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The Term Structure of Currency Futures' Risk Premia

The use of futures instead of forwards exchange contracts completes the maturity spectrum of the correlation between spot yields and the premium. We find that the forward premium puzzle appears to be a precrisis phenomenon and is only observed for maturities longer than about 1 month. Differences in the exposure to risk help to explain cross-sectional spreads in currency excess returns. However, this only applies for medium and longer maturities. Considering that most studies that test the validity of a risk-based approach to currency excess returns focus on short maturity securities, this explains why this approach is so often rejected.

JEL codes: F31, F37, G12, G13, G15
Keywords: forward premium puzzle, uncovered interest parity, futures rates, price of risk, currency excess returns, capital asset pricing model

According to the expectations hypothesis (EH), forward exchange rates are unbiased predictors of future spot exchange rates. As a consequence, currency excess returns should be zero on average over time and across

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currencies. This hypothesis is an important building block of models of international macroeconomics and finance. It manifests itself also in the form of the well-known uncovered interest parity (UIP) condition. However, empirical support is weak at best. Fama (1984) was the first to report that, in a regression of foreign exchange returns on forward premia, the estimated slope coefficient is negative rather than one. This phenomenon is known as the "forward premium puzzle" (FPP). Lustig and Verdelhan (2007) added that the UIP fails not only in the time series of individual currencies but also in the cross-section; high-yield currencies tend to produce positive excess returns, while low-yield currencies generate negative excess returns, which explains large and sustained carry trade gains.

The first contribution of our paper is that we close existing gaps in the overall picture of currency excess returns. More specifically, we analyze the time series of individual currencies and the cross-section of currency excess returns for the entire available term structure. This is possible due to using futures instead of forward data. While data for forward contracts are available only for fixed maturity *horizons*, futures contracts have fixed delivery *dates*. Since futures contracts are traded in secondary markets, this makes it possible to analyze futures rates from the first to the last trading day of a given contract and to construct the full maturity spectrum of futures premia in daily units. While differences in trading mechanisms, default, or liquidity premia between forward and futures contracts might somewhat cloud the comparability of the two, empirical studies suggest that this is not the case.[1] Only the early paper by Hodrick and Srivastava (1987) uses data from 3-months futures contracts to test a hypothesis related to the EH. To the best of our knowledge, no paper has exploited these data to obtain the estimates at the daily grid level.

We examine the behavior of exchange rates for the United States relative to all countries for which currency futures have been traded at the Chicago Merchantile Exchange. These comprise nine developed countries and six emerging market economies. The time period covered is 1979Q1–2018Q4 and we consider futures rates with a time to maturity ranging between 1 day and one and a half years.

Focusing first on time series of individual currencies, we find that the slope coefficient in a regression of the spot exchange rate return on the futures premium ("Fama regression") depends significantly on the maturity horizon of the futures contract and on the choice of sampling period. For maturities shorter than about a month, it is generally positive, and the EH is not rejected by the data. For longer maturity horizons, however, the sign and also size of the slope coefficient depend on the time period covered. Focusing on the period before the global financial crisis, the slope coefficient tends to become negative as the maturity horizon over which expectations are formed increases. This finding is consistent with the often described FPP and indicates that a currency tends to appreciate when the futures premium would indicate a depreciation and vice versa. When focusing on the postcrisis period, however, we cannot reject

1. See, for example, Cornell and Reinganum (1981), Hodrick and Srivastava (1987), Chang and Chang (1990), and Polakoff and Grier (1991).

the validity of the EH for most currencies and maturities. In the few cases where there are significant deviations from the EH, these are upward rather than downward: A currency whose futures premium predicts an expected appreciation actually appreciates, but by more than the EH indicates. All in all, we confirm the findings by Thornton (2007) and Kim et al. (2017) that violations of the EH or UIP vary considerably across periods. More specifically, we find that the FPP/UIP violation in the time series of individual currencies appears to be very much a precrisis phenomenon for most currencies and is only evident for medium to longer maturities.

Our paper is closely related to a strand of literature, suggesting that maturity of derivative contracts matters for the validity of the EH. Chaboud and Wright (2005) and Yang and Shintani (2006) give estimates at very short maturities at the intraday or overnight horizon. Alexius (2003), Chinn and Meredith (2004), and Fama and Bliss (1987), and more recently Engel (2016) look at the other end of the spectrum, even going as far as considering multiyear horizons.[2] Most papers focus on intermediate horizons by using monthly forward data starting at 1 month up to several months. Examples in this category are Froot and Frankel (1989), Backus et al. (2001), Baillie and Kilic (2006), and Clarida et al. (2009). The summary finding from these papers is that the EH may hold at the very short term and in the very long run. But significant deviations are reported for intermediate periods, mostly negative and sometimes positive. At intermediate periods, however, the evidence is rather granular as it contains relative long gaps since monthly data are used, so that only evidence at the 1 month, 2 month, etc., horizons is available.

In the next step, we analyze the cross-section of currency excess returns over the entire maturity spectrum. For this, we build similarly to Lustig and Verdelhan (2007), Menkhoff et al. (2012), and Lustig et al. (2011) portfolios of currencies sorted by their futures discounts. We find that on average a U.S. investor generates negative excess returns on currencies with small futures premia. For currencies with the largest futures discounts, the excess returns are generally positive, rising to up to 3% as the maturity increases. Consequently, the zero cost (carry trade) strategy, which goes long in the portfolio with high futures premia and short in the portfolio with low futures premia, provides significant positive returns. Furthermore, these positive carry trade returns grow monotonically with the maturity of the futures contracts. To our knowledge, this result has not been described in the literature so far.

A second contribution of the this paper is that we test over the entire maturity spectrum, whether the observed excess returns on futures contracts reflect a fair compensation for currency risk.[3] As stressed by Burnside (2011) and Barroso and Santa-Clara (2015), one criticism of a risk-based explanation is that general proxies

2. It is worth mentioning that Engel (2016) attributes the multiperiod excess return to the one-period interest rate differentials. Therefore, the maturities of assets and interest rates do not coincide.

3. In a previous paper entitled "Estimating a Latent Risk Premium in Exchange Rate Futures," we took a different approach and derived a methodology to correct the bias in the Fama regression caused by the existence of a latent risk premium. This allowed us to test whether the unbiased Fama coefficient is actually one and therefore consistent with the EH.

of systematic risk are very often estimated to be uncorrelated with currency returns.[4] We add to this discussion by arguing that asset maturity plays a critical role in whether or not currency excess returns reflect exposure to risk. In examining the validity of different types of linear asset pricing models in connection with currency excess returns, the literature has so far concentrated only on selected maturities of usually 1 or 3 months. The novelty of our paper is that the use of futures exchange rates instead of forwards allows us to estimate the CAPM-based model for the entire term structure. This allows us to shed light on why the results in the relevant literature are so heterogeneous and sometimes contradictory; see, for instance, the debate between Lustig and Verdelhan (2007), ,2011) and Burnside (2011).

Theoretical models such as the capital asset pricing model (CAPM) or the arbitrage pricing theory (APT) suggest that the expected excess returns should be linear in asset betas with respect to risk factors. Different variables have been suggested in the literature to measure risk. The static CAPM model proposes market risk measured by excess stock market returns (Jensen 1972). The intertemporal CAPM suggests the marginal rate of substitution of consumption over time as a common factor, most often expressed as a function of the growth rate of consumption (Merton 1973, Breeden 1979). Lustig et al. (2011) find that sufficient heterogeneity in the exposure of countries to global or common innovations can explain both cross-sectional differences in currency excess returns and conditional deviations from the UIP. They show that the "High Minus Low" (HML) carry factor, which measures the return on a zero cost strategy that goes long in currencies with high forward premia and short in currencies with low forward premia, identifies these common shocks. Other global risk factors were also proposed, such as the global currency volatility factor (Menkhoff et al. 2012) or the FX correlation risk factor (Mueller et al. 2017). For reasons of space, we cannot examine the relevance of all these potential risk factors. However, market risk and consumption risk are the most frequently discussed risk factors in connection with currency excess returns. By focusing on these, we also contribute to the debate between Lustig and Verdelhan (2007), ,2011) and Burnside (2011). Moreover, we also use the HML carry factor as a measure for global risk, which is now used as the "standard" factor to control for when estimating CAPM models on carry trades (Lustig et al. 2011, ,2014, Orlov 2016, Colacito et al. 2018).

We show that all three, market, consumption, and carry trade risk are important drivers of risk premia in the cross-section of currency excess returns. High futures premium currencies load more on these risk factors than low futures premium currencies. Each of the three factors accounts for most of the cross-sectional variation in average excess returns. When applying a joint asset pricing test, the HML carry factor appears to dominate both the market and consumer risk factor. This result

4. A recent branch of the literature argues that the weak link between standard risk factors and currency excess returns can be overcome by considering a CAPM version that distinguishes between exposure to factor risk in periods of low returns (downside risk) and in periods of high returns (upside risk) (Lettau et al. 2014, Atanasov and Nitschka 2014).

supports the finding of Lustig et al. (2011), who argue that it is global factors that are important to explain cross-sectional differences in currency excess returns.

However, we find that the pricing power of our risk measures only applies when the maturity of the assets is longer than about 3 months. Considering that most studies that test the validity of a risk-based approach to currency excess returns focus on short maturities of 1 or 3 months, our results serve as an explanation for why this approach is so often rejected. Our findings suggest that these studies simply considered maturities too short to confirm the risk-based approach to currency returns. Moreover, when focusing on the postcrisis period only, we reject that currency excess returns reflect a compensation for risk. One possible explanation is that the relationship between exchange rate returns and futures premia is distorted in this period due to a conflict between exchange rate policy and the zero lower bound of nominal interest rates, as also noted by Amador et al. (2020).

The remainder of this paper proceeds as follows. Section 1 investigates the relationship between the spot return and the futures premium over the complete maturity spectrum ranging from 2 days up to one and a half years and for various time periods. Section 2 gives the estimation results of the CAPM to test, whether excess returns in currency markets reflect a compensation for currency risk. Section 3 concludes. Figures and tables are delegated to the Appendix at the end of the paper and to a web-only appendix.

