$$

where *sign* is the sign operator.

We form currency portfolios based on χ and χ' in a similar way. By design of our strategy, our adjusted excess return will not depend on the sign of interest rate differential (carry), but on that of our proposed predictor (χ or χ'). Specifically, the excess return generated by our model would be

$$sign\left[\frac{i_t^* - \bar{i^*}}{1-\hat{\phi}^*} - \frac{i_t - \bar{i}}{1-\hat{\phi}}\right]\left[(1+i_t^*)\frac{S_{t+1}}{S_t} - (1+i_t)\right]$$

Thus when the foreign prospective interest rate is higher than the domestic counterpart, we long the foreign currency, and short otherwise. As we have obtained the short rate persistence in two ways, by OLS and by Kalman filter, we label our predictor $\chi = \frac{i_t^* - \bar{\imath}^*}{1-\phi^*} - \frac{i_t - \bar{\imath}}{1-\phi}$, and $\chi' = \frac{i_t^* - \bar{\imath}^*}{1-\phi'^*} - \frac{i_t - \bar{\imath}}{1-\phi'}$.

We use our 'prospective' predictor in three different ways to construct currency portfolios and examine the portfolio performance. First, we long or short individual currencies based on our predictor and combine all the individual currency positions in an equally-weighted (EW) portfolio with the total value of the bet normalized to 1 USD at the time it is initiated. As the number of currencies to long or short may vary over the time, we scale accordingly to ensure that the "\$1-long/\$1-short" characteristics would remain. We refer to portfolios constructed using this method as EW portfolios.

We also construct a high-minus-low (HML) strategy as in Lustig, Roussanov, and Verdelhan (2011). In each period, all available currencies in our sample, including the USD, are sorted into 5 bins: S1, S2, S3, S4, and S5[5] according to their forward discount against the USD (of course, the USD's forward discount is always 0). The first bin S1 includes those currencies with the smallest forward discounts (the lowest interest rates), the second bin S2 the next smallest, etc., with the highest rank bin S5 consisting of those currencies with the largest forward discounts (and, therefore, the highest interest rates). We then compute the payoff associated with borrowing one dollar in order to invest equally on the currencies of each bin. The HML strategy then invests 1 USD in the highest rank bin and −1 USD in the lowest rank bin. This is, effectively, equivalent to executing a carry trade in which the investor borrows the low interest rate currencies in S1 to invest in the high interest rate currencies in S5. Burnside (2011) refers to this portfolio as the HML carry trade portfolio when the sorting variable is interest rate differential. We construct

[5] 3 bins if the number of currencies is no more than 10, and 4 bins if the number of currencies is between 11 and 16.

our HML portfolio in the exactly same manner, except the sorting variable is χ and χ'.

The third strategy is based on spread in the prospective interest rate differential and relies on the cross sectional demeaned-standardized value of it (z-scores). As the portfolio return is equivalent to the OLS slope regressing next period returns on signals, we label this strategy "OLS" ((Hoberg and Welch 2009)). We then again scale properly to maintain the "\$1-long/\$1-short" characteristic. Unlike the EW strategy, OLS strategy exploits the relative strength of the signal thus invests more in currencies that have larger prospective interest rate differentials.

Table 4 about here.

Table 4 reports the portfolios analysis results based on three signals: carry, χ, and χ'. In the following we refer to them as carry portfolio, χ portfolio, and χ' portfolio. For each signal we report the basic portfolio characteristics in percentage points for all the three strategies: EW, HML, and OLS, in panel A, B, and C.

For the three strategies, both the χ and χ' portfolios uniformly dominate the carry portfolio. The EW portfolio based on χ returns 1.73% and based on χ' returns 2.08% per annum and outperforms the carry strategy which returns 1.49%. The average return of our proposed portfolios are 16% to 40% higher than that of the carry portfolio. Moreover, the standard deviation of χ portfolio and χ' are 3.89% and 4.37% per year, considerably lower than that of the carry portfolio at 4.49%. Overall, the Sharpe ratio of χ and χ' portfolios are 0.446 and 0.476, 34% and 43% higher than that of the carry portfolio. More importantly, χ' portfolio shows a skewness of 1.482 and the largest monthly gain is larger than the magnitude of the largest monthly loss. This contrasts with the carry portfolio, which displays a skewness of -0.719 and is prone to crashes (Brunnermeier, Nagel, and Pedersen (2008) and Jurek (2013)). Our predictors are constructed using the long run forecast of all future interest rate differentials and therefore our EW portfolio displays a positive yet modest correlation of 0.48 and 0.34 with the carry portfolio. The average return of carry trades is slightly lower than that reported in Burnside (2011) because our sample covers a shorter period and carry trades are more profitable immediately after the Bretton Woods than the more recent period. Our sample period is shorter because we need matching fixed income data to estimate the mode parameters and our out-of-sample test needs an additional 30 months of data to initialize.

The HML strategy differs with the EW strategy along two dimensions. First, the long or short currency positions are determined by the relative ranking of the sorting variables, rather than the sign of the sorting variables. Second, the HML strategy only trades the extreme currencies and takes more aggressive positions than the EW portfolio. Therefore, both the mean returns and the standard deviations of the HML portfolio are higher than the equivalent EW portfolio, for both carry and our portfolios. The average returns for carry, χ and χ' portfolios are individually 4.22%, 6.25% and 6.24%. From a risk-return trade off perspective, the HML portfolio based on our predictors has a Sharpe ratio of 0.776 and 0.777, 84% higher than that of the HML carry portfolio. Our HML portfolio becomes negatively skewed because of the extreme currency positions. Nonetheless, the magnitude of the negative skewness is much smaller than that of the HML carry strategy.

Finally, we turn to OLS strategy. The average returns for carry, χ and χ' portfolios are individually 2.21%, 2.69% and 2.76%. The OLS portfolio based on our predictors has a Sharpe ratio of 0.637 and 0.783, 30% and 60% higher than that of the OLS carry portfolio. We also note as the OLS strategy exploits the relative magnitude rather than just sign of the signal, χ' portfolio is considerably superior to χ portfolio in performances. The difference comes from the estimate of the short rate persistence. When the foreign prospective interest rate is less than the U.S. counterpart, even the estimate of ϕ exceeds one, it does not affect the sign of the signal (prospective interest rate differential). However, when the relative magnitude is used in building portfolio, the erroneous estimate adversely affects the portfolio performance.

4.3 Risk based explanation

Since prospective interest rate differential is estimated as the infinite sum of expected interest rate differentials and is correlated with carry, we examine whether the existing asset pricing models designed to explain carry trade portfolio returns could also explain χ and χ' portfolio returns. Table 5 presents asset pricing tests using conventional risk factors.

Following Burnside (2011), we consider the most conventional asset pricing models: CAPM, FF three-factor model (MKT, SMB and HML), FF three-factor augmented with MOM, and the two-factor currency market asset pricing model à la Lustig, Roussanov, and Verdelhan (2011) ("LRV model" thereafter): RX and $\mathrm{HML_{FX}}$. The sample period is 1982:07∼2011:08, except 1983:11∼2011:08 for the LRV model. The Newey-West standard error is used to calculate the significance of α in each model.

