Conditional Risk Premia in Currency Markets and Other Asset Classes

Martin Lettau* Matteo Maggiori† and Michael Weber*

This version: January 2013

Abstract

The downside risk CAPM (DR-CAPM) can price the cross section of currency returns. The market-beta differential between high and low interest rate currencies is higher conditional on bad market returns, when the market price of risk is also high, than it is conditional on good market returns. Correctly accounting for this variation is crucial for the empirical performance of the model. The DR-CAPM can jointly explain the cross section of equity, commodity, sovereign bond and currency returns, thus offering a unified risk view of these asset classes. In contrast, popular models that have been developed for a specific asset class fail to jointly price other asset classes.

JEL classification: F31, F34, G11, G15

Keywords: Carry Trade, Currency Returns, Downside Risk, Exchange Rates, UIP, Conditional risk premia, Cross Section of Equities and Commodities

*Haas School of Business, University of California at Berkeley, Berkeley, USA. Corresponding author: lettau@haas.berkeley.edu.

†Stern School of Business, New York University, New York, USA.
We thank Yoshio Nozawa, Fan Yang, and Adrien Verdelhan for sharing their data, the discussants Harald Hau and Ralph Koijen and seminar participants at UC Berkeley, AEA, EFA, EEA and ESNAW meetings, University of Mannheim, University of Michigan, Black Rock, and University of Chicago Booth Junior Faculty Symposium. Financial support from the Clausen Center and the Coleman Fung Center at UC Berkeley are gratefully acknowledged. Maggiori also thanks the International Economics Section, Department of Economics, Princeton University for hospitality during part of the research process for this paper.

Foreign exchange is a potentially risky investment and the debate on whether currency returns can be explained by their association with risk factors remains ongoing. We find that the cross section of currency returns can be explained by a risk model where investors are concerned about downside risk. High yield currencies earn higher excess returns than low yield currencies because their co-movement with aggregate market returns is stronger conditional on bad market returns than it is conditional on good market returns. We find that this feature of the data is characteristic not only of currencies but also of equities, commodities and sovereign bonds, thus providing a unified risk view of these markets.

The carry trade in foreign exchange consists of investing in high yield currencies while funding the trade in low yield currencies. This trading strategy has historically yielded positive returns because returns on high yield currencies are higher than returns on low yield currencies. A number of explanations for this cross-sectional dispersion have been advanced in the literature, varying from risk based to behavioral.

We provide a risk-based explanation by showing that the downside risk capital asset pricing model (DR-CAPM) prices the cross section of currency returns. We follow Ang, Chen, and Xing (2006), who study equity markets, by allowing both the market price of risk and the beta of currencies with the market to change conditional on the aggregate market return. Intuitively, the model captures the changes in correlation between the carry trade and the aggregate market returns: the carry trade is more correlated with the market during market downturns than it is during upturns.

Correctly capturing the variations in betas and prices of risk is crucial to the empirical performance of the DR-CAPM. It also clarifies why the unconditional CAPM does not explain the cross section of currency returns. While high yield currencies have higher betas than lower yield currencies, the difference in betas is too small to account for the observed spread in currency returns.

We extend our results by testing the performance of the DR-CAPM jointly on currencies, equities, commodities and sovereign bonds. The variations in betas and prices of risk in the DR-CAPM can jointly explain the cross-sectional returns of all of these asset classes. This contrasts with the inability of a number of asset-class-specific models to price asset classes other than the one for which they have been built.

We compare the DR-CAPM with models based on principal component analysis (PCA) both within and across asset classes. Within each asset class the DR-CAPM captures the cross-sectional dispersion in returns summarized by the most important principal components. Across asset classes the DR-CAPM continues to capture expected returns with only two fundamental factors, while a PCA-based model requires as many as eight factors to generate similar explanatory power.

This paper contributes to two strands of literature: the international finance literature on exchange rates and currency returns and the asset pricing literature on the joint cross section of returns of multiple asset classes.

Among a vast international finance literature, Lustig and Verdelhan (2007) provide an explanation for the cross section of currency returns based on the Durable Consumption CAPM (DC-CAPM). Burnside (2011b) and Lustig and Verdelhan (2011) discuss the association of currency returns with consumption growth. Burnside, Eichenbaum, Kleshchelski, and Rebelo (2011); Burnside, Eichenbaum, and Rebelo (2011, 2009); Burnside, Han, Hirshleifer, and Wang (2011) focus on explanations of the carry trade such as investor overconfidence and peso problems. Lustig, Roussanov, and Verdelhan (2011) (LRV) provide a model that employs the principal component analysis of currency returns. They show that currencies that load more heavily on the first two principal components, approximated by the returns on a dollar and carry trade portfolio respectively, earn higher excess returns on average. Menkhoff, Sarno, Schmeling, and Schrimpf (2012) link the carry trade factor to exchange rate volatility.