1. THE EXPECTATIONS HYPOTHESIS AND UNCOVERED INTEREST PARITY

Let s_t denote the log of the spot exchange rate between two countries at time t and f^t_{t-m} the log of the futures exchange rate at time $t-m$ with delivery at time t and maturity m. Exchange rates are defined in indirect quotation, where the cost of one unit of domestic currency is given in units of foreign currency. According to the EH, f^t_{t-m} should be an efficient predictor for the spot exchange rate s_t. Since exchange rates are known to be close to nonstationarity, the EH is usually not examined by regressing s_t on f^t_{t-m}, but the lagged spot exchange rate is subtracted from both variables. To simplify the notation, each variable is indexed by a tuple (m, t) denoting m days before the delivery date t. We define the log spot return $y_{m,t} = s_t - s_{t-m}$ and the futures premium $x_{m,t} = f^t_{t-m} - s_{t-m}$. The standard EH test involves estimating the following regression:

$$y_{m,t} = \alpha_m + \delta_m x_{m,t} + \varepsilon_{m,t}. \tag{1}$$

Under the EH, $\alpha_m = 0$ and $\delta_m = 1$. We refer to specification (1) as the *Fama Regression*.[5] The forward or futures premium puzzle (FPP) describes the phenomenon that

5. Assuming that the covered interest rate parity (CIP) is fulfilled, examining the validity of the EH is closely linked to testing whether the condition of UIP (UIP) is met. Let $i_{m,t}$ be the domestic nominal

the "Fama coefficient" δ_m is very often estimated to be negative, which would suggest that if the futures premium indicates an expected appreciation of the domestic currency, the currency actually tends to depreciate, and vice versa.

Let the log excess return on buying a foreign currency in the futures market and then selling it in the spot market after m days be defined as $r_{m,t} = f^t_{t-m} - s_t$, which is equivalent to the log futures discount minus the change in the spot rate, $r_{m,t} = x_{m,t} - y_{m,t}$. Regression (1) can then be reformulated as follows:

$$r_{m,t} = \tilde{\alpha}_m + \tilde{\delta}_m x_{m,t} + \varepsilon_{m,t}, \tag{2}$$

where $\tilde{\alpha}_m = -\alpha_m$ and $\tilde{\delta}_m = 1 - \delta_m$. Under the EH, $\tilde{\alpha}_m = 0$ and $\tilde{\delta}_m = 0$ and excess returns should be zero. Thus, if $\tilde{\delta}_m \neq 0$, excess returns exist and are a function of the futures premium and thus predictable, which violates the EH.

A negative estimate of the Fama coefficient δ_m in equation (1) corresponds to a positive estimate of the coefficient $\tilde{\delta}_m$ in the excess return equation (2). For example, the often described FPP indicates that the country with a positive futures premium tends to have positive excess returns because its currency tends to appreciate rather than depreciate, as suggested by the EH. If the Fama coefficient is greater than the assumed value of one, the country with a positive futures premium tends to have negative excess returns because its currency depreciates more than the EH predicts.

1.1 Data

Our empirical work uses daily closing spot exchange rates and 3-months exchange rate futures contracts with delivery dates at the third Wednesday in March, June, September, and December of each year. We examine the behavior of exchange rates for the United States relative to all countries for which currency futures have been traded at the Chicago Merchantile Exchange. These are nine developed countries, that is, Australia, Canada, Germany, Japan, New Zealand, Norway, Sweden, Switzerland, the United Kingdom, and six emerging market economies, that is, Brazil, Czech Republic, Hungary, Mexico, Poland, and South Africa.[6] For estimation, we always consider the United States as the domestic country, and consider the other economies as the foreign country. Hence, exchange rates are quoted in terms of the foreign currency price of one USD. Data sources are Bloomberg and Datastream.

interest rate of the m period, where $i^*_{m,t}$ is the corresponding foreign interest rate. According to the CIP condition, the futures premium corresponds to the interest rate differential between the two respective countries, $x_{m,t} = (i^*_{m,t} - i_{m,t})$. The validity of the EH could therefore be reformulated to $y_{m,t} \equiv (i^*_{m,t} - i_{m,t})$, which corresponds to the UIP condition. However, recent evidence shows that the CIP condition has broken down for several advanced economies since the great financial crisis of 2008 (Du et al. 2018).

6. After the introduction of the Euro in 1999, we use for Germany Euro/USD rates instead of DM/USD rates. We have not considered futures data for the South Korean won, the Israeli shekel and the Turkish lira as trading did not start until 2006 or 2012, respectively. In addition, we have removed the Russian rouble from our sample due to the occurrence of several currency crises in the last two decades. Since the Euro/USD exchange rate in our sample is already covered by Germany, we have not included the data on French Franc futures.

TABLE 1

OVERVIEW

Currency	First traded contract
German Mark(Euro)/USD	September 1972
Australian Dollar/USD	March 1987
Canadian Dollar/USD	March 1973
Swiss Franc/USD	March 1973
Sterling Pound/USD	December 1975
Czech Koruna/USD	September 2004
Brazilian Real/USD[a]	March 2007
Hungarian Forint/USD	September 2004
Japanese Yen/USD	March 1973
S-African Rand/USD	June 1997
New Zealand Dollar/USD	June 1997
Mexican Peso/USD	June 1995
Polish Zloty/USD	September 2004
Swedish Krona/USD	June 2004
Norwegian Krona/USD	June 2004

NOTES: This table reports the expiration month of the first traded 3-months futures contract on the Chicago Merchantile Exchange for each individual currency included in our sample.

[a] Trading for Brazilian Real/USD futures contracts has started already in 1995, however, until 2007 trading was on an irregular basis.

Table 1 gives the expiry month of the first traded futures contract of each individual currency contained in our sample. Only five bilateral currencies futures of our sample have been traded since the mid-1970's. These are the Deutsche mark, Canadian dollar, Swiss franc, Pound sterling, and Japanese yen. Trade of the remaining currency futures contracts has started later in the 1990s or mid-2000s. The maximum length of time to maturity m at which futures contracts have been traded, do not differ much between the individual currencies, and develop very homogeneously over time. Figure 1 shows, for simplicity's sake, the average of the maximum maturity across all currencies in our sample. As can be seen, available maturities of the considered futures contracts have increased over time. From the mid-1970s to 2002, futures contracts were traded with an average maximum maturity ranging between 9 and 12 months (or 200 and 280 business days). Between 2002 and 2014, the average of the maximum length of time to maturity has increased to around 390 working days, which is about one and a half years. From 2015 onward, futures contracts were offered for the major currencies, that is, the German mark, Canadian dollar, Swiss franc, Pound sterling, and Japanese yen, with a continuously rising maturity of up to 5 years (or 1,305 working days).

1.2 Results

The Fama regression across the maturity spectrum. To examine the EH for a sufficiently long time period, we first base our estimates of equation (1) on a subsample consisting of the German mark, Canadian dollar, Swiss franc, pound sterling, and Japanese yen against USD futures contracts. This set of five currencies is particularly interesting for examining the FPP because of their large market depth. For each

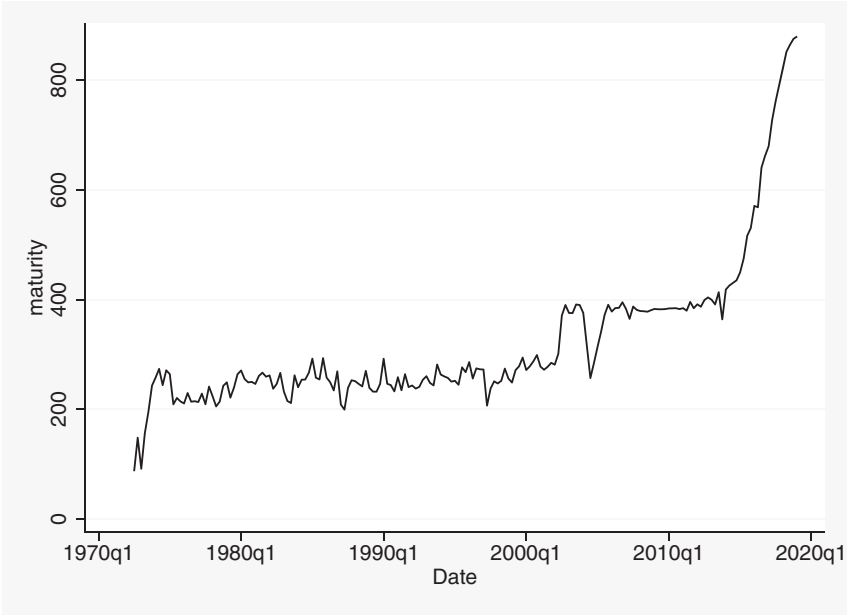

Fig 1. Average Maximum Maturity over Time.

NOTES: This figure plots the average of the maximum maturity across all 15 currencies contained in the sample.

currency, we focus on a total of 161 futures contracts with settlement days between March 1979 and December 2018, thus $t = 1, \ldots, 161$. We chose this starting date, since it was not until 1976 that these major countries made a firm transition to a modern flexible exchange rate regime ratified by the Interim Committee of the International Monetary Fund. Moreover, for the earlier Japanese yen futures contracts, the maximum length of maturity was rather volatile.

We begin by investigating whether the relationship between the log spot return $y_{m,t}$ and the futures premium $x_{m,t}$ depends on the maturity of the futures contract, m. For this, we estimate for each currency the Fama regression covering all 161 futures contracts but allowing for separate slope coefficients for futures prices with different maturities.[7] We consider futures prices with maturities ranging from two business days to the longest maturity that is available for all contracts falling within the observed period (M). This ensures that all M regressions cover the entire period under consideration. For the DM/Euro, Japanese yen, and Pound sterling futures rates, the longest available maturity for all contracts is 175 business days

7. We have also considered a pooled regression covering the data for all five currencies together, but our estimates for the individual currencies suggest that the estimated coefficients vary considerably from currency to currency. Therefore, pooling appears not to be a good idea.

(8 months), and for the Canadian dollar and Swiss franc, it is 199 business days (9 months).

One way to estimate equation (1) is to apply an OLS estimator separately for every maturity $m \in \{2, \ldots, M\}$.[8] In this case, we would end up with $M - 1$ individual regressions each based on 161 observations for each currency. However, since futures and spot prices are correlated across maturities, these regressions would not be independent of each other and the error vectors $\varepsilon_{m,t}$ would be correlated across m. Taking this dependence into account leads to more efficient estimates of the standard errors. To do that, we treat equation (1) as a panel with maturity length m as the cross-sectional and the maturity dates t of the individual contracts as the time dimension. To estimate the panel, we apply the Beck and Kratz (1995) OLS estimator with panel-corrected standard errors. The estimator corrects for heteroskedasticity, correlation across maturities, and, if necessary, serial correlation.

For all five currencies and maturity horizons, we find that the estimated intercepts α_m are small and not significantly different from zero. Figure 2 plots the estimates for the slope coefficients δ_m together with their 95% confidence intervals against the maturity length in days, m. We find for maturities shorter than about a month that the slope coefficients are positive and very often not significantly different from the hypothesized value of 1. Thus, we cannot reject the validity of the EH at the short end of the maturity spectrum. However, except for the Canadian Dollar futures contracts, the estimated slope coefficients eventually turn negative at longer horizons. For Euro/DM, Pound sterling, and Swiss franc futures contracts, this reversal is observed for maturities longer than 1 month; for Japanese Yen futures contracts, this only occurs at maturities longer than about 3 months (66 business days). With a few exceptions, these slope coefficients are significant for Japanese yen, pound sterling, and Swiss francs futures with maturities of more than 90 working days. This is in line with the often described FPP, indicating that countries with a positive futures premium tend to have positive excess returns.