Table 5 about here.

Panels A and B report the asset pricing tests on portfolio returns using χ and χ' separately. For each panel, we also conduct factor regressions of EW, HML, and OLS separately. For each portfolio return, we examine different models, first market model, then FF three-factor model, then four-factor model, and finally the LRV model.

It seems that none of the risk factors explain away the χ and χ' portfolio αs, under the EW, HML, and OLS strategies. In fact, across all the models for all the portfolios, the monthly alpha is between 0.1% and 0.5%. Additionally, most of the risk factors have insignificant loadings, suggesting that the prospectχ and χ' portfolio returns are not strongly related to most of the conventional risk factors. The asset pricing tests further highlight the difference between the prospectχ and χ' and carry portfolios, although they are positively correlated.

There are also some interesting patterns regarding these asset pricing tests. The alphas are the largest for the HML strategies relative to EW and OLS strategies, both under χ and χ' portfolios, and can be two to three times larger. Also, generally, the asset pricing tests seem to have even a harder time explaining away the χ' portfolio alphas than χ portfolio alphas, both the EW and HML strategies.

We also examine whether our two strategy returns can also explain away the two factors in Lustig, Roussanov, and Verdelhan (2011). This time in the regression, the dependent variables are their RX and $\mathrm{HML_{FX}}$ factors, and the independent variables are EW and HML returns generated by χ and χ' strategies. We report the results in Table 6.

Table 6 about here.

Interestingly, the two factors in Lustig, Roussanov, and Verdelhan (2011) can be completely explained by our two factors, no matter produced under χ or χ' strategy. We note that although the portfolio strategies are similar, however we have a different sample (actually much smaller sample) and our return predictor χ theoretically contains more information than carry.

4.4 Does inflation matter?

In light of the extant literature on the relative importance of real and nominal components of the violations of UIP (Holliefield and Yaron (2003)), comparing the return predictability between the nominal and real prospective interest rate differentials helps to tease out the potential role of inflation. By studying the effect of the expected sum of real and nominal interest rate differentials, we can also infer the role of expected sum of inflation differentials in predicting currency return, thereby providing additional empirical evidence for macroeconomic models. Because interest rates are persistent, empirical findings of correlation between the expected sum of interest rate differentials and cumulative risk premium will also impose more restrictions on existing asset pricing models.

We next turn to real exchange rate q_t, and let the real interest rate be $r_t = i_t - E_t\pi_{t+1}$, where r_t and $E_t\pi_{t+1}$ are the real interest rate and expected inflation rate, respectively. This decomposition yields:

$$l_t = E_t q_{t+1} - q_t + r_t^* - r_t$$

where real exchange rates and nominal exchange rates are expressed by $E_t q_{t+1} - q_t = E_t s_{t+1} - s_t + E_t\pi_{t+1}^* - E_t\pi_{t+1}$. Assuming no deterministic time trend, this same formula also yields:

$$q_t - \lim_{j\to\infty} E_t q_{t+j} = \sum_{j=0}^{\infty} \left(E_t\left[r_{t+j}^* - \bar{r}^*\right] - E_t\left[r_{t+j} - \bar{r}\right] \right) - \sum_{j=0}^{\infty} E_t\left(l_{t+j} - \bar{l}\right) \tag{4}$$

Again, assuming an AR(1) process for real interest rates with autocorrelation coefficient θ and

θ^*, we obtain:

$$\sum_{j=0}^{\infty} E_t\left(l_{t+j}-\bar{l}\right)=\left(\frac{r_t^*-\bar{r}^*}{1-\theta^*}-\frac{r_t-\bar{r}}{1-\theta}\right)-[q_t-\lim_{j\to\infty}E_t q_{t+j}]$$

Thus, the sum of multiple period risk premium relative to its trend is related to real variables. As with the nominal prospective interest rate, we would like to study the predictive power of the real χ on the next period expected excess return.

Table 7 about here.

We repeat the portfolio analysis in Table 7, by running OLS AR(1) to obtain the estimate of parameter θ. The EW portfolio based on real χ returns 0.96% per annum, lower than the real carry strategy, which returns 1.99%. The Sharpe ratio of our strategy with real χ is 0.239 and also lower than that of the real carry strategy. Interestingly, both the real χ portfolio and real carry portfolio are positively skewed. Next, we turn to the HML strategy, and the real χ portfolio has a Sharpe ratio of 0.611, 48% higher than that of the HML real carry portfolio. The HML real χ portfolio returns continue to display a positive skewness of 0.198, in contrast to -0.682 for the HML real carry portfolio.[6] Finally, the OLS portfolio based on real χ strategy also generates lower returns and Sharpe ratio than that on the real carry strategy.

Overall, the relative performance of real χ and real carry is rather mixed, suggesting that the role of inflation is perhaps limited in the superior predictive power of χ.

4.5 Comparing with momentum strategies

Another popular currency investment strategy is momentum (Menkhoff, Sarno, Schmeling, and Schrimpf (2012)), which continues to buy when the last period currency return is positive, and sell when the last period return is negative. On appearance, there are similarities between the momentum strategy and our newly developed strategy. Both exploits the persistence in the return predictor. However, the momentum strategy depends on the persistence of the last period return,

[6] We also conduct the asset pricing tests. We obtain fairly similar conclusion that conventional risk factors can explain the real carry portfolio returns but not real χ portfolio returns.

while we take into consideration of the persistence of each interest rate in building up the return predictor. Still, it remains an empirical issue which persistence is more important in forecasting cross sectional currency returns.

Following Burnisde, Eichenbaum, and Rebelo (2011) and Menkhoff, Sarno, Schmeling, and Schrimpf (2012), we also consider three momentum strategies: EW, HML, and OLS. In the first strategy, we consider each individual currency's momentum strategy then equally average them. In the second strategy, we long the portfolio with highest lagged excess currency return and short the portfolio with lowest lagged excess currency return. Lastly, OLS portfolio makes use of all the lagged excess returns.

Table 8 about here.

We report the momentum portfolio analysis, and repeat that on χ and χ' portfolios for comparison, in Table 8. The EW, HML, and OLS momentum portfolio generates returns of 1.99%, 2.75%, and 1.24% per annum. The Sharpe ratios are 0.361, 0.318, and 0.291, respectively. All of these measures indicate that the χ strategy clearly outperforms currency momentum strategy again. Thus we conclude incorporating the persistence of interest rate is quite different from and potentially more important than using the persistence of currency returns.

4.6 Robustness

We also consider two variations of our baseline χ' predictor. First, the average interest rate does not vary much within a country and its effect in the cross section is worth exploring. Thus, we consider excluding this average interest from our predictor and have the following: $i_t^*/[1-\hat{\phi'}^*] - i_t/[1-\hat{\phi}']$.

Moreover, we conduct Beveridge and Nelson decomposition on both sides of equation (2), but haven't take advantage of the information contained in the transitory component of the spot exchange rate, which plays a pivotal role in our analysis. Thus we consider another predictor incorporating the transitory component s^T: $[i_t^* - \bar{\imath}^*]/[1-\phi'^*] - [i_t - \bar{\imath}]/[1-\phi'] - s^T$. To do this, we strictly follow the state-space approach suggested by Morley (2002) and use Kalman filter to conduct the decomposition. For each currency, we work on the rate of depreciation (the difference of spot rates) and assume an ARMA(p, q) process where neither p or q is more than 3. Then we examine the nine possible time series process and obtain a specific value of p and q with the largest likelihood. We further use steady-state Kalman gain and covariance matrices to identify the transitory and permanent component of the spot rate.