Our contribution to this literature is to provide an explanation of currency returns based on the *conditional* association of currency returns with a *traditional* risk factor, the market return. We not only reconcile our findings with the more statistical factors used in the literature, but also show that currencies are affected by the same aggregate risk that drives expected returns in other assets classes such as equities and commodities.

A nascent literature is exploring the joint cross section of returns in multiple asset classes. Cochrane (2011) emphasized this research agenda, which aims to reconcile the discount factors in different asset classes. In his American Finance Association presidential address he ponders: "*What is the factor structure of time-varying expected returns? Expected returns vary over time. How correlated is such variation across assets and asset classes? How can we best express that correlation as factor structure? [...] This empirical project has just begun, [...] but these are the vital questions.*"

In recent and ongoing research Asness, Moskowitz, and Pedersen (2012); Frazzini and Pedersen (2012); Koijen, Moskowitz, Pedersen, and Vrugt (2012) document that a number of cross-sectional phenomena such as value, carry, momentum, and the slope of the unconditional-CAPM-based capital market line that were previously only documented for specific asset classes are actually pervasive across multiple asset classes.

We contribute to this literature by showing that the DR-CAPM can jointly reconcile the cross-sectional dispersion in returns across multiple asset classes. We also explore the factor structure by comparing the model to several PCA-based models. We find that PCA-based models tailored to a specific asset class are unable to price other asset classes, and that a PCA model based on the joint cross-section of multiple asset classes overestimates the number of risk factors. We view our results as a step in the research agenda emphasized by Cochrane (2011).

We stress that the purpose of this paper is not to suggest that the DR-CAPM is the true model of all asset prices, nor is it to discourage the use of PCA to summarize patterns in asset returns. The purpose of this paper is to verify how much of the cross sectional variation in returns across asset classes can be rationalized by the association of returns, both unconditionally and conditionally, with a traditional risk factor, the market return. For this purpose and for completeness, we also report in Section V.*E.* a number of test assets the returns of which the DR-CAPM does not rationalize.

In a separate online appendix we provide a number of details, robustness checks, and extensions of our results that are omitted in the main body of the paper.

I Carry Trade and Market Returns

We follow Ang et al. (2006) in allowing a differentiation in unconditional and downside risk. This captures the idea that assets that have a higher beta with market returns conditional on low realization of the market return are particularly risky. Ang et al. (2006) motivate this insight using the disappointment aversion model of Gul (1991). Routledge and Zin (2010) extend the disappointment aversion model to not only account for a threshold return below the certainty equivalent, but also to generate time varying expected returns. Downside-risk aversion is potentially also a feature of models with wealth constraints, where the agent is particularly concerned about the performance of assets once her aggregate wealth is below a threshold. Ultimately, the quantitative importance of downside risk is linked to the rare disasters model of Barro (2006). Farhi and Gabaix (2008) develop a model of exchange rates in the presence of rare disasters.

To capture the relative importance of downside risk we propose that expected returns follow:

$$
\begin{aligned}
E[r_i] &= \beta_i \lambda + (\beta_i^- - \beta_i)\lambda^- \qquad\qquad i = 1, \ldots, N, \qquad (1)\\
\beta_i &= \frac{cov(r_i, r_m)}{var(r_m)},\\
\beta_i^- &= \frac{cov(r_i, r_m | r_m < \delta)}{var(r_m | r_m < \delta)},
\end{aligned}
$$

where r_i is the log excess return of asset i over the risk-free rate, r_m is the log market excess return, β_i and β_i^- are the unconditional and downside beta defined by an exogenous threshold (δ) for the market return, and λ and λ^- are the unconditional and downside prices of risk, respectively.

This empirical framework is flexible in allowing variations both in the quantity and the price of risk while maintaining a parsimonious parametrization with a single threshold δ.