Table 2 summarizes the results of various hypothesis tests on the Fama coefficients and confirms the graphical examination.[9] For all five currencies, the acceptance probability of the EH, $\delta_m = 1$, converges to zero with the maturity. In contrast, we cannot reject the null hypothesis of $\delta_m = -1$ for DM/Euro and Pound sterling futures contracts for all maturities over 3 months; for the Japanese yen and Swiss franc, this is the case for about 90% of the considered maturities.

It could be that the negative coefficients are an artifact due to a winding down of trading activity as the expiration day of a contract draws closer. To assure that this is not the case, we analyze the trading volume, the average daily return, and the annualized volatility of the futures prices with respect to maturity. We find that the liquidity of futures markets seems to be high also for futures contracts close to

8. Dickey–Fuller tests show that the futures premium and the exchange rate returns are stationary.

9. All hypothesis tests are based on a significance level of 5%. The web-only appendix shows in Tables 1–3 the test results using a significance level of 10%. The results differ only very slightly.

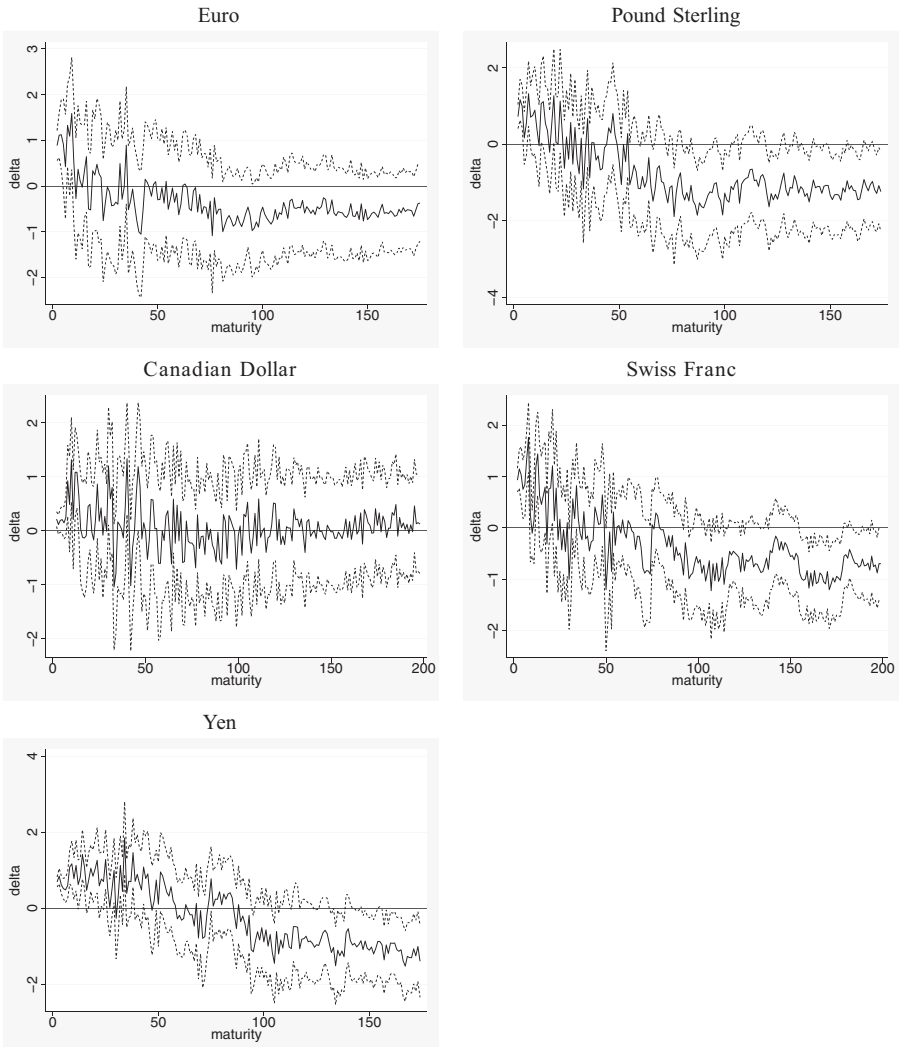

Fig 2. Slope Coefficients δ_m of the Fama Regression: 1979–2018.

NOTES: This figure plots the estimates for the slope coefficients δ_m resulting from the estimation of equation (1) together with their 95% intervals against the maturity length in days, $m = 1, \ldots, 174$. The sample period is 1979Q1–2018Q4.

expiry. For very short maturities of less than 5 days, the trading volume is somewhat lower, but it increases steadily in maturity and reaches its maximum 7 days prior to expiry. For maturities up to 77 days, the liquidity stays high. However, thereafter the trading volume decreases rapidly, which confirms the usual finding that investors tend to invest mostly in the nearest-maturity futures contract. However, the pattern

TABLE 2

HYPOTHESIS TESTS ON FAMA COEFFICIENTS: 1979–2018

	H_0	$\delta_m = -1$	$\delta_m = 0$	$\delta_m = 1$
DM/Euro	all maturities	90%	97%	26%
	$m \geq 66$	100%	100%	3%
	$m \geq 135$	100%	100%	0%
Canadian dollar	all maturities	49%	96%	56%
	$m \geq 66$	51%	100%	50%
	$m \geq 135$	34%	100%	48%
Swiss franc	all maturities	69%	66%	16%
	$m \geq 66$	90%	60%	0%
	$m \geq 135$	94%	40%	0%
Japanese Yen	all maturities	59%	59%	37%
	$m \geq 66$	87%	58%	13%
	$m \geq 135$	100%	15%	0%
Pound Sterling	all maturities	86%	55%	22%
	$m \geq 66$	100%	35%	0%
	$m \geq 135$	100%	18%	0%

NOTES: This table summarizes the results of hypothesis tests on the Fama coefficients $\delta_m = 0$ from regression equation (1). Entries show the percentage of regressions for which the null hypotheses $\delta_m = 0$, $\delta_m = -1$ and $\delta_m = 1$ is not rejected at the 5% significance level, where the index m refers to the maturity in the range of 1 to 174 days. The sample period is 1979Q1 to 2018Q4.

of the trading volume seems to have no significant effect on the daily returns nor on the volatility of futures prices.[10]

The Fama regression over time. In the following, we analyze the occurrence of the FPP in more detail over time. Thornton (2007) shows for forward data that the appearance of the FPP depends significantly on the choice of the sample period. This result is also recently confirmed by Kim et al. (2017) who analyze the related UIP condition for fourteen major U.S. trading partners over various time periods and policy regimes. On the basis of this evidence, we employ a supremum Wald test (Andrews 1993) to detect a possible structural break in the relationship between exchange rate innovations, $y_{m,t}$, and the futures premium, $x_{m,t}$, at an unknown date for all M maturities. For this test, one needs to define a trimming parameter that specifies how far into the sample (as a percentage of the full sample size) one starts looking for a break, with a symmetric fraction of the sample left after the latest break evaluated. We use a 15% trimming, that is, we look for a structural break in the time period that includes all futures contracts that settle between June 1985 and March 2013.[11]

For the Pound sterling and the Canadian dollar, we can reject the null hypothesis of no structural break in 151 of 175 regressions and 122 of 199 regressions, respectively. For DM/Euro futures prices, Wald test statistics indicate the presence of a statistically significant structural break in 39 of 175 regressions. The signs of a

10. We have also repeated all our estimations dropping all observations for maturities longer than 77 days and all our results were unaffected. Figures and estimation results are available on request.

11. As a robustness test, we also used a 10% trimming. The estimation results did not differ substantially.

structural break are weaker for futures contracts in Swiss francs and Japanese yen. Here, the Wald test statistics are only significant for 14 out of 199 and 27 out of 175 regressions at the 90% significance level.

Figure 1 and Figure 2 in the web-only appendix plot the Wald statistics of the null hypothesis of no structural break for selected maturities of 1, 3, 6, and 8 months. One can see that the probability of a structural break in δ_m increases in the maturity of futures rates. For maturities longer than 3 months, we observe for all five currencies a peak in the break statistics in the period around the great financial crisis of 2007–10. With the exception of the Swiss franc and the Japanese yen, the test statistics are significant at least at the 90% significance level. It is worth noting that we do not confirm the result of Kim et al. (2017), who found evidence of a structural break immediately after the Volcker era of 1987. Only for Pound sterling futures contracts, we observe a second significant breakpoint around 1990, coinciding with the period when the UK joined the European Exchange Rate Mechanism (ERM) and experienced a short period of currency crisis 2 years later when it was forced to leave the exchange rate system (Black Wednesday). These results suggest that the relationship between exchange rate innovations and the FPP changes primarily during turbulent periods.

In view of the indications of a structural break in the Fama coefficient δ_m after the outbreak of the global financial crisis, we have divided our sample into two subsamples: The first subsample covers the precrisis period, which includes all futures contracts that mature between March 1979 and June 2007. The estimates are shown in Figure 3. The second sample covers the postcrisis period, including all futures contracts that settle between September 2007 and December 2018. Since futures contracts are available for more USD currency pairs in the postcrisis period (see Table 1), we extend our analysis to 15 instead of only five currencies for the second subsample. Moreover, the longest maturity at which futures contracts have been traded in the postcrisis period has also increased, which allows us to extend the maturity spectrum for which we estimate the Fama coefficients δ_m up to one and a half years (385 business days). Figure 4 shows the results.

We confirm that the occurrence of the FPP significantly depends on the choice of the sample period. When we focus on the precrisis sample, we find for all five currencies—thus, this time also for the Canadian dollar—a negative relationship between the slope coefficient of the Fama regression and the time to maturity of the futures contract m. The slope coefficients continuously decrease from positive values close to one for short maturities to negative values fluctuating between 0 and -2.5 for longer maturities. As shown in Table 3, we have to reject the EH for almost all maturities over 3 months, which confirms significant excess returns on currency markets. Instead, with the exception of Japanese yen futures, we reject the occurrence of the FFP ($\delta_1 = -1$) for medium to long maturities in only a few cases. Thus, a country with the a positive futures premium tends to have positive excess returns because its currency tends to appreciate in contrast to the prediction of the EH.