Table 9 about here.

Table 9 reports the portfolio performance using these two alternative predictors. Throwing away country individual average of short rates lowers our baseline portfolio performance measured by mean returns and Sharpe ratios, in EW, HML, and OLS strategies, nevertheless the results are still better than those of carry. On the other hand, incorporating the estimated transitory component of spot exchange rate weakens the performance of all three portfolio strategies. This result suggests that, although theoretically useful, the role of the transitory component is limited perhaps due to large estimation uncertainty or model misspecifications.

Our last robustness check asks whether our results are currency specific. We alternatively take the currencies in Burnside and focus on 20 currencies including USD. We call this sample "19 currencies" and report the results in 10. Again, using this subsample does not deteriorate our portfolio performance and consistently shows that prospectχ and χ' still greatly dominate carry strategy.

Table 10 about here.

4.7 Decomposing prospective interest rate differential

Our decomposition shows that the prospective interest rate differential equals the present value of all the demeaned carry in the future. In this section we explore the source of value added by decomposing the prospective interest rate differential to two parts: carry and 'prospective minus carry'. We then run panel regressions to contrast the predictive power of the two separate parts of prospective interest rate differential.

As our model establishes a long run relationship between the prospective interest rate differential and the expected excess returns. Therefore, we examine the long horizon predictability of both carry and χ' and results are presented in Table 11. We calculate the cumulative return for 1, 2, 3, 4, 5, 6, 9, and 12 months and take monthly average so the regression coefficients become easily comparable. To facilitate comparison, we trim the shorter horizon panel regression sample sizes to equal that of longer horizon panel regression sample sizes.

As stated before, we burn in the first 30 months of our sample period (1980:01 to 1982:06) to obtain the first estimate of ϕ' and the historical mean, then continuously update the model estimate with new information, and our OOS period covers the 350 months from 1982:07 to 2011:08. Two conventional approaches are employed to evaluate the predictive power of our proposed variable: the pooling regressions and the country fixed effects regressions. We use two way clustered standard errors to calculate statistical inference.

Table 11 about here.

The pooling panel regression results are presented in Panel A of Table 11. The point estimates of the carry and χ' are both individually significant at all horizons. Regarding economic significance, for example, one standard deviation of carry (0.283%) times the regression coefficient in the first model of 1 month regression (1.002) is 0.2835% per month. Similarly, one standard deviation of χ' (5.323%) times the regression coefficient in the first model of 1 month regression (0.051) is 0.2715% per month. However, when we put both the carry and χ' in the multiple regression, the t-stat for carry decreases from 2.06 to 1.44, losing significance. The t-stat for χ' also drops from 2.74 to 2.43, however still significant. The pattern also appears again for 2 month regression, then the coefficient for carry starts to recover its significance afterwards. However, χ' seems to be always more important than carry in generating future returns. For 12 month multiple regression (the third model), one standard deviation of χ' would raise average monthly excess return of 0.1597%, compared to 0.1480% by carry.

We have an unbalanced panel with fewer countries at the beginning period of the sample, and increasing number of countries in the later part. Panel B of Table 11 presents the country fixed effect regression results (The country effects are not reported to save space). After controlling for country individual effects, we find that the above pattern even more pronounced such that carry is overshadowed by χ' in the multiple regression. As a matter of fact, the coefficient of carry still retains significance only for 6 and 9 month horizon.

How to interpret these results? Under the BN decomposition, the long-term trend component of foreign exchange rate represents the fundamentals determining the long-run equilibrium value of the exchange rate, such as the present value of expected future realizations of domestic and foreign money stocks, real incomes, inflation rates, and current account balances (Engel, Wang, and Wu (2010), Mussa (1982)). The transitory component, on the other hand, can be interpreted as the effects of portfolio shifts among international investors (Evans and Lyons (2002)), central-bank intervention, microstructure phenomena such as bubbles and rumors, or the effects of technical trading by noise traders (Baum, Caglayan, and Barkoulas (2001)). Over time, the transient component will be reversed and generating predictable currency returns. Just like the adjustment that Lacerda and Santa-Clara (2011) make on the dividend yield to predict market excess return, we incorporate more information from the term structure and replace the current interest rate differential with prospective interest rate differential, which is the sum of expected future interest rate differentials. A positive excess return implies a positive prospective interest rate differential and/or a negative transitory component of spot rate. Then the parameter ϕ is critical in comparing different foreign currencies. Other things equal, the larger the value of ϕ and the larger prospective interest rate differential, the smaller transitory component of spot rate, and the more positive excess return is.

5 Conclusion

We develop a new predictor for foreign currency excess returns which outperforms the conventional interest rate differentials (carry). Following Engel (2011) we model the exchange rate using a present-value relationship, then conduct Beveridge Nelson decomposition to express the transitory component of spot exchange rate as the sum of 'prospective interest rate differentials' and multi-period risk premium. We decompose the pricing kernel to extract information from government zero coupon bonds to estimate the prospective interest rate differentials to predict foreign currency returns.

Within an out-of-sample (OOS) period of 350 months from 1982:07 to 2011:08, our predictor systematically outperforms the conventional carry signal in portfolio analysis based on several investment strategies. Our results also hold in panel predictive regressions, in variations of baseline strategies, and in different set of currencies.

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6 Appendix

6.1 Model derivation

We start from the no-arbitrage relationship that the rate of depreciation between two currencies capture the difference between the pricing kernels in the two countries. Therefore, decomposing rate of depreciation equals decomposing pricing kernels in different countries.

In the same fashion as Alvarez and Jermann (2005) and Lustig, Stathopoulos, and Verdelhan (2014), we consider the following discrete-time model of the log pricing kernel, $m_t \equiv \ln M_t$: [7]

$$m_{t+1} - \mu_{t+1} = \phi\left(m_t - \mu_t\right) + u_{0,t+1}; \quad |\phi| < 1, \tag{5}$$

$$\mu_{t+1} = -\nu + \mu_t + u_{1,t+1}, \tag{6}$$

where $u_{0,t+1} \sim$i.i.d.$N\left(0, \sigma_0^2\right)$ and $u_{1,t+1} \sim$i.i.d.$N\left(0, \sigma_1^2\right)$ are Gaussian white noise processes.

The long-run mean of the log pricing kernel, μ_t, follows a random walk with drift [equation (6)]. In other words, the μ_t process characterizes the "stochastic trend" of the log pricing kernel. Equation (5) describes the transitory variation of the log pricing kernel (m_t) around μ_t.[8] Therefore, our model is a two factor model of the pricing kernel, where $u_{0,t+1}$ and $u_{1,t+1}$ represent the transitory and permanent factors and are likely to be correlated with each other. To our knowledge, apart from Alvarez and Jermann (2005), Koijen, Lustig, and Nieuwerburgh (2009), and Lustig, Stathopoulos, and Verdelhan (2014) very few models study the asset pricing implications of permanent-transitory decomposition of the pricing kernel.