Note that the model reduces to CAPM in the absence of differential pricing of downside risk from unconditional market risk: $\lambda^- = 0$; or if the downside beta equals the CAPM beta: $\beta_i^- = \beta_i$. As in the case of CAPM, the model also restricts the unconditional price of risk to equal the expected market excess return:

$$E[r_m] = \lambda, \qquad (2)$$

because both the unconditional and downside beta of the market with itself are equal to 1.

A. Data

We use the bilateral currency returns dataset in Maggiori (2012); details of the data are included in the online appendix and in the original reference. The data are monthly, from January 1974 to March 2010, and cover 53 currencies. We follow Lustig and Verdelhan (2007) in defining a cross section of currency returns based on their interest rate. We sort currencies into 6 portfolios, in ascending order of their respective interest rates.

Since the dataset includes currencies for which the corresponding country has undergone periods of extremely high inflation and consequently high nominal interest rates, we split the sixth portfolio into two baskets: 6A and 6B. Portfolio 6B includes currencies that belong to portfolio 6 and that have annualized inflation at least 10% higher than US inflation in the same month.[1]

We also use an alternative sorting that only includes developed countries' currencies.[2] In this case we sort the currencies into 5 rather than 6 baskets, to take into account the overall reduced number of currencies.

We calculate one-month real-dollar bilateral log excess returns r_{t+1} as the sum of the interest differential and the rate of exchange rate depreciation of each currency with the US dollar:

$$r_{t+1} = i_t^{\star} - i_t - \Delta s_{t+1}, \tag{3}$$

where i^{*} and i are the foreign and US interest rate, and s_t is log spot exchange rate expressed in foreign currency per US dollar.

Figure 1 shows that the sorting produces a monotonic increase in returns from portfolios 1 to 6. Further descriptive statistics are reported in Table 1. Portfolios 6A and 6B highlight the very different behavior of high inflation currencies. The standard deviation of returns for portfolio 6B is almost double that of all other baskets. Bansal and Dahlquist (2000) note that the uncovered interest parity condition cannot be rejected for these currencies. These findings and the general concern about the effective tradability of these currencies during periods of economic turmoil lead us to present our benchmark results using only basket 6A and to provide robustness checks including both basket 6 and 6B in the online appendix.

For our benchmark results on the cross section of equity returns we use the 6 Fama & French portfolios sorted on size and book-to-market for the period from January 1974 to March 2010. For the cross section of commodity returns we use the 5 commodity-futures portfolios sorted by the commodity basis for the period from January 1974 to December 2008 by Yang (2010). For the cross section of sovereign bonds we use the 6 sovereign-bond portfolios sorted by the probability of default and bond beta for the period from January 1995 to March 2010 by Borri and Verdelhan (2011). For the aggregate equity market we use the value-weighted CRSP US equity market log excess return for the period January 1974 to March 2010. Table 2 provides summary statistics for the equity, commodity futures and sovereign bond portfolios.

[1] We view our results excluding the high inflation currencies as conservative since these noisy observations are eliminated. Our results are robust to different threshold levels or to the inclusion of all the currencies in the 6th portfolio. The inflation data for all countries is from the IMF International Financial Statistics.

[2] A country is considered developed if it is included in the MSCI World Equity Index.

B. Conditional Correlations

The central insight underlying our work is that the currency carry trade, as well as other carry strategies, is more correlated with aggregate returns conditional on low aggregate returns than it is conditional on high aggregate returns. This insight is supported by a growing empirical literature including Brunnermeier, Nagel, and Pedersen (2008); Burnside (2011a); Lustig and Verdelhan (2011); Christiansen, Ranaldo, and Soederlind (2011); Mueller, Stathopoulos, and Vedolin (2012) all of which find a state dependent correlation. In ongoing work, Caballero and Doyle (2013) and Dobrynskaya (2013) highlight the strong correlation of the carry trade with market risk during market downturns. Our paper differs from all previous studies both by providing systematic evidence over a longer time period and larger sample of this state dependent correlation and by relating the resulting downside risk to that observed in other asset classes such as equities, commodities, and sovereign portfolios.

We define the downstate to be months where the contemporaneous market return is more than one standard deviation below its sample average. A one standard deviation event is a reasonable compromise between a sufficiently low threshold to trigger concerns about downside risk and a sufficiently high threshold to have a large number of downstate observations in the sample. Our definition assigns 55 monthly observations to the downstate, out of 435 total observations in our sample. For robustness we test our model with different threshold levels[3] as well as a finer division of the state space into three rather than two states.