However, when we repeat the estimates for the later subsample, we find that for all currencies except the Brazilian real, the Mexican peso, and the South African rand, the slope coefficients remain positive over the entire maturity horizon. For

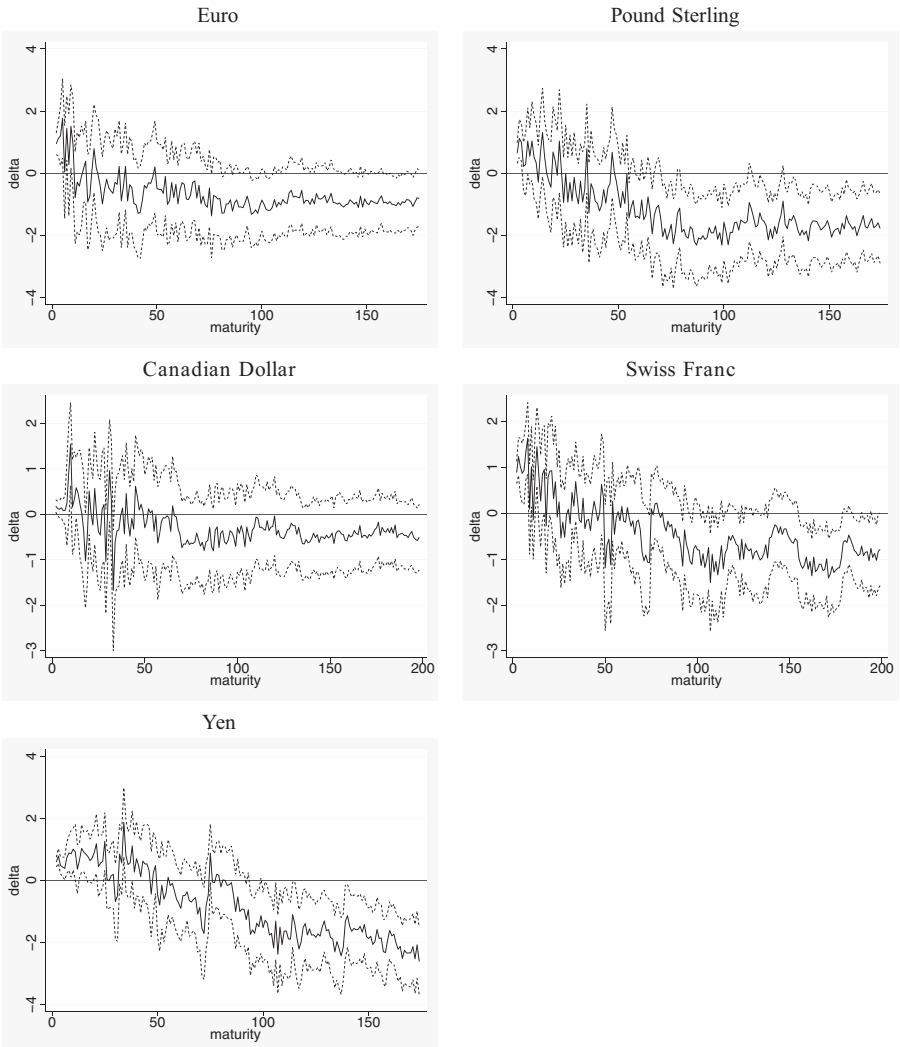

Fig 3. Slope Coefficients δ_m of the Fama Regression: 1979–2007.

NOTES: This figure plots the estimates for the slope coefficients δ_m resulting from the estimation of equation (1) together with their 95% intervals against the maturity length in days, $m = 1, \ldots, 174$. The sample period is 1979Q1 to 2007Q2.

DM/Euro, Swiss franc, Japanese yen, Australian dollar, South African rand, Czech koruna, Brazilian real, Hungarian forint, Polish zloty, and Swedish and Norwegian krona futures contracts, we cannot reject at the 5% significance level the EH of a Fama coefficient of one for the majority of maturities, as summarized in Table 4 the

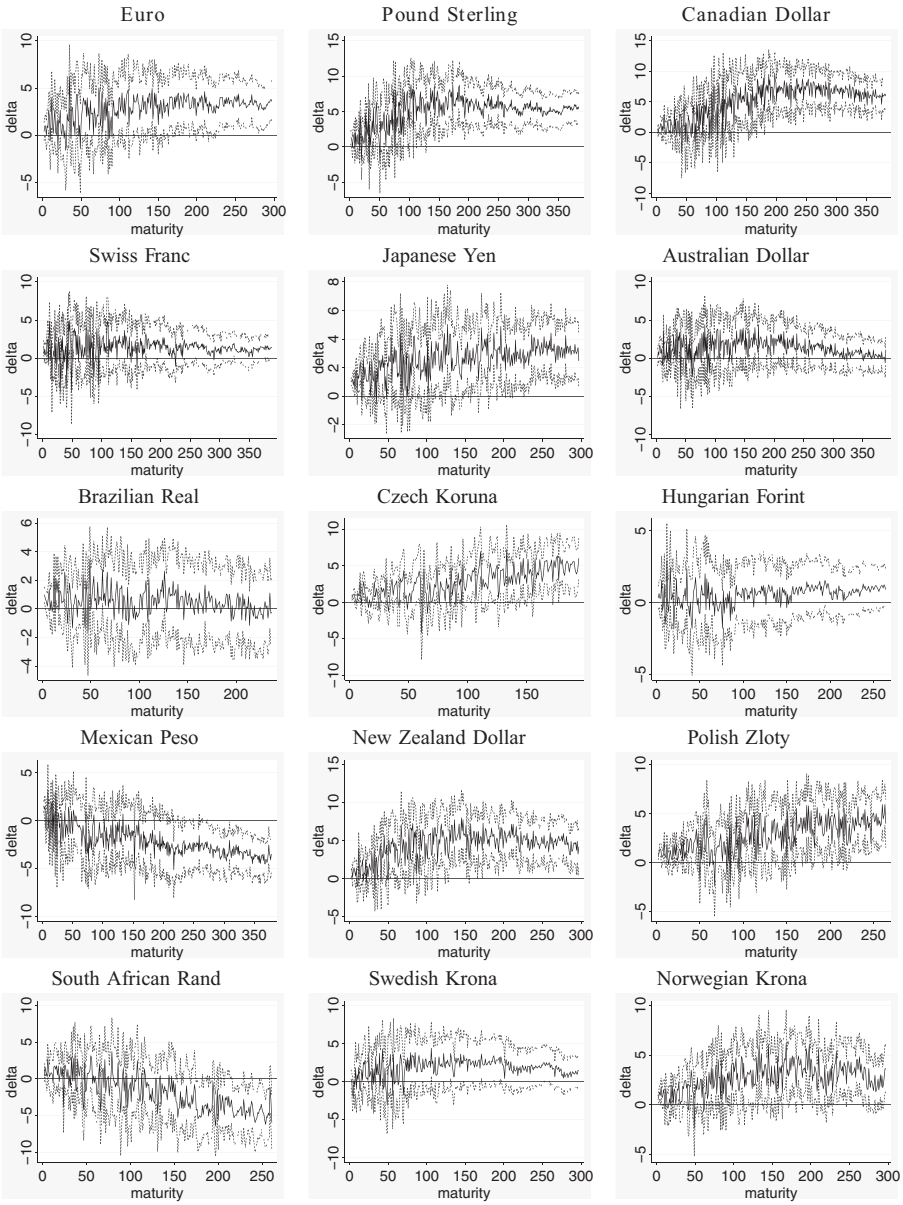

Fig 4. Slope Coefficients δ_m of the Fama Regression: 2007–18.

NOTES: This figure plots the estimates for the slope coefficients δ_m resulting from the estimation of equation (1) together with their 95% intervals against the maturity length in days, $m = 1, \ldots, 174$. The sample period is 2007Q3–2018Q4.

TABLE 3

HYPOTHESIS TESTS ON FAMA COEFFICIENTS: 1979–2007

	H_0	$\delta_m = -1$	$\delta_m = 0$	$\delta_m = 1$
DM/Euro	all maturities	94%	77%	20%
	$m \geq 66$	100%	69%	1%
	$m \geq 135$	100%	51%	0%
Canadian dollar	all maturities	86%	98%	18%
	$m \geq 66$	97%	100%	0%
	$m \geq 135$	97%	100%	0%
Swiss franc	all maturities	77%	66%	19%
	$m \geq 66$	95%	57%	1%
	$m \geq 135$	100%	37%	0%
Japanese Yen	all maturities	63%	41%	28%
	$m \geq 66$	80%	24%	6%
	$m \geq 135$	58%	0%	0%
Pound Sterling	all maturities	87%	37%	17%
	$m \geq 66$	97%	8%	0%
	$m \geq 135$	98%	0%	0%

NOTES: This table summarizes the results of hypothesis tests on the Fama coefficients $\delta_m = 0$ from regression equation (1). Entries show the percentage of regressions for which the null hypotheses $\delta_m = 0$, $\delta_m = -1$ and $\delta_m = 1$ is not rejected at the 5% significance level, where the index m refers to the maturity in the range of 1 to 174 days. The sample period is 1979Q1 to 2007Q2.

web-only appendix.[12] Thus, excess returns are not observed anymore for these currencies. In contrast to the precrisis period, however, we estimate for futures on DM/Euro, Pounds sterling, Canadian dollars, Japanese yen, Czech koruna, New Zealand Dollar, and Polish zloty a *positive* trend between the δ_m and the maturity horizon of the futures contracts. As a result, the EH tends to hold for these currencies only for short to medium maturities. For longer maturities, δ_m is very often significantly larger than one. Thus, deviations from the EH in these cases go in the opposite direction in comparison to the precrisis period. The country with a positive futures premium tends to have now negative excess returns. Our results are essentially consistent with the outcome of Kim et al. (2017) and Du et al. (2018). Analyzing 3-months foreign currency excess returns, they find that the UIP fails to hold during the Volcker era in the 1980s but tends to hold looking at the post-Volcker era from 1987 to 2007. The only difference is that, according to our findings, the break of the slope coefficient occurs much later with the outbreak of the global financial crisis.[13]

12. The test results for a 10% significance level for both sample periods are presented in the web-only appendix.

13. Although not indicated by the tests for a structural break, we have, following Kim et al. (2017), estimated the Fama regression also separately for the post-Volcker period (1987–2007). With the exception of the futures on Pounds sterling, we also find negative slope coefficients in the post-Volcker period, which decrease in maturity. Thus, we do not confirm that the occurrence of the FPP is a particular phenomenon of the Volcker era. These regressions results are available from the authors on request.

Currency excess returns in the cross-section. In the following, we show that the EH fails not only in the time series of the individual currencies but also in the cross-section. Similar to Lustig and Verdelhan (2007), Lustig et al. (2011), and Menkhoff et al. (2012), we look at portfolios of futures exchange contracts. More specifically, at the end of each period t, we assign all currencies in the sample to five portfolios based on their futures premium $x_{m,t}$ observed at the end of the period t.[14] Portfolio 1 contains the currencies with the smallest futures premia, and Portfolio 5 contains the currencies with the largest futures premia. The portfolios are rebalanced at the end of each quarter. We calculate the log currency excess $r^j_{m,t}$ for portfolio j by taking the average of the log currency excess returns of each currency contained in this portfolio. The total number of currencies in our portfolios varies over time as more futures exchange contracts are traded on international markets over the considered period.