This specific dynamics of the pricing kernel gives us a parsimonious expression for the log return of a n-period default-free zero-coupon bond held from time t to $t+1$ is

$$\begin{aligned} i_t &= -\frac{1}{2}\sigma_w^2 - E_t\left[\Delta m_{t+1}\right]; \; \sigma_w^2 = Var_t\left[u_{0,t+1} + u_{1,t+1}\right] \\ b_{t+1}^{n-1} - b_t^n &= i_t + \frac{1}{2}\left[2\left(1 - \phi^{n-1}\right)\sigma_{01} + \left(1 - \phi^{2(n-1)}\right)\sigma_0^2\right] - \left(1 - \phi^{n-1}\right)u_{0,t+1} \end{aligned}$$

[7] Alvarez and Jermann (2005) model is much more general than ours as it focuses on volatility bounds.

[8] The specification (5)-(6) implies that the log stochastic discount factor obeys an ARMA process as per the Granger's lemma. As we show, even in the presence of the moving average component, our mode implies a simple autoregressive process for short-term interest rates.

where b_t^n is the log price of the coupon at time t with maturity n. From the dynamics of short rate i_{t+1}, iterating we have for the long run

$$\begin{aligned} i_{t+j} &= \phi^j i_t + \frac{1-\phi^j}{1-\phi} a - (\phi - 1)\, u_{0,t+j}; \\ \bar{\imath} &= \frac{1}{1-\phi} a;\ a = \frac{1}{2}(\phi - 1) - (\phi - 1)\,\nu \end{aligned}$$

then we have for out the above infinite sum (2)

$$\sum_{j \to 1}^{\infty} E_t\left[i_{t+j} - \bar{\imath}\right] = \frac{i_t}{1-\phi} + \frac{\frac{1}{2}\sigma_w^2 - \nu}{1-\phi}.$$

Finally the equation (2) becomes

$$s_t^T = \frac{i_t^*}{1-\phi^*} + \frac{\frac{1}{2}\sigma_w^{*2} - \nu^*}{1-\phi^*} - \frac{i_t}{1-\phi} - \frac{\frac{1}{2}\sigma_w^2 - \nu}{1-\phi} - \frac{l_t - \bar{l}}{1-\gamma}$$

and we thus have

$$\frac{l_t - \bar{l}}{1-\gamma} = \Big(\frac{i_t^*}{1-\phi^*} + \frac{\frac{1}{2}\sigma_w^{*2} - \nu^*}{1-\phi^*} - \frac{i_t}{1-\phi} - \frac{\frac{1}{2}\sigma_w^2 - \nu}{1-\phi}\Big) - s_t^T \tag{7}$$

The above expression links the short-term interest rate, persistence of short rate, and temporary component of exchange rate through one equation. It is well documented that carry trade is profitable because high interest rate currencies tend to appreciate. Under the BN decomposition framework, the expected change of exchange rate in the long run is by construction negative of the transitory component of exchange rate. In other words, a high interest rate currency is expected to appreciate and the transient component of its exchange rate must be negative. This implies a negative correlation between the interest rate differential and the transient component of exchange rate. Equation (8) shows that the negative relation between current short rate and the transient component of exchange rate is amplified by the persistence level of short rate. The multiplier effect highlights the importance of the short rate dynamics and prospective interest rates in predicting currency returns.

We follow the term structure of interest rates literature to estimate the model via Kalman filter.

Since our goal is to forecast risk premium, we choose the most parsimonious approach possible and focus on the persistence of transitory component of pricing kernel ϕ only. We back out the $\bar{\imath}$ from the data to avoid joint estimation of variances of the permanent and transitory components, as that of permanent component will require equity data given the entropy bound implied by Alvarez and Jermann (2005). We also abstract away from estimating the return persistence parameter γ following Lacerda and Santa-Clara (2011). It is worth noting that there may be large cross sectional differences in γ, and portfolio strategies taking advantage of foreign currency momentum is shown to generate considerable profitabilities (Menkhoff, Sarno, Schmeling, and Schrimpf (2012)). Thus ignoring it should weaken our empirical results when forming currency portfolios. Even so, we show that our parsimonious empirical strategy still achieve success and out-perform the conventional carry strategy.

Guess the default free zero coupon bond log price b_t^n (at time t with maturity n) to be an exponential function of $E_t\Delta m_{t+1}$ with time varying coefficients g_n and f_n

$$b_t^n = g_n + f_n E_t \Delta m_{t+1}$$

From

$$E_t\left[M_{t+1}B_{t+1,n-1}\right] = M_t B_{t,n}$$

We can guess and verify

$$f_n = \frac{1-\phi^n}{1-\phi}$$

so the one period zero coupon bond log holding return from t to $t+1$ with maturity n, $r^b_{t+1,n} = b^{n-1}_{t+1} - b^n_t$ is

$$r_{t+1,n} = i_t + \frac{1}{2}\left[2\left(1-\phi^{n-1}\right)\sigma_{01} + \left(1-\phi^{2(n-1)}\right)\sigma_0^2\right] - \left(1-\phi^{n-1}\right)u_{0,t+1}$$

Then the unexpected return is

$$r_{t+1,n}^{b}-E_{t}r_{t+1,n}^{b}=-\left(1-\phi^{n-1}\right)u_{0,t+1}$$

long run bond return has the unexpected return by setting $n\rightarrow\infty$

$$r_{t+1,\infty}^{b}-E_{t}r_{t+1,\infty}^{b}=-u_{0,t+1}$$

This basically says that the bond return is driven only by the transitory shocks of the pricing kernel. For equity returns, we need both shocks. Finally the risk free interest rate is obtained by setting $n=1$

$$i_{t+1}=\phi i_{t}+a-(\phi-1)\,u_{0,t+1}.$$

Finally, we have:

$$\sum_{j=1}^{\infty}E_{t}\left(l_{t+j}-\bar{l}\right)=\Big(\frac{i_{t}^{*}}{1-\phi^{*}}+\frac{\frac{1}{2}\sigma_{w}^{*2}-\nu^{*}}{1-\phi^{*}}-\frac{i_{t}}{1-\phi}-\frac{\frac{1}{2}\sigma_{w}^{2}-\nu}{1-\phi}\Big)-s_{t}^{T} \tag{8}$$

This final expression, which contains the risk premium l_t on the left-hand-side, links the short-term interest rate, the persistence of short rate, and the temporary component of exchange rate in one equation. This simple and stylized model allows us to estimate the persistence of short rate by taking advantage of the term structure of bond prices within a single country, and fails to generate implications to currency risk premium.

6.2 Estimation via Kalman filter

We follow the term structure of interest rates literature to estimate the model using the Kalman filter[9]. Since our goal is to forecast risk premium, we choose the most parsimonious approach possible and focus on the persistence of the transitory component of pricing kernel ϕ only. We

[9]Our estimation is conducted within countries. For the currency risk premium implied in a multi-country affine term structure model, see Backus, Foresi, and Telmer (2001). Sarno, Schneider, and Wagner (2012) estimate a global affine term structure model to study the currency risk premium.

estimate the $\bar{\imath}$ from the data to avoid joint estimation of variances of the permanent and transitory components, as that of the permanent component would require equity data, given the entropy bound implied by Alvarez and Jermann (2005).