Table 3 shows that the carry trade is unconditionally positively correlated with market returns. The correlation is 0.14 and statistically significant for our benchmark sample and robust to the exclusion of emerging markets or to various thresholds of inflation for the basket 6B. The table also shows that most of the unconditional correlation is due to the downstate: conditional on the downstate the correlation increases to 0.33, while it is only 0.03 in the upstate.[4]

Figure 2 highlights this characteristic of the data by plotting the kernel-smoothed conditional correlation between the carry trade and the market returns. The top panel shows that the correlation of high yield currencies with the market returns is a decreasing function of market returns. The opposite is true for low yield currencies in the middle panel. The bottom panel highlights that our results are not sensitive to the exact choice of threshold.

[3]Thresholds of the sample average minus 0.5 or 1.5 standard deviations assign 118 observations and 27 observations to the downstate, respectively.

[4]The upstate includes all observations that are not included in the downstate.

II Econometric Model

We estimate the model in (1) with the two-stage procedure of Fama and MacBeth (1973). In our model the first stage consists of two time-series regressions, one for the entire time series and one for the downstate observations. These regressions produce point estimates for the unconditional and downstate betas, $\hat{\beta}$ and $\hat{\beta}^{-}$, which are then used as explanatory variables in the second stage. The second-stage regression is a cross-sectional regression of the average return of the assets on their unconditional and downstate betas. In our estimation we restrict, following the theory section above, the market price of risk to equal the sample average of the market excess-return. Therefore, in the second-stage regression we estimate a single parameter: the downside price of risk λ^{-}.

Formally, the first-stage regressions are:

$$
\begin{aligned}
r_{it} &= a_i + \beta_i r_{mt} + \epsilon_{it}, \qquad \forall t \in T, && (4)\\
r_{it} &= a_i^{-} + \beta_i^{-} r_{mt} + \epsilon_{it}^{-}, \qquad \text{whenever} \;\; r_{mt} \leqslant \bar{r}_m - \sigma_{r_m}, && (5)
\end{aligned}
$$

where $\bar{r}_m$ and σ_{r_m} are the sample average and standard deviation of the market excess return, respectively. The second-stage regression is given by:

$$
\bar{r}_i = \hat{\beta}_i \bar{r}_m + (\hat{\beta}_i^{-} - \hat{\beta}_i)\lambda^{-} + \alpha_i, \quad i = 1, \ldots, N, \tag{6}
$$

where $\bar{r}_i$ and $\bar{r}_m$ are the average excess returns of the test assets and the market excess-return, respectively and α_i are pricing errors. Notice that by not including a constant in the second-stage regression we are imposing that an asset with zero beta with the risk factors has a zero excess return.

We employ the concept of *conditionality* in the context of realizations of states of the world: market return above or below a threshold. A part of the asset pricing literature has instead applied similar terminology in the context of time variation of expected returns and return predictability tests.

We stress that while we do not allow for time variation in the betas or the prices of risk, but only for variation across realized states of the world, our empirical methodology is consistent with some predictability in expected returns. Since we test our model on sorted portfolios that capture a characteristic associated with expected returns, the interest rate differential, we allow for predictability generated by variation over time in this characteristic. Cochrane (2005) notes the similarity between testing the model on sorted portfolios and testing the model on unsorted assets while allowing for time variation in instruments that proxy for managed portfolios. Our procedure, however, does not allow variation in expected returns through time for a fixed characteristic.

For example, we capture the fact that the expected return for a specific currency pair varies through time as the corresponding interest rate differential varies, but we do not allow for the expected return of a specific currency pair to vary through time given a constant interest rate differential. Lustig et al. (2011) similarly allow predictability only through variation in the interest rate differential.

III Empirical Results

A. Risk Premia: Currency

We find that while the CAPM shows that currency returns are associated with market risk, it cannot explain the cross section of currency returns because the CAPM beta is not sufficient to explain the cross sectional dispersion in returns. The left panel of Figure 3 shows that the increase in CAPM beta going from the low yield portfolio (portfolio 1) to the high yield portfolio (portfolio 6) is small compared to the increase in average returns for these portfolios. As it will shortly become evident, once the market price of risk of CAPM is pinned down by the average market excess return, CAPM fails to price these currency portfolios.

The middle panel of Figure 3 shows that average currency returns are also strongly related to the downstate beta. While this finding supports the importance of downside risk for currency returns, it is not per se evidence of a failure of CAPM because currencies that have a higher downstate beta do have a higher CAPM beta.