Table 5 plots averages (log) currency excess returns $r^j_{m,t}$ for selected maturities of 3, 6, and 8 months for each portfolio j, $j = 1, \ldots, 5$, for futures contracts that settle between March 1979 and December 2018.[15] On average, a U.S. investor achieves excess returns on currencies with low futures discounts of around minus 70 basis points for a maturity of 3 months and minus 2.3% for a maturity of 8 months. For currencies with the largest futures premium, excess returns are generally positive and increase to up to 2% with maturity. Consequently, we find that the zero cost (carry trade) strategy, which goes long in the portfolio with high futures premia and short in the portfolio with low futures premia, delivers considerable positive returns, which is in line with the findings of Lustig and Verdelhan (2007) and Lustig et al. (2011). Moreover, these carry trade returns grow monotonically with the maturity of the futures contracts. Extrapolating these returns on an annual basis, they are moving fairly monotonously around the average of 725 basis points.

However, when we focus only on the postcrisis period covering futures contracts that settle between June 2007 and December 2018, the maturity effect on the average excess return in the five portfolios, with the exception of the third portfolio, has disappeared. On average, the excess returns of all five portfolios are negative across the entire maturity spectrum. Moreover, the return of the zero cost strategy (return of the last portfolio minus the return of the first portfolio) moves around zero when plotted against the maturity of the futures contracts. Therefore, the carry trade strategy no longer seems to deliver a clear excess return.

In summary, the existence of currency excess returns and the occurrence of the FPP is not set in stone. They depend both on the maturity of the assets under consideration and on the choice of sampling period. The FPP appears to be a precrisis phenomenon for most currencies and disappears afterwards. Since the onset of the global crisis, we cannot reject the validity of the EH and the absence of currency excess returns for most currencies and maturities. Furthermore, we find that in the precrisis period,

14. Lustig et al. (2011) show that the estimation results are robust to the question of whether the portfolios are sorted by forward (futures) discounts or interest rate differentials.

15. Plots of excess returns for the entire maturity spectrum are available on request from the authors.

TABLE 4

HYPOTHESIS TESTS ON FAMA COEFFICIENTS: 2007–2018

	H_0	$\delta_m = -1$	$\delta_m = 0$	$\delta_m = 1$
DM/Euro	all maturities	25%	47%	80%
	$m \geq 66$	14%	36%	75%
	$m \geq 135$	2%	20%	66%
Canadian dollar	all maturities	18%	26%	34%
	$m \geq 66$	11%	15%	22%
	$m \geq 135$	2%	4%	8%
Swiss franc	all maturities	50%	93%	97%
	$m \geq 66$	50%	96%	99%
	$m \geq 135$	43%	96%	100%
Japanese Yen	all maturities	10%	29%	71%
	$m \geq 66$	8%	23%	66%
	$m \geq 135$	1%	12%	58%
Pound Sterling	all maturities	11%	17%	23%
	$m \geq 66$	3%	5%	10%
	$m \geq 135$	0%	0%	1%
Australian dollar	all maturities	69%	91%	98%
	$m \geq 66$	70%	92%	99%
	$m \geq 135$	68%	92%	100%
New Zealand dollar	all maturities	12%	21%	36%
	$m \geq 66$	5%	9%	22%
	$m \geq 135$	0%	1%	14%
South African rand	all maturities	79%	73%	63%
	$m \geq 66$	80%	67%	53%
	$m \geq 135$	69%	49%	33%
Czech koruna	all maturities	29%	47%	69%
	$m \geq 66$	22%	40%	63%
	$m \geq 135$	3%	17%	45%
Brazilian real	all maturities	86%	95%	99%
	$m \geq 66$	95%	99%	100%
	$m \geq 135$	99%	100%	100%
Hungarian forint	all maturities	65%	99%	98%
	$m \geq 66$	60%	100%	99%
	$m \geq 135$	41%	100%	100%
Mexican peso	all maturities	78%	56%	37%
	$m \geq 66$	76%	50%	27%
	$m \geq 135$	70%	38%	16%
Polish zloty	all maturities	21%	44%	65%
	$m \geq 66$	19%	38%	59%
	$m \geq 135$	5%	22%	48%
Swedish krona	all maturities	46%	92%	98%
	$m \geq 66$	37%	92%	100%
	$m \geq 135$	26%	92%	100%
Norwegian krona	all maturities	18%	46%	77%
	$m \geq 66$	13%	41%	72%
	$m \geq 135$	7%	33%	67%

NOTES: This table summarizes the results of hypothesis tests on the Fama coefficients $\delta_m = 0$ from regression equation (1). Entries show the percentage of regressions for which the null hypotheses $\delta_m = 0$, $\delta_m = -1$ and $\delta_m = 1$ is not rejected at the 5% significance level, where the index m refers to the maturity in the range of 1 to 260 days. The sample period is 2007Q3 to 2018Q4.

EH also fails on a cross-sectional basis. For currencies with the largest futures premium, excess returns are significantly positive, for currencies with the lowest futures premium they tend to be clearly negative. This leads to significant carry trade returns, which even increase as the maturity of the futures contracts increases. After the global financial crisis, these carry trade returns have disappeared.

TABLE 5

EXCESS CURRENCY RETURNS OF PORTFOLIOS

	Selected maturities	P1	P2	P3	P4	P5
1979–2018	3 months	−0.786	−0.415	0.19	−0.323	1.371
	6 months	−1.356	−0.847	0.499	−0.083	2.602
	8 months	−2.199	−1.196	−0.172	−0.152	2.051
2007-2018	3 months	−0.522	−0.706	−0.607	−0.448	−0.286
	6 months	−0.89	−1.43	−1.388	−1.41	0.068
	8 months	−1.517	−1.429	−2.625	−1.396	−1.739

NOTES: This table shows the average excess returns of the five quarterly rebalanced currency portfolios for the sample 1979Q1 to 2018Q4 and 2007Q3 to 2018Q4 in percent. The portfolios were created by sorting the currencies into five groups based on the futures premium at time t. Portfolio 1 (P1) contains currencies with the smallest futures premium, Portfolio 5 (P5) contains currencies with the largest futures premium.

2. EXCESS RETURNS AND RISK PREMIA

A common explanation for the failure of the EH/UIP is that it is driven by a (time-varying) risk premium that investors demand for foreign currency denominated investments (Fama 1984, Hsieh 1984, Hodrick and Srivastava 1987, Sarno et al. 2012, Lustig et al. 2011).[16] In this section, we follow this theory and investigate whether the sizable currency excess returns on futures contracts are indeed matched by covariances with common risk factors.

Theoretical models such as the CAPM of Sharpe (1964), Lintner (1965), and Black (1972) or the APT of Ross (1976) suggest that the expected excess returns should be linear in asset betas with respect to risk factors. As potential risk factors, we follow Jensen (1972), Merton (1973), and Breeden (1979) and consider excess stock market returns and nondurable consumption growth.[17] In this way, we contribute to the debate between Lustig and Verdelhan (2007), ,2011) and Burnside (2011). We also follow Lustig et al. (2011), which emphasizes the importance of global factors in explaining cross-sectional differences in currency returns. We do this by using the HML carry factor as an additional measure of risk. It measures the return of a zero cost strategy that goes long in the currencies with the highest futures premia and short in the currencies with the lowest futures premia.

16. The negative Fama coefficient estimated for medium to long maturities for the majority of currencies for the precrisis sample would indicate that this risk premium and the expected change in the exchange rate covary negatively and that this covariance is of a magnitude larger than the expected exchange rate volatility. We estimate for 7 of the 15 currencies a Fama coefficient larger than one at longer maturities in the postcrisis period. This indicates that the volatility of the risk premium is in these cases greater than the volatility of the expected exchange rate changes. A detailed derivation of these conclusions is found in Fama (1984).

17. We also used durable consumption growth as risk factor. However, we find that consumption growth in durable goods does not appear to be volatile enough to accurately measure consumption beta, and consumption beta cannot take into account the cross-sectional distribution of currency returns. For space reasons, we do not show these results below, but they are available from the authors on request.

In examining the validity of different types of CAPM-based models in connection with currency excess returns, the literature has so far concentrated on selected maturities of usually 1 or 3 months. The novelty of our paper is that the use of futures exchange rates instead of forwards allows us to estimate the asset pricing models for a wide range of maturities. This allows us to analyze, whether asset maturity plays a critical role in whether or not excess currency returns reflect exposure to risk.

2.1 Methodology

In the remainder of this section, we follow Lustig et al. (2011) and Menkhoff et al. (2012) and use discrete currency excess returns instead of log returns to avoid having to assume a common log normality of returns.[18] Discrete currency excess returns are defined as $R_{mt} = (F^t_{t-m} - S_t)/S_{t-m}$. We simplify the notation by omitting the maturity index. Let R_{jt} denote the average currency excess return of all currencies contained in the portfolio j at a fixed maturity length m. By focusing on currency portfolios instead of on individual currencies, we allow that the risk exposure of a given currency is not fixed, but rather depends on the relative level of the futures premium, which varies over time. We assume that currency excess returns are determined by a factor model:

$$R_{jt} = \xi_j + \beta_j \mathbf{f}_t + \nu_{jt}, \quad j = 1, \ldots, J, \quad t = 1, \ldots T, \tag{3}$$

where $\mathbf{f}_t$ is a $k \times 1$ vector of risk factors, ξ_j is a constant, and ν_{jt} is a random error term. β_j is a $1 \times k$ vector measuring the sensitivity of the excess return of portfolio j futures contract to variation in the common factors and thus serves as the measure of riskiness of the futures contract. Instead of estimating equation (3) for all J portfolios separately by OLS, we estimate the factor betas jointly with the generalized method of moments (GMMs), which is robust to conditional heteroscedasticity, cross-sectional correlation, as well as serial correlation in the return residuals and the factor. Thus, the $J \times 2$ moment restrictions are as follows:

$$\mathbb{E}_{\mathbb{t}} \begin{bmatrix} R_{jt} - \xi_j - \beta_j \mathbf{f}_t \\ \left(R_{jt} - \xi_j - \beta_j \mathbf{f}_t\right)\mathbf{f}_t \end{bmatrix} = 0, \tag{4}$$

Taking into account that the time span covered differs between the individual currencies (see Table 1), we do not restrict the estimation sample to be the same for all equations. We use a robust weighting matrix with the identity as the initial one.