We have from our model:

$$\begin{aligned} r^b_{t+1,T} &= -\frac{1}{2}Var_t\left[\phi^{T-1}u_{0,t+1}+u_{1,t+1}\right] - E_{t-1}\Delta m_t\phi - \left(1-\phi^{T-1}\right)u_{0,t+1} \\ E_t\left[\Delta m_{t+1}\right] &= -\nu\left(1-\phi\right) + E_{t-1}\left[\Delta m_t\right]\phi + \left(\phi-1\right)u_{0,t} \end{aligned}$$

Then, we have a state space expression. Let $y_{t+1} = r^b_{t+1,T}$, $x_t = E_t\Delta m_{t+1}$, then the measurement equation becomes:

$$y_t = -\frac{1}{2}Var_t\left[\phi^{T-1}u_{0,t+1}+u_{1,t+1}\right] + \begin{bmatrix} 0 & -1 & -\left(1-\phi^{T-1}\right) \end{bmatrix}\begin{bmatrix} x_t \\ x_{t-1} \\ u_t \end{bmatrix} + \sqrt{\tau_i}u_t$$

where we assume bond returns contain measurement error, which are proportional to the maturity dates following the affine term structure model literature. Therefore, the transition equation becomes:

$$\begin{bmatrix} x_{t+1} \\ x_t \\ u_{t+1} \end{bmatrix} = \begin{bmatrix} -\nu\left(1-\phi\right) \\ 0 \\ 0 \end{bmatrix} + \begin{bmatrix} \phi & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}\begin{bmatrix} x_t \\ x_{t-1} \\ u_t \end{bmatrix} + \begin{bmatrix} \phi-1 \\ 0 \\ 1 \end{bmatrix}u_{t+1}$$

We can then put this equation in a standard form:

$$\begin{pmatrix} \alpha_{t+1} \\ y_t \end{pmatrix} = \delta + \mathbf{\Phi}\alpha_t + \varepsilon_t,\ \ \varepsilon_t \sim \text{NID}\left(0,\Omega\right)$$

where

$$
\begin{aligned}
\delta &= \begin{bmatrix} -\nu\left(1-\phi\right) \\ 0 \\ 0 \\ -\frac{1}{2}Var_t\left[\phi^{T-1}u_{0,t+1}+u_{1,t+1}\right] \end{bmatrix}, \\
\mathbf{\Phi} &= \begin{bmatrix} \phi & 0 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & -1 & -\left(1-\phi^{T-1}\right) \end{bmatrix}, \\
\Omega &= \begin{bmatrix} \left(\phi-1\right)^2 & 0 & \phi-1 & 0 \\ 0 & 0 & 0 & 0 \\ \phi-1 & 0 & 1 & 0 \\ 0 & 0 & 0 & \tau \end{bmatrix}\sigma_0^2.
\end{aligned}
$$

Table 1: Summary statistics of foreign currency market returns for each country

country	min	mean	median	max	std. dev.	skewness	autocorr
Australia	-187.73	4.47	5.47	115.13	11.32	-0.48	0.08
Germany	-127.35	1.18	1.43	116.53	11.26	-0.01	0.08
Belgium	-132.86	2.99	3.65	116.56	11.03	-0.16	0.08
Canada	-142.19	2.36	2.77	112.97	7.14	-0.28	-0.03
Czech	-137.72	9.39	9.94	122.90	13.26	-0.27	0.04
Denmark	-124.17	3.67	5.28	121.71	10.83	-0.11	0.08
EMU	-115.15	4.69	2.77	119.65	10.78	-0.07	0.05
Spain	-117.37	1.90	3.57	116.56	10.94	-0.26	0.10
Finland	-152.23	0.67	3.19	116.37	11.47	-0.24	0.10
France	-123.79	2.94	3.97	116.56	10.75	-0.20	0.07
Greece	-119.19	4.72	2.53	115.45	10.87	-0.04	0.08
Hungary	-206.44	10.60	15.05	144.78	14.73	-0.95	0.08
Ireland	-219.21	2.47	2.59	134.61	12.92	-0.50	0.14
Italy	-145.58	1.84	3.09	116.56	10.79	-0.29	0.12
Japan	-121.33	2.12	0.10	203.14	11.58	0.51	0.04
Netherland	-128.76	1.23	1.74	116.55	11.28	0.01	0.09
Norway	-144.83	3.20	4.24	94.81	10.87	-0.27	0.11
New Zealand	-151.39	5.21	6.85	159.78	11.26	-0.20	0.06
Austria	-123.33	2.49	2.61	116.31	10.89	-0.17	0.10
Poland	-173.39	7.77	8.76	122.75	15.02	-0.68	0.14
Portugal	-117.06	2.14	3.09	116.56	10.19	-0.00	0.08
South Africa	-174.00	12.49	15.95	161.72	18.11	-0.45	-0.02
Sweden	-172.90	2.70	3.64	110.66	11.44	-0.32	0.15
Switzerland	-119.03	1.56	-0.14	162.61	11.92	0.29	0.04
UK	-143.18	1.32	0.03	178.54	10.64	0.06	0.12

This table reports the summary statistics of foreign currency market excess return for each country. The sample period is 1982:07$\sim$2011:08. For each country, we report the min, median, mean, max and std. dev., skewness, and autocorrelation of returns. The mean, std dev, max, and min of returns are expressed in percentage per annum.

Table 2: Summary statistics of ϕ estimates

country	OLS estimation of ϕ				
	min	mean	median	max	std. dev.
Australia	0.758	0.944	0.965	0.969	0.053
Germany	0.722	0.969	0.979	0.989	0.034
Belgium	0.789	0.945	0.973	0.986	0.047
Canada	0.732	0.955	0.976	0.989	0.062
Czech	0.974	0.990	0.985	1.071	0.018
Denmark	0.430	0.790	0.837	1.165	0.132
EMU	0.954	0.987	0.991	1.001	0.012
Spain	0.332	0.895	0.961	0.979	0.131
Finland	0.432	0.936	0.969	0.975	0.105
France	0.594	0.850	0.912	0.958	0.105
Greece	0.967	0.973	0.970	1.004	0.008
Hungary	0.916	0.944	0.947	1.004	0.015
Ireland	0.500	0.755	0.783	1.134	0.102
Italy	0.613	0.947	0.989	0.997	0.089
Japan	0.313	0.935	0.994	0.999	0.148
Netherland	0.794	0.960	0.970	0.989	0.025
Norway	0.029	0.669	0.750	0.859	0.235
New Zealand	0.001	0.860	0.892	0.932	0.118
Austria	0.757	0.954	0.977	0.989	0.057
Poland	0.945	0.950	0.949	0.971	0.005
Portugal	0.782	0.937	0.954	0.963	0.039
South Africa	0.940	0.981	0.980	1.001	0.010
Sweden	0.652	0.839	0.875	0.948	0.095
Switzerland	0.913	0.958	0.968	0.983	0.022
UK	0.848	0.962	0.974	0.989	0.025
US	0.680	0.944	0.961	0.978	0.047
Cross country	0.001	0.899	0.960	1.165	0.100

This table reports the summary statistics of ϕ estimated by ordinary least squares (OLS). Sample period is 1980:01$\sim$2011:08. For each country, we report the min, median, mean, max and std dev of ϕ estimated, and also report the cross country time-series average.