However, the right panel of Figure 3 shows that the relative beta, the difference between downstate and unconditional beta, is also associated with contemporaneous returns. Currencies that have higher downstate than unconditional beta are on average riskier and earn higher excess returns. We show in our benchmark regressions that this state dependency is not fully captured by the CAPM beta.

Figure 4 and Table 4 illustrate both the failure of CAPM and the performance of the DR-CAPM. The top panels of Figure 4 present the results employing all currencies, the bottom panels present the results employing only currencies of developed countries. Since higher yield currencies have higher CAPM beta, they earn a higher return on average. However, the CAPM beta does not fully capture the risk-return tradeoff: the spread in betas is too small to account for the spread in currency returns. The failure is evident in the first column of Table 4, where CAPM cannot jointly price the market return and the cross section of currency returns producing a R^2 of only 10%. Correspondingly, the left panels of Figure 4 show that CAPM predicts almost identical returns for all currency portfolios.

In contrast, the DR-CAPM explains the cross section of currency returns. In the second column of Table 4, the DR-CAPM explains 79% of the cross-sectional variation in mean returns even after imposing the restriction that the market portfolio (included as a test asset) is exactly priced. The right quadrants of Figure 4 correspondingly show that the test assets lie close to the 45 degree line. The estimated price of downside risk is positive (2.18) and statistically significant. The model fits the returns of portfolios 2 to 6A with small pricing errors. The absolute pricing error is on average 0.07% (in terms of monthly excess returns) across these portfolios. Portfolio 1, which contains the low yield currencies, is priced with the biggest pricing error, −0.2%.[5] We also report the χ^2 test that all pricing errors in the cross-sectional regression are jointly zero. While both the CAPM and the DR-CAPM are formally rejected with p-values of 0% and 0.04% respectively, we stress that the DR-CAPM produces a root mean square pricing error (RMSPE) that is 40% smaller than that of CAPM.[6]

Potential sources of concern about the reliability of our currency returns are sovereign default and international capital restrictions. To alleviate these concerns, we test the DR-CAPM on a subsample of developed countries' currencies. The results for this subsample of countries are also reported in Figure 4 and Table 4 and show that the model performs equally well on these portfolios. The price of downside risk is 2.34 and is consistent with the 2.18 estimate obtained on the full sample and the R^2 increases to 85%. We confirm on this subsample the pattern of small DR-CAPM pricing errors for all portfolios except portfolio 1. The null hypothesis of zero joint pricing errors cannot be rejected at the 5% confidence level with a p-value of the χ^2 test of 8%. The RMSPE of 0.10% is almost 50% smaller than the one produced by CAPM on the same test assets.

[5]Note that the pricing errors here and in all subsequent tables and references in the text are expressed in monthly percentage excess returns, while the figures are annualized percentage excess returns. The pricing errors are defined as the difference between the actual and model-predicted excess return, so that a positive price error corresponds to an under prediction of the return by the model.

[6]The test is under the null hypothesis of zero joint pricing errors, therefore the model is not rejected at the 5% confidence level if the p-value statistic is higher than 5%.

B. Risk Premia: Other Asset Classes

The conditional association of asset returns and the market portfolio and the variation in prices of risk is not unique to currencies and is, in fact, shared by other asset classes. Providing a unified risk-based treatment of expected returns across asset classes is both informative from a theoretical perspective and an important check of the empirical performance of theoretical models.

Figure 5 shows that equity, commodity, and sovereign bond portfolios' expected returns are positively related to these assets' relative downside betas. In all three asset classes, assets that are more strongly associated with market returns conditional on the downstate than unconditionally have higher average excess returns. This conditional variation – which is not captured by CAPM – is the central mechanism that underlies the performance of the DR-CAPM across asset classes.

We investigate next whether the DR-CAPM can jointly explain the cross section of currency and equity returns. We add the 6 Fama & French portfolios sorted on book-to-market and size to the currency and market portfolios as test assets. Figure 6 and Table 5 show that the DR-CAPM jointly explains these returns. The estimated price of downside risk is consistent across asset classes but the estimate of 1.41 is lower than that obtained on currencies alone (2.18).[7] The model explains 72% of the observed variation in mean returns, a noticeable increase over the 24% explained by CAPM. Figure 6 shows that the largest pricing errors occur for the small-growth equity portfolio (portfolio 7) in addition to the low-yield currency portfolio (portfolio 1). The average absolute pricing error on all other portfolios is 0.08%, while the pricing errors on the small-growth equity portfolio and the low-yield currency portfolios are -0.2% and -0.47%, respectively. Section V.*B.* provides further details about the pricing of the small-growth equity portfolio. Both CAPM and the DR-CAPM are statistically rejected with p-values of the χ^2 test of 0% and 0.3% respectively, but the DR-CAPM produces a RMSPE two thirds smaller than CAPM.