The asset pricing hypothesis is that currency returns are a function of the sensitivities to the risk factors—the factor betas β_j—and the price of risk γ_1:

$$E_t[R_t] = \gamma_0 + \beta' \gamma_1, \tag{5}$$

18. The difference between log and discrete currency excess returns is very small. If we estimate our model with log excess returns, the results do not differ significantly from the results based on discrete returns.

where $E_t[R_t]$ is the J-vector of expected excess returns, and β is the $J \times k$-matrix of the estimated betas of equation (4). The intercept γ_0 can be interpreted as the zero-beta return and allows for a common over- or underpricing in the cross-section of returns.[19]

The primary interest in the literature is to test, whether specific risk factors are priced; thus, whether the null hypothesis $H_0 : \gamma_1 = 0$ holds. Fama and MacBeth (1973) have proposed a two-step regression approach in which the estimated β_j's of equation (4) are used as regressors in the cross-sectional regression (5) to estimate the prices of risk γ_1. However, as is criticized by Burnside (2011), this approach neglects the fact that first-pass betas are estimated with uncertainty. Failure to account for this uncertainty results in biased standard errors in the γ_1 estimate. One way to avoiding this error-in-variable problem is the correction of the standard errors in the two-step approach, as suggested by Shanken (1992). Another solution is to estimate the prices of risk γ_1 directly by GMM. Jagannathan and Wang (1998) point out that in case of heteroskedasticity, Shanken's correction is inappropriate and that more general GMM errors are preferred. In addition, Shanken and Zhou (2007) perform a simulation analysis of various possible estimators and find that the GMM estimator performs best in terms of the mean square error (RMSE). For this reason, we estimate the model using the GMM approach, using as initial values for γ_0 and γ_1 the estimates resulting from the two-step approach with Shanken-corrected standard errors. Note that equation (5) can be written as:

$$E_t[R_t] = \gamma_0 + \gamma_1 \frac{cov(R_t, f_t)}{\sigma^2}, \tag{6}$$

where σ^2 is the factor variance. Based on Harvey and Kirby (1995) and Shanken and Zhou (2007), we therefore use the following moment conditions:

$$\mathbb{E}_{\mathbb{j}} \begin{bmatrix} R_t - \mu_r \\ f_t - \mu_f \\ \left(f_t - \mu_f\right)^2 - \sigma^2 \\ R_t - \gamma_0 - \gamma_1 \frac{(R_t - \mu_r)(f_t - \mu_f)}{\sigma^2} \end{bmatrix} = 0, \tag{7}$$

where μ_r and μ_f are the population means of the excess returns and the factor. Since we base our estimates on J portfolios, we use $2(J + 1)$ moment conditions for the estimate. We use again robust weighting matrices for the estimates.

Our contribution complements the literature by estimating the complete term structure of the price of risk. We estimate the models (3) and (5) for all maturities between 1 day and 8 months ($m = 1, \ldots 174$), when we consider the complete time horizon from 1979 to 2018, and between 1 day and 1 year ($m = 1, \ldots 260$), when we

19. Since our explanatory variable is the excess currency return and not—as is often the case in CAPM literature—an excess asset return above the risk-free interest rate, the inclusion of an intercept makes economic and econometric sense.

limit the estimation to the postcrisis period in the robustness section below.[20] We consider the log of the U.S. excess stock market returns, U.S. per capita nondurable real consumption growth, and the carry trade return (HML) as risk factors.[21] All factors are demeaned as in Lustig and Verdelhan (2007). Data on daily excess stock market returns are provided by Fama and French Research Factor file, from which we calculate m-period returns.[22] The consumption data were downloaded from the website of the Federal Reserve Bank of St. Louis. The shortest available frequency is monthly. We therefore attribute the 1-month consumption growth rate to all excess currency returns with a time to maturity of less than 1 month, the 2-month consumption growth rate to excess currency returns with a time to maturity between 1 and 2 months, and so on. The HML carry factor is calculated by the difference between the (log) excess return on the last portfolio and the one on the first portfolio.

2.2 Results

Given the small size of the cross-section, we estimate a single factor model, using each of the three risk factors separately. This has the advantage that we keep the degrees of freedom in the second-step estimation as large as possible. Furthermore, all three risk factors are positively correlated with each other, which is not surprising considering that all three are regarded as measures of risk. By considering them separately, we avoid a potential multicollinearity problem. Nevertheless, in the robustness section below, we run a horse race between our three risk factors to test, which of them is the most dominant one.

Portfolio Betas. Figures 3–5 in the web-only appendix show the factor betas of each currency portfolio in relation to the futures contracts' maturity m together with their 95% significance band. The betas are estimated over the entire sample including all futures contracts with expiration dates between March 1979 and December 2018. The sensitivity of the first two portfolios to excess equity market returns, that is, the traditional market betas, proves with only a few exceptions to be virtually zero and insignificant across the considered maturity spectrum (see Figure 3 in the web-only appendix). Therefore, low futures premium currencies—which corresponds to low interest rate currencies under the premise that CIP holds—turn out to be immune to stock market movements and could therefore serve as a "safe haven." For portfolios 3–5, we find consistently positive betas and the sensitivity to market risks appears

20. We limit the estimates to maturities of up to 174 and 260 working days, respectively, as we would shorten the observation period if longer maturities were chosen. The reason for this is that earlier futures contracts were not traded for very long maturities.

21. We focus here on U.S. data, as we look at currency excess returns from the perspective of a U.S. investor. We have also considered calculating relative consumption growth and stock market excess returns between the two countries under consideration, but quarterly consumption data are not available for all countries under consideration. In addition, the relevant literature also focuses on U.S. consumption and excess returns in the market. Therefore, our results are more comparable.

22. http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/

to increase with the maturity of the futures contract. For short maturities of less than 2–3 months, the beta estimate is very often insignificant; for longer maturities, it is usually statistically significant. This result suggests that currency derivatives with higher futures premia and longer maturity are considered riskier due to their positive correlation with equity market risk and therefore pay a higher excess return.

We find that currency excess returns also reflect consumption risk. For the five portfolios, the sensitivity of currency returns to nondurable consumption rises with increasing maturity (Figure 4 in the web-only appendix). While the consumption betas for short maturities are usually insignificant, they are clearly positive for medium to long maturities, indicating falling returns when consumption declines. In addition, the estimated consumption betas increase in the portfolio ranking. For Portfolios 1 and 2, which contain currencies with lower futures premia, the consumption beta fluctuates around a value of one for medium to long maturities, while for portfolios 4 and 5, which contain the currencies with the largest futures premia, the beta converges to a value of two. This shows that the currencies included in portfolios 4 and 5 are considered "riskier" and therefore pay a higher excess return.

Figure 5 in the web-only appendix shows the estimated betas for the HML carry factor. Unlike the estimates based on market and consumer risk, we do not find that maturity is important for the sensitivity of portfolios to this risk factor. But we note again that the betas are monotonically increasing with the portfolio rank. For the first portfolio, the betas are all significantly negative and range between -0.6 and -0.3. For portfolio 2, the betas are also negative throughout, but very often do not differ significantly from zero. The HML factor for portfolios 3 and 4 fluctuates around zero and, with few expectations, is insignificant. For the last currency portfolio, however, we estimate consistently positive and significant beta coefficients ranging from 0.4 to 0.7. These results are consistent with the findings of Lustig et al. (2011) and suggest that currencies with low futures premia (which corresponds to a low interest rate differential under the premise that CIP holds) provide a hedge against carry trade risk because they offer higher excess returns when the carry yield is low. In contrast, currencies with high futures premia can be considered "riskier" because their excess returns increase when the carry risk is high.

In summary, we can state that, on average, higher futures premium portfolios expose U.S. investors to higher market and consumer growth risk and also carry trade risk. We find that currency excess returns in portfolios with high futures premia are highly procyclical, that is, move with risk factors like the market factor, while currency excess returns of currencies with low futures premia are either acyclical or even countercyclical to risk factors.

Prices of risk. Figure 5 shows the result of estimates of the factor price of risk γ_1. Figure 6 reports the model fit as measured by the R^2. For all three risk factors, at the shorter maturities, estimates of the price of risk are close to zero and insignificant. However, the size of γ_1 increases monotonically over the maturity of the futures contracts. If we consider market risk and consumer risk as factors, the risk price becomes significant at the level of 95% at the longer end of the maturity spectrum

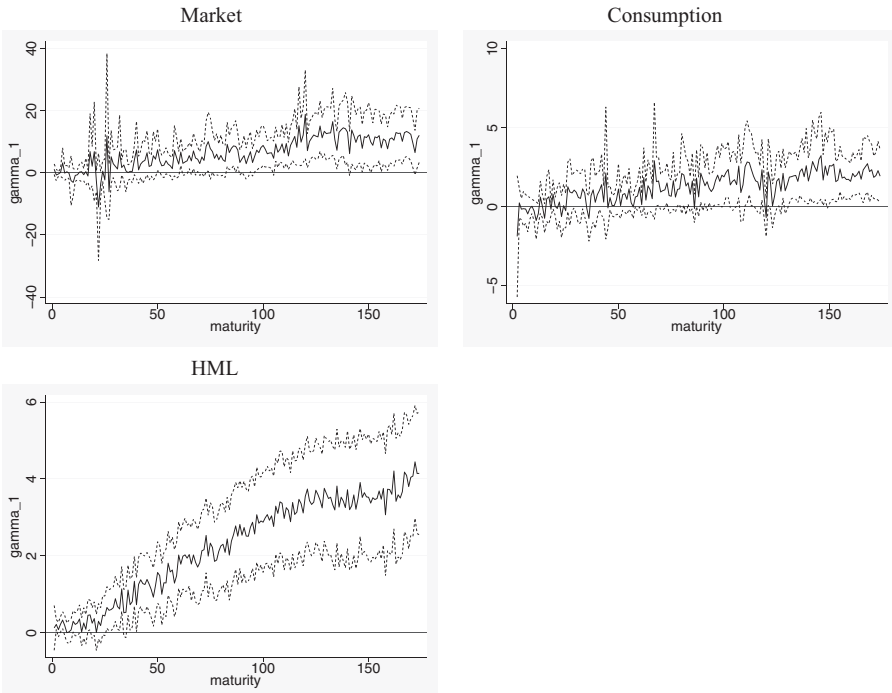

Fig 5. Prices of Risk γ_1: 1979–2018.

NOTES: This figure shows the estimates of the factor price of risk γ_1 obtained from the GMM estimation of equation (7) together with their 95% intervals against the maturity length in days, $m = 1, \ldots, 174$. The sample period is 1979Q1 and 2018Q4. The currencies considered are Deutsche Mark/Euro, Canadian Dollar, Swiss Franc, Pound Sterling, and Japanese Yen with respect to the U.S. Dollar. The factors used are excess market risk (market), consumption risk (consumption), and carry trade risk (HML).

from 90 working days onward. The price of HML carry risk becomes significantly positive already for maturities longer than about 1 month (22 working days). For all three factors, the model fit shows quite high volatility across the entire maturity spectrum, but generally tends to increase and approach the value of one for longer maturities (see Figure 6). This indicates a high collinearity of all three factors, at least at the long end of the maturity spectrum. This suggests that it is not advisable to introduce all three factors into one model. Nevertheless, in the following section on robustness, we estimate a multifactor model.