Table 3: Summary statistics of ϕ estimates

country	Kalman filter estimation of ϕ				
	min	mean	median	max	std. dev.
Australia	0.860	0.903	0.906	0.910	0.011
Germany	0.914	0.961	0.986	0.988	0.032
Belgium	0.976	0.979	0.979	0.981	0.001
Canada	0.965	0.966	0.966	0.968	0.001
Czech	0.979	0.981	0.981	0.984	0.001
Denmark	0.916	0.972	0.975	0.979	0.014
EMU	0.951	0.954	0.954	0.957	0.002
Spain	0.845	0.889	0.890	0.891	0.004
Finland	0.882	0.885	0.886	0.886	0.000
France	0.845	0.918	0.918	0.955	0.005
Greece	0.905	0.907	0.907	0.908	0.001
Hungary	0.759	0.894	0.895	0.902	0.013
Ireland	0.702	0.845	0.861	0.942	0.061
Italy	0.860	0.875	0.875	0.877	0.002
Japan	0.718	0.971	0.978	0.983	0.046
Netherland	0.826	0.868	0.867	0.903	0.008
Norway	0.913	0.924	0.922	0.961	0.010
New Zealand	0.883	0.888	0.888	0.889	0.001
Austria	0.836	0.920	0.941	0.946	0.030
Poland	0.895	0.896	0.896	0.896	0.000
Portugal	0.865	0.868	0.868	0.868	0.001
South Africa	0.899	0.913	0.914	0.924	0.007
Sweden	0.868	0.873	0.874	0.874	0.001
Switzerland	0.770	0.844	0.855	0.856	0.024
UK	0.922	0.937	0.936	0.945	0.005
US	0.876	0.917	0.922	0.935	0.014
Cross country	0.702	0.910	0.911	0.988	0.049

This table reports the summary statistics of ϕ' estimated by Kalman filter. Sample period is 1980:01$\sim$2011:08. For each country, we report the min, median, mean, max and std dev of ϕ estimated, and also report the cross country time-series average.

Table 4: Currency portfolios

	Carry			χ			χ'		
	EW	HML	OLS	EW	HML	OLS	EW	HML	OLS
Mean	1.490	4.215	2.213	1.732	6.250	2.688	2.078	6.236	2.759
Std dev	4.486	9.973	4.523	3.887	8.050	4.220	4.370	8.030	3.523
SR	0.332	0.423	0.489	0.446	0.776	0.637	0.476	0.777	0.783
Max	61.852	97.348	48.441	56.564	101.184	52.001	106.804	97.393	42.300
Min	-95.500	-151.036	-63.607	-95.500	-99.659	-75.330	-95.500	-126.507	-53.436
Skew	-0.719	-0.780	-0.621	-1.161	-0.082	-0.699	1.482	-0.311	-0.260
AR(1)	0.087	0.087	0.039	0.047	0.061	0.014	-0.082	0.014	0.021

This table considers three different predictors and each with three portfolio formation strategies. Our sample includes 25 currencies, and we remove all the currencies in the euro zone when they all adopted the euro after 1999:01 (resulting in 14 currencies thereafter). The table reports out-of-sample Equally-weighted (EW), High-minus-Low (HML), and OLS portfolio performances. The sample period is 1982:07~2011:08. We consider three predictors: a regular carry (interest rate differential), a prospective interest rate differential estimated using OLS regression (χ) and a prospective interest rate differential estimated using Kalman filter (χ'), and report the mean, std dev, max, min, and autocorrelation of each portfolio. The mean, std dev, max, and min of returns are expressed in percentage per annum. The Sharpe ratios are annualized for convenience of comparison.

Table 5: Asset pricing tests

	EW portfolio return				HML portfolio return				OLS portfolio return			
Panel A: χ												
MKT	0.015	0.019	0.023		0.038	0.045	0.051		0.015	0.018	0.025	
	(1.16)	(1.41)	(1.59)		(1.20)	(1.35)	(1.46)		(1.03)	(1.19)	(1.66)	
SMB		-0.018	-0.019			0.028	0.027			0.049	0.047	
		(0.89)	(0.96)			(0.63)	(0.61)			(1.86)	(1.86)	
HML		0.007	0.012			0.057	0.064			0.050	0.059	
		(0.33)	(0.56)			(1.10)	(1.24)			(1.94)	(2.18)	
MOM			0.015				0.022				0.026	
			(1.42)				(0.87)				(1.76)	
RX				0.159				0.396				0.079
				(2.67)				(4.68)				(2.11)
LRV HML				0.047				0.138				0.111
				(2.01)				(2.31)				(3.50)
alpha	0.147	0.144	0.132	0.109	0.497	0.471	0.453	0.383	0.215	0.191	0.169	0.161
	(2.38)	(2.25)	(2.05)	(1.76)	(4.09)	(3.82)	(3.69)	(3.42)	(3.49)	(3.10)	(2.65)	(2.59)
R2	0.001	-0.002	-0.001	0.093	0.004	0.004	0.003	0.173	0.001	0.019	0.026	0.079
Panel B: χ'												
MKT	0.012	0.015	0.016		0.071	0.088	0.100		0.048	0.054	0.059	
	(0.97)	(1.00)	(0.97)		(2.29)	(2.65)	(2.95)		(3.17)	(3.45)	(3.57)	
SMB		-0.002	-0.002			0.009	0.006			0.030	0.029	
		(0.10)	(0.11)			(0.19)	(0.13)			(1.56)	(1.54)	
HML		0.010	0.011			0.090	0.104			0.053	0.059	
		(0.39)	(0.42)			(1.74)	(2.02)			(2.33)	(2.51)	
MOM			0.004				0.044				0.017	
			(0.31)				(1.49)				(1.46)	
RX				0.355				0.367				0.106
				(4.97)				(4.06)				(2.85)
LRV HML				-0.035				0.229				0.126
				(1.01)				(3.83)				(4.51)
alpha	0.180	0.176	0.173	0.134	0.475	0.435	0.398	0.353	0.200	0.176	0.161	0.152
	(2.60)	(2.46)	(2.38)	(2.12)	(3.99)	(3.53)	(3.20)	(3.24)	(3.85)	(3.34)	(3.05)	(3.04)
R2	-0.001	-0.006	-0.009	0.278	0.019	0.028	0.033	0.206	0.050	0.072	0.076	0.182

This table examines the risk-based explanations of portfolio returns. Panels A and B report the asset pricing tests on portfolio returns formed using χ and χ', separately. For each panel, we conduct factor regressions on EW, HML, and OLS portfolios separately. We consider 4 asset pricing models: CAPM, FF three-factor model (MKT, SMB and FF HML), FF three-factor augmented with MOM, and a two-factor currency market asset pricing model à la Lustig, Roussanov and Verdelhan (2011): RX and HML_{FX}. The sample period is 1982:07$\sim$2011:08, except 1983:11$\sim$2011:08 for the LRV model. Newey-West standard errors are used to calculated the significance of α in each model.