As Lewellen et al. (2010) point out, in order to make a correct judgment about an asset pricing model, we need to consider not only the statistical significance of the price of risk, but also its economic significance. Focusing on market risk as a factor, the estimated price of risk increases from about 6%, when we consider futures with a maturity of 3 months to about 12% when focusing on futures with longest maturity considered, 174 working days. In a regression of the excess stock market

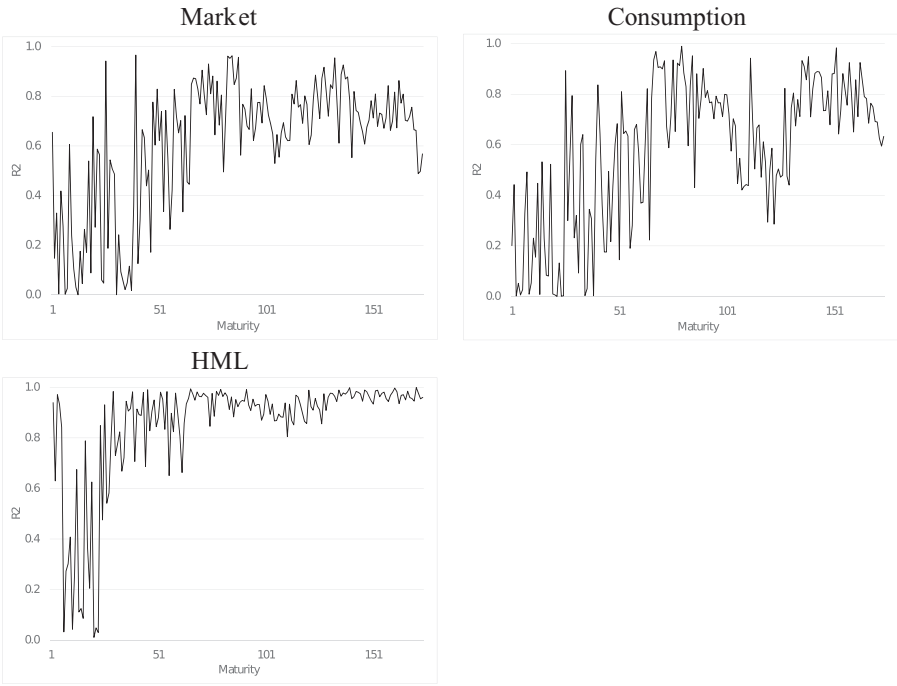

Fig 6. R^2 across the Maturity Spectrum: 1979–2018.

NOTES: This figure shows the model fit as measured by the R^2 estimate of the GMM model described in equation (7). Sample period is 1979Q1 and 2018Q4.

return on itself, the β coefficient would be one. For this reason, the price of market risk, γ_1, should be equal to the average excess U.S. stock market return over a m-day maturity range in order to meet the condition of no arbitrage. When we annualize the significant estimates of the prices of market risk, the returns turn out to be very monotonous over the entire maturity spectrum with an average of around 20% p.a. This is about twice as high as the historical average excess return of the U.S. stock market of 9% according to the Fama and the French Research Data file. However, the estimated confidence range of the annualized estimates of γ_1 covers the observed long-term average excess returns of the U.S. market.

For small and medium maturities, the constant term turns out to be insignificant. For maturities longer than 135 working days, however, γ_0 is mostly significant with an average value of minus two. Projected over the year, this means that investors in foreign currencies have on average a return that is about 3.3% lower than if borrowed abroad and invested in the United States, which reflects the exorbitant privilege of the United States. We find that market risk explains between 0% and 97% of the cross-sectional variation in currency returns (see Figure 6). The average R^2 over all 174 estimated models is 61%.

When annualizing the estimated prices of (nondurable) consumption risk, our estimates suggest that a futures contract with a consumption growth beta of one yields on average a risk premium of 3.8% p.a. (using only the estimates that are significant). This is in line with the observed average growth rate of consumption of 4% p.a. over the observed period. Thus, the condition of no-arbitrage is fulfilled in this case as well. For maturities of more than about 3 months (61 working days), the constant γ_0 is significant in about half of the maturities considered. The annualized return is minus 5.5% considering the significant estimates. Thus, we find again that investments in foreign currencies tend to deliver a lower return than an investment in U.S. dollars. Consumption risk explains between 0% and 99% of the cross-sectional variation in currency returns. The average R^2 is 59%.

The annualized price of carry trade risk measures on average 720 basis points. This means that an asset with a beta of one earns a risk premium of 7.2% per year, which corresponds very closely to the reported average annualized excess returns on the HML carry strategy observed in our data. As such, the no-arbitrage condition is satisfied. The constant γ_0 is with an average of -0.034 small in magnitude and significant at the level of 95% only in 4 out of the 174 considered maturities. The model fit is extremely good. With maturities of more than 60 working days, the R^2 is consistently above 80% (see Figure 6). The average R^2 over the entire maturity spectrum considered is 85%.

In summary, we find that differences in the exposure to risk help to explain the cross-sectional spread in foreign currency returns in a significant way. Currencies with a low futures premium are less exposed to market risk, consumption growth and carry trade risk than currencies with a high futures premium. However, this only applies for medium and longer asset maturities. Considering that most studies that test the validity of a risk-based approach to excess currency returns focus on short securities maturities of 1 or 3 months, our results could explain why this approach is so often rejected. Our findings suggest that these studies simply considered maturities too short to confirm the risk-based approach to currency returns. As such, our results also contribute to the debate between Lustig and Verdelhan (2007), ,2011) and Burnside (2011). While Lustig and Verdelhan (2007) estimate significantly positive prices of risk for market and consumer risk, Burnside (2011) finds these to be insignificant. He argues that the differences are due to the fact that Lustig and Verdelhan (2007) do not adequately consider the error-in-variable problem in the two-step approach discussed above. According to our results, the different results could also be due to the fact that, with a focus on a 3 months maturity, they are exactly in the maturity spectrum in which the risk-based approach is ambiguous. Our GMM-based confidence bands take care both of the fact that the betas used in the second step are estimated and the fact that the factors are random.

2.3 Robustness

In this section, we run three robustness checks: First, we constrain our sample to focus only on the postcrisis period.[23] Second, we conduct a horse race between the three risk factors considered to find out which of them is the most prevalent. Third, we reestimate the model on portfolios containing only currency futures of developed countries.

Postcrisis period. In Section 1, we have shown that the FPP appears to be a precrisis phenomenon and that for the period after 2007Q2, it seems to have disappeared for the majority of currencies. For only 3 of the 15 currencies, we still observe deviations from the EH, but this time in the opposite direction. One possible explanation is that exposure to risk no longer explains the cross-currency returns when we focus on the later subsample, and that the significance of prices of risk observed across the entire data sample is mainly determined by the precrisis period. We therefore repeat our estimates focusing only on futures contracts expiring between September 2007 and December 2018.

Figure 7 shows the estimated risk prices for the postcrisis period. The corresponding beta estimates are displayed in Figures 6–8 in the web-only appendix. We consider all futures prices with a maturity between 1 day and 1 year ($m = 1, \ldots, 260$). While the betas of all three risk factors show a similar pattern and size as we have estimated over the entire data sample, the estimates of the price of risk, γ_1, are highly insignificant for all considered maturity horizons. Furthermore, the R^2 no longer increases with the maturity horizon of the futures contracts, rather the opposite happens, as these tend to converge toward zero (Figure 8). This indicates that the CAPM model fails in the postcrisis period. The significant beta estimates suggest that excess currency returns reflect the "riskiness" of the currency portfolios. The different risk exposures of our portfolios, however, cannot explain the cross-sectional distribution of excess currency returns.

Thus, our estimates support the hypothesis that a time-varying risk premium is responsible for the occurrence of FPP. In the precrisis period, excess currency returns seem to compensate investors for risk, which is also the period in which the FPP is observed. Why this is no longer the case after the global financial crisis should be the subject of future research. An explanation could be that the relationship between exchange rate returns and futures premia is further distorted in the postcrisis period due to a decrease in capital available for currency arbitrage. Suppose that currency excess returns not only reflect risk premia, but also deviations from the covered interest parity (CIP) condition. The CIP holds when the futures premium corresponds to the interest rate differential between two countries. In the precrisis period, deviations from CIP were small and negligible (Akram et al. 2008) so that the risk-based approach explains the observed cross currency excess return. Since the great financial crisis of 2008, however, there is evidence that the CIP condition

23. We refrain from estimating the model separately for the precrisis period, as trading in futures for 6 of the 15 currencies only began in 2004 or 2007, respectively.

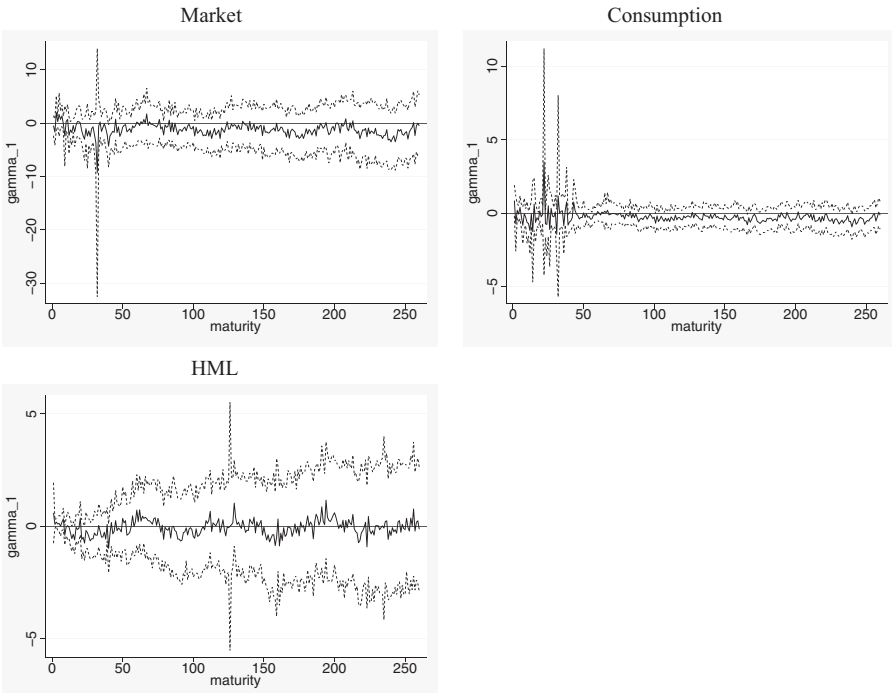

Fig 7. Prices of Risk γ_1: 2007–18.