Table 6: Explaining factors

	Panel A: χ factors		Panel B: χ' factors	
	RX	HML_{FX}	RX	HML_{FX}
EW	0.269		0.763	
	(1.34)		(9.63)	
HML	0.253		-0.013	
	(2.77)		(0.14)	
EW		0.037		-0.506
		(0.23)		(3.27)
HML		0.299		0.573
		(2.49)		(5.37)
alpha	-0.021	0.242	0.011	0.209
	(0.19)	(1.59)	(0.09)	(1.43)
R2	0.122	0.050	0.254	0.125

This table examines the explanatory power of our portfolio returns on the currency risk factors. Panels A and B report the regressions of risk factors à la Lustig, Roussanov and Verdelhan (2011): RV and HML_{FX}, on the portfolio returns formed using χ and χ', separately. For each panel, we conduct factor regressions on RV and HML_{FX} separately. The sample period is 1983:11$\sim$2011:08. Newey-West standard errors are used to calculated the significance of α in each model.

Table 7: Effect of real interest rates

	Real Carry			Real χ		
	EW	HML	OLS	EW	HML	OLS
Mean	1.988	2.983	1.069	0.957	4.337	0.501
Std dev	3.943	7.267	3.649	3.995	7.095	2.913
SR	0.504	0.411	0.293	0.239	0.611	0.172
Max	67.849	67.389	50.043	68.827	105.685	44.577
Min	-80.437	-89.858	-46.349	-80.437	-68.424	-34.554
Skew	0.189	-0.682	-0.324	0.304	0.198	0.219
AR(1)	-0.054	-0.05	0.008	-0.054	0.008	0.013

This table reports portfolio results based on real carry and real χ strategies. Our sample includes 25 currencies, and we remove all the currencies in the euro zone when they all adopted the euro after 1999:01 (resulting in 14 currencies thereafter). The table reports out-of-sample Equally-weighted (EW), High-minus-Low (HML), and OLS portfolio performances. The sample period is 1982:07$\sim$2011:08. We consider two strategies based on real interest rates: a real carry and a real χ, and report the mean, std dev, max, min, and autocorrelation of each portfolio. The mean, std dev, max, and min of returns are expressed in percentage per annum. The Sharpe ratios are annualized for convenience of comparison.

Table 8: Currency momentum

	Momentum			χ			χ'		
	EW	HML	OLS	EW	HML	OLS	EW	HML	OLS
Mean	1.991	2.746	1.236	1.732	6.25	2.688	2.078	6.236	2.759
Std dev	5.51	8.64	4.251	3.887	8.05	4.22	4.37	8.03	3.523
SR	0.361	0.318	0.291	0.446	0.776	0.637	0.476	0.777	0.783
Max	94.204	143.451	62.492	56.564	101.184	52.001	106.804	97.393	42.3
Min	-106.804	-92.435	-53.205	-95.5	-99.659	-75.33	-95.5	-126.507	-53.436
Skew	-0.22	0.262	0.136	-1.161	-0.082	-0.699	1.482	-0.311	-0.26
AR(1)	0.042	-0.045	0.024	0.047	0.061	0.014	-0.082	0.014	0.021

This table considers the currency momentum strategy. Our sample includes 25 currencies, and we remove all the currencies in the euro zone when they all adopted the euro after 1999:01 (resulting in 14 currencies thereafter). The table reports out-of-sample Equally-weighted (EW), and High-minus-Low (HML), and OLS portfolio performances. The sample period is 1982:07$\sim$2011:08. We focus on the currency momentum strategy and compare it with the portfolios formed by *pi* and χ', and report the mean, std dev, max, min, and autocorrelation of each portfolio. The mean, std dev, max, and min of returns are expressed in percentage per annum. The Sharpe ratios are annualized for convenience of comparison.

Table 9: Alternative strategies

	$[\frac{i_t^*}{1-\hat{\phi}^*} - \frac{i_t}{1-\hat{\phi}}]$			$[\frac{i_t^*-\bar{\imath}^*}{1-\hat{\phi}^*} - \frac{i_t-\bar{\imath}}{1-\hat{\phi}} - s^T]$		
	EW	HML	OLS	EW	HML	OLS
Mean	0.838	3.590	1.632	-0.459	-0.105	0.089
Std dev	2.497	6.789	2.658	2.894	7.068	2.800
SR	0.335	0.529	0.614	-0.159	-0.015	0.032
Max	37.934	88.405	43.931	48.678	73.870	24.961
Min	-38.539	-104.202	-32.378	-95.500	-120.237	-43.494
Skew	0.155	-0.336	0.207	-3.232	-0.560	-0.587
AR(1)	0.082	0.006	-0.073	-0.039	0.074	0.088

This table considers two alternative strategies, the first one exclude the estimation of long run trend, while the second incorporates the estimation of transitory component of exchange rate. Our sample includes 25 currencies, and we remove all the currencies in the euro zone when they all adopted the euro after 1999:01 (resulting in 14 currencies thereafter). The table reports out-of-sample Equally-weighted (EW), High-minus-Low (HML), and OLS portfolio performances. The sample period is 1982:07∼2011:08. We consider two variations of χ' strategies: the un-demeaned χ $([\frac{i_t^*}{1-\hat{\phi}^*} - \frac{i_t}{1-\hat{\phi}}])$ and the χ' minus the transitory component $([\frac{i_t^*-\bar{\imath}^*}{1-\hat{\phi}^*} - \frac{i_t-\bar{\imath}}{1-\hat{\phi}} - s^T])$, and report the mean, std dev, max, min, and autocorrelation of each portfolio. The mean, std dev, max, and min of returns are expressed in percentage per annum. The Sharpe ratios are annualized for convenience of comparison.

Table 10: Different currencies

	Carry			χ			χ'		
	EW	HML	OLS	EW	HML	OLS	EW	HML	OLS
Mean	1.487	4.332	2.401	1.671	5.786	2.273	2.040	5.756	2.224
Std dev	4.495	8.945	4.566	3.680	7.599	3.945	4.242	7.435	3.119
SR	0.331	0.484	0.526	0.454	0.761	0.576	0.481	0.774	0.713
Max	61.852	88.405	53.100	56.564	101.184	41.181	106.804	97.393	42.300
Min	-95.500	-109.683	-58.950	-95.500	-95.753	-76.244	-95.500	-104.353	-51.183
Skew	-0.673	-0.694	-0.462	-1.218	0.071	-0.878	1.701	-0.030	0.089
AR(1)	0.079	0.045	0.023	0.041	0.085	0.058	-0.089	0.034	0.067

This table considers a different set of currencies, 19 currencies as in Burnside (2011). The table reports out-of-sample Equally-weighted (EW), High-minus-Low (HML), and OLS portfolio performances. The sample period is 1982:07$\sim$2011:08. We consider three predictors: a regular carry (interest rate differential), a prospective interest rate differential estimated using OLS regression (χ) and a prospective interest rate differential estimated using Kalman filter (χ'), and report the mean, std dev, max, min, and autocorrelation of each portfolio. The mean, std dev, max, and min of returns are expressed in percentage per annum. The Sharpe ratios are annualized for convenience of comparison.

Table 11: Long horizon panel predictability of excess returns

	Panel A: Pooling regression											
	1 month			2 month			3 month			4 month		
carry	1.0016**		0.7085	0.9825**		0.6937	0.9269**		0.6470*	0.9456***		0.6660*
	(2.058)		(1.437)	(2.350)		(1.628)	(2.498)		(1.680)	(2.878)		(1.934)
$\chi' - c$		0.0506***	0.0293**		0.0497***	0.0289***		0.0475***	0.0280***		0.0481***	0.0280***
		(2.743)	(2.429)		(3.171)	(2.910)		(3.326)	(2.839)		(3.547)	(2.796)
	5 month			6 month			9 month			12 month		
carry	0.9409***		0.6565**	0.9265***		0.6490**	0.8809***		0.5984**	0.8182***		0.5232**
	(3.136)		(2.058)	(3.389)		(2.209)	(3.998)		(2.446)	(4.115)		(2.304)
$\chi' - c$		0.0483***	0.0285***		0.0474***	0.0278***		0.0465***	0.0284***		0.0456***	0.0296***
		(3.748)	(2.804)		(3.834)	(2.711)		(4.277)	(2.884)		(4.494)	(3.054)
	Panel B: Fixed effects regression											
	1 month			2 month			3 month			4 month		
carry	1.2302*		0.7598	1.2089*		0.7441	1.1290**		0.6730	1.1622**		0.7088
	(1.683)		(0.943)	(1.938)		(1.082)	(2.074)		(1.111)	(2.434)		(1.343)
$\chi' - c$		0.0649**	0.0390*		0.0639***	0.0385**		0.0608***	0.0378**		0.0618***	0.0376**
		(2.443)	(1.765)		(2.863)	(2.121)		(3.026)	(2.151)		(3.249)	(2.169)
	5 month			6 month			9 month			12 month		
carry	1.1449***		0.6925	1.0986***		0.6315**	1.0270***		0.5259*	1.1592***		0.6949
	(2.954)		(1.635)	(3.566)		(1.964)	(3.716)		(1.871)	(2.686)		(1.461)
$\chi' - c$		0.0612***	0.0375**		0.0604***	0.0388**		0.0596***	0.0416***		0.0622***	0.0385**
		(3.536)	(2.185)		(3.882)	(2.410)		(4.033)	(2.651)		(3.447)	(2.230)

This table reports long horizon (1, 2, 3, 4, 5, 6, 9, and 12 months) panel predictive regression of foreign exchange market excess returns. Sample period is 1982:07∼2011:08. To facilitate comparison, we trim the shorter horizon panel regression sample sizes to equal that of longer horizon panel regression sample sizes. We remove all the currencies in the euro zone, when they all adopted euro after 1999:01 (14 currencies). The dependent variable is different horizon excess return, and the predictors used are in turn a regular 'carry' (interest rate differential), our 'χ'' predictor minus 'carry' ($\chi' - c$) and both. Panel A reports the results with pooling regressions and Panel B reports fixed effect regression results. In fixed effect regressions, month-specific effects are not reported to save space. Two-way clustered standard errors are used to compute the t-statistics (reported in parentheses) and significance at the 1%, 5%, and 10% level is indicated by ***, **, and *, respectively.

Table A.1: Default-free bond indexes from Datastream

country	beginning month	Maturities									
		02	03	05	07	10	15	20	30	50	Total
Australia	198702	1	1	1	1	1					5
Germany	197912	1	1	1	1	1		1	1		7
Belgium	198412	1	1	1	1	1	1		1		7
Canada	198412	1	1	1	1	1		1	1		7
Czech	200004	1	1	1	1	1	1				6
Denmark	198412	1	1	1	1	1		1			6
EMU	199901	1	1	1	1	1	1	1	1		8
Spain	198812	1	1	1	1	1	1		1		7
Finland	198910		1	1		1					3
France	198412	1	1	1	1	1	1	1	1	1	9
Greece	199903	1	1	1		1	1				5
Hungary	199901	1	1	1		1					4
Ireland	198412		1	1	1	1	1				5
Italy	198812	1	1	1	1	1	1		1		7
Japan	198112	1	1	1	1	1	1	1	1		8
Netherland	197912	1	1	1	1	1			1		6
Norway	198812			1	1	1					3
New Zealand	198812	1	1	1	1	1					5
Austria	198412	1	1	1	1	1			1		6
Poland	200012	1	1	1	1	1		1			6
Portugal	199211	1	1	1	1	1					5
South Africa	200008		1	1	1	1			1		5
Sweden	198412	1	1	1	1	1	1				6
Switzerland	198012	1	1	1	1	1					5
UK	197912	1	1	1	1	1	1	1	1	1	9
US	197912	1	1	1	1	1			1		6
		22	25	26	23	26	11	8	13	2	156

This table reports the data availability of default-free bond index from Datastream. For each country, we report the first month the data on bond indexes become available (i.e., beginning month), and the ending month is uniformly 2011:08. We also report a '1' when data on a specific maturity of default-free bond index is in the sample.

Table A.2: Summary statistics of θ estimates

country	min	mean	median	max	std. dev.
Australia	0.183	0.756	0.798	0.862	0.121
Germany	0.042	0.633	0.650	0.756	0.125
Belgium	0.568	0.778	0.766	0.903	0.064
Canada	0.630	0.755	0.775	0.844	0.049
Czech	0.636	0.712	0.685	1.190	0.086
Denmark	0.084	0.697	0.759	0.934	0.155
EMU	0.166	0.628	0.601	0.797	0.101
Spain	0.571	0.838	0.867	0.911	0.074
Finland	-0.217	0.748	0.890	0.920	0.277
France	-0.095	0.603	0.588	1.100	0.103
Greece	0.529	0.775	0.845	0.868	0.110
Hungary	0.009	0.370	0.388	0.436	0.071
Ireland	-0.051	0.474	0.448	0.663	0.155
Italy	0.209	0.509	0.463	0.729	0.121
Japan	0.465	0.697	0.725	0.783	0.083
Netherland	0.425	0.870	0.912	0.945	0.092
Norway	-0.013	0.463	0.556	0.718	0.188
New Zealand	-0.016	0.343	0.372	0.524	0.140
Austria	-0.203	0.672	0.701	0.787	0.162
Poland	-0.109	0.669	0.768	0.788	0.220
Portugal	0.172	0.629	0.743	0.788	0.187
South Africa	0.476	0.658	0.663	0.787	0.075
Sweden	-0.021	0.343	0.311	0.640	0.170
Switzerland	-0.199	0.774	0.786	0.909	0.099
UK	-0.207	0.699	0.757	0.852	0.130
US	0.525	0.707	0.755	0.852	0.093
Cross country	-0.217	0.646	0.706	1.190	0.181

This table reports the summary statistics of θ estimated by AR(1) regression. The sample period is 1980:01$\sim$2011:08. For each country, we report the min, median, mean, max, and std dev of θ estimated, and also report the cross-country time-series average.