NOTES: This figure shows the estimates of the factor price of risk γ_1 obtained from the GMM estimation of equation (7) together with their 95% intervals against the maturity length in days, $m = 1, \ldots, 260$. The sample period is 2007Q3 and 2018Q4. The currencies considered are Australian Dollar, Brazilian Real, Canadian Dollar, Czech Koruna, Deutsche Mark/Euro, Hungarian Forint, Japanese yen, Mexican peso, New Zealand Dollar, Norwegian Krona, Polish Zloty, Pound Sterling, South African Rand, Swedish Krona and Swiss Franc with respect to the US Dollar. The factors used are excess market risk (market), consumption risk (consumption) and carry trade risk (HML).

has broken down for several advanced economies, as documented in detail by Du et al. (2018).[24] Similar to Amador et al. (2020), they document that CIP deviations are negative for countries and periods characterized by very low nominal interest rates, while they are rather small for positive interest rates. This matches with what we see in Figure 4. If these CIP deviations move in the opposite direction to currency risk premia, which is likely given the fact that high yield currencies have higher risk premia, this incentivizes investors to go short in low interest rate currencies, exactly the opposite of what happens in the carry trade. In this case the currency risk would be offset and the risk approach to explain the cross-currency returns fails.

24. Du et al. (2018) argue that these deviations are the result of balance sheet constraints on financial intermediaries, probably caused by stricter banking regulations in the wake of the financial crisis. This causes a liquidity squeeze in the international Dollar swap market. Amador et al. (2020) show that deviations can be particularly large for currencies with interest rates close to the lower band.

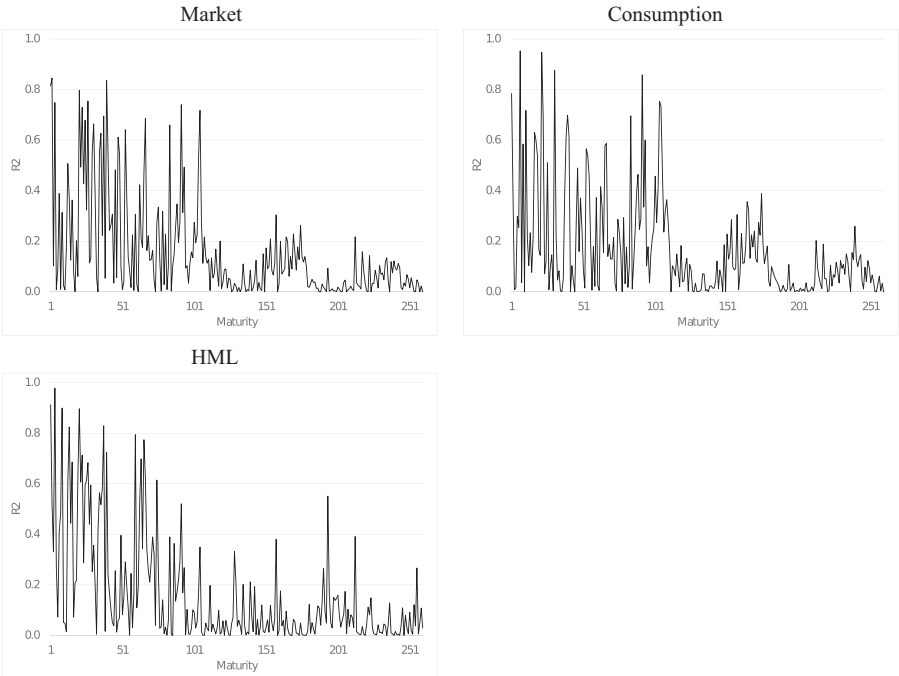

Fig 8. R^2 Across the Maturity Spectrum: 2007–18.

NOTES: This figure shows the model fit as measured by the R^2 estimate of the GMM model described in equation (7). Sample period is 2007Q3 and 2018Q4.

Horse Races between the market, consumption, and carry trade risk. To get an indication of which of our three risk factors is the most dominant one, we organize horse races between them. We do this by including two of the three factors jointly in our regression model. We find that the HML carry factor clearly dominates both the market risk factor and the consumer risk factor. The risk prices of the latter two become insignificant when we estimate them together with the HML factor. In contrast, the prices of the carry trade risk for medium and longer maturities remain significant and are of comparable size to those in the single-factor model. This result is in line with the finding of Lustig et al. (2011), who argue that it is global factors that are important to explain cross-sectional differences in currency excess returns. If we consider market risk and consumption risk together in our regression, we find that their factor prices and most of their β loadings become insignificant. Since these two factors are highly correlated (41%), this result can be attributed to multicollinearity problems.

Developed currencies. We also reestimate our models by excluding the five currencies of developing countries in our sample. As noted by Lustig and Verdelhan

(2007), this prevents against the possibility that our results are due to sovereign risk instead of currency risk. The estimates stay broadly the same in the reduced sample (see Figure A1 in the Appendix and Figures 9–11 in the web-only appendix).

3. CONCLUSION

The FPP is the empirical observation that currency forward premia and the realized foreign exchange returns tend to be negatively correlated, which contradicts the EH and the related UIP condition. In this paper, we reconsider the FPP using futures instead of forward rates. We investigate the relation between the spot return and the futures premium for the U.S. dollar exchange rates against the currencies of nine developed countries and six emerging markets economies between 1979Q1 and 2018Q4. Futures rates allow us to analyze the relationship at a daily basis with maturity horizons ranging from 2 days to several months. This yields estimates on a much finer grid than is currently available in the related literature.

Our first result is that not only the maturity horizon is important for the occurrence of the FPP, but also the observation period. So far as we know, we are the first, who obtain these results combined within a single study. For short maturities, the Fama coefficient is generally positive, and the EH is not rejected by the data. For longer maturity horizons, however, the sign and also size of the slope coefficient depends on the time period covered. When focusing on the period prior the global financial crisis, the slope coefficient tends to become negative as the maturity horizon over which expectations are formed increases, which confirms the FPP. When we focus on the later period starting after the financial crisis, however, we observe that the FPP vanishes for almost all currencies. We cannot reject the EH of a Fama coefficient of 1 for the majority of maturities considered except for Pound sterling, Canadian dollar, and Japanese yen futures contracts. For these contracts, we observe a deviation from the EH for maturities of more than half a year, but this time upwards instead of downwards. These currencies tend to appreciate by more than is indicated by the futures premium. We conclude that the FPP seems to be a precrisis phenomenon.

Furthermore, we find that in the precrisis period, EH also fails not only at a time-series dimension, but also on a cross-sectional basis. For currencies with the largest futures premium, excess returns are significantly positive, for currencies with the lowest futures premium they tend to be clearly negative. This leads to significant carry trade returns, which even increase as the maturity of the futures contracts increases. After the global financial crisis, these carry trade returns have disappeared.

Subsequently, we follow the common explanation that the FPP is caused by an omitted variable bias due to the presence of a risk premium that investors demand for foreign currency denominated investments. We investigate whether the sizable currency excess returns on futures contracts are indeed matched by covariances with (global) risk factors. Our contribution complements the broad literature by estimating the CAPM model for the complete term structure available. We find that currency

excess returns are associated with exposure to aggregate market risk, consumer risk, and the carry trade factor, which supports a risk-based view of exchange rates. High futures premium currencies load more on these risk factors than low futures premium currencies. Each of these factors accounts for most of the cross-sectional variation in average excess returns. When applying a joint asset pricing test, the HML carry factor appears to dominate both the market and consumer risk factors. This supports the hypothesis that global factors are most important to explain cross-sectional differences in currency excess returns. However, the pricing power of our risk measures only applies for assets with a maturity of longer than about 3–4 months. Since most studies testing the validity of a risk-based approach to currency excess returns focus on short securities maturities of 1 or 3 months, our results provide a possible explanation for why the risk-based approach is so often rejected.

When focusing on the postcrisis period only, we do not only find that the FPP has disappeared but we also reject that currency excess returns reflect a compensation for risk. Why this is the case should be the subject of future research. An explanation could be that the relationship between exchange rate returns and futures premia is further distorted in the post-crisis period. There is evidence that there are deviations from CIP due to insufficient capital available for arbitrage. If these CIP deviations move in the opposite direction to currency risk premia, which is likely given the fact that high yield currencies have higher risk premia, this would intend investors to go short in low interest rate currencies, exactly the opposite of what happens in the carry trade. In this case, the currency risk would be offset and the risk approach to explain the cross-currency returns fails.

Our results open new paths for future research. Given the proven empirical evidence, a complete theory of exchange rate and interest rate behavior needs to explain not only the FPP, but also why the magnitude and sign of the slope coefficient of the Fama regression depends on the maturity of the asset and the observed sample period.

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APPENDIX

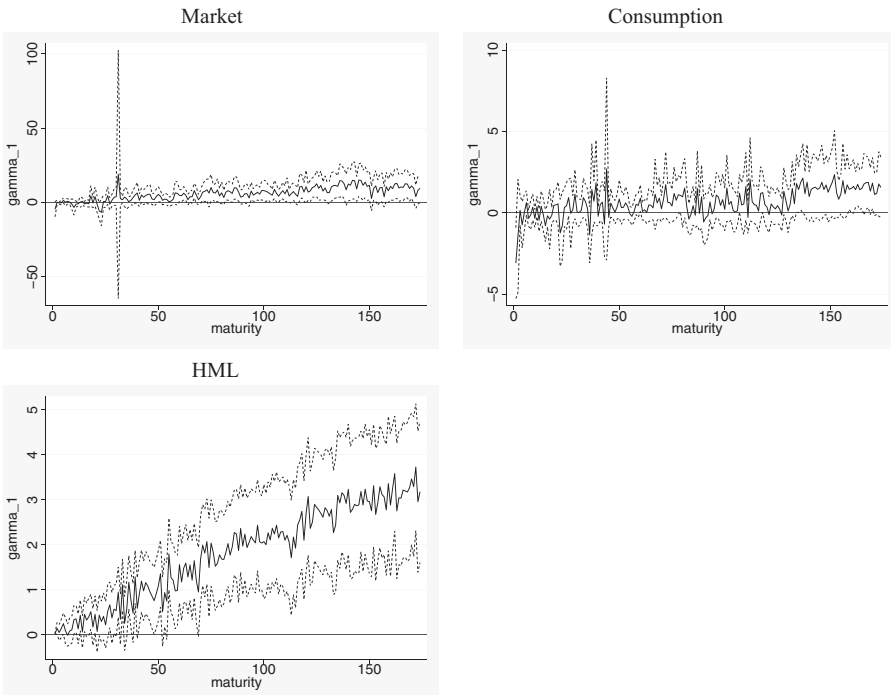

Fig A1. Prices of Risk γ_1: Developed Countries.

NOTES: This figure plots the result of the estimates of the factor price of risk γ_1 obtained from the GMM estimation of equation (7), together with their 95% intervals against the maturity length in days, $m = 1, \ldots, 174$. The sample period is 1979Q1–2018Q4 and only currencies of developed countries are considered (Australian Dollar, Canadian Dollar, Deutsche Mark/Euro, Japanese yen, New Zealand Dollar, Norwegian Krona, Pound Sterling, Swedish Krona, and Swiss Franc with respect to the US Dollar). The factors used are excess market risk (market), consumption risk (consumption), and carry trade risk (HML).

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.