A close analog to the currency carry trade is the basis trade in commodity markets. The basis is the difference between the futures price and the spot price of a commodity. Among others, Yang (2010) shows that commodities with a lower basis earn higher expected returns (see Table 2 Panel B).[8] We extend our results by adding the commodity portfolios

[7] If the small-growth equity portfolio is excluded as a test asset, the estimated price of risk increases to 1.70. Section V.*B.* provides a detailed discussion of the returns and pricing of the small-growth equity portfolio.

[8] Also see Gorton, Hayashi, and Rouwenhorst (2013).

to the currency and equity portfolios. Figure 7 and Table 6 show that the same economic phenomenon, the conditional variation of the quantity and price of market risk, underlies the variation in expected returns in commodity markets. The estimated price of downside risk (1.40) is essentially unchanged after the addition of the commodity portfolios to the currency and equity portfolios studied above and is statistically significant. The model explains 74% of the cross sectional variation in returns across these asset classes compared to an adjusted R^2 of -17% for CAPM. The biggest pricing error occurs for the high-basis commodity portfolio (portfolio 11) in addition to the low-yield currency portfolio (portfolio 1) and the small-growth equity portfolio (portfolio 12). The pricing errors for these three portfolios are -0.24%, -0.22%, and -0.46%, respectively. The average absolute pricing error of all other portfolios included as test assets is 0.07%. While both CAPM and the DR-CAPM are again statistically rejected, the DR-CAPM produces a RMSPE 50% smaller than CAPM.

Finally, we investigate whether sovereign bonds are priced by the DR-CAPM. We use the cross-sectional sorting of sovereign bonds according to default probability and market beta in Borri and Verdelhan (2011). Figure 8 and Table 7 confirm yet again the ability of the DR-CAPM to price multiple asset classes. An important caveat in this case is that the data of Borri and Verdelhan (2011) are only available over a relatively short sample period (January 1995 to March 2010), thus limiting the number of observations, particularly for our downstate. The shorter sample produces noisier estimates of the prices of risk and different point estimates overall from our full sample. The sample limitations impose caution in interpreting the positive performance of our model on sovereign bonds. Consequently, we exclude these portfolios from the analysis in the rest of the paper.

For completeness we also report in Section V.*E.* a number of alternative test assets whose return factor structure cannot be rationalized by the DR-CAPM.

IV Robustness

An important verification of our results is to confirm the association of currency returns with downside market risk. In Panel A of Table 8 we provide the first-stage estimates of the unconditional CAPM betas and the downstate betas for the six currency portfolios. The CAPM betas are increasing from portfolio 1 to 6 and the spread in betas between the first and last portfolio is statistically different from zero. The increase in betas, however, is small;

the beta of the first portfolio is 0.03 while the beta of the last portfolio is 0.11. We provide both OLS and bootstrapped standard errors.[9] The downstate betas highlight the central mechanism of the DR-CAPM: conditional on below-threshold market returns, high yield currencies (portfolio 6A) are more strongly related to market risk than low yield currencies (portfolio 1). In fact, we find that while the downside beta of portfolio 6A (0.30) is larger than its unconditional beta (0.11), the opposite is true for portfolio 1 with a downside beta of 0.02 and an unconditional beta of 0.03.

Splitting the sample into the downstate picks up the conditional variation in currencies' association with market risk, but also reduces the variation available in each subsample to estimate the betas. Therefore, the standard errors of the first-stage regressions that estimate downstate betas are wider than those of the corresponding regressions for unconditional betas. We perform a number of robustness checks of our first-stage estimates and their impact on the second-stage estimates.

We perform two bootstrap tests to check the robustness of the main driver of our results: the different conditional association of high yield and low yield currencies with the market excess-return. We first test whether high yield currencies are more associated with market risk than low yield currencies conditional on the downstate under the null hypothesis that $\beta^-_{6A} - \beta^-_1 = 0$. We then test whether the different loading on risk of high and low yield currencies varies across states under the null hypothesis that $(\beta^-_{6A} - \beta^-_1) - (\beta_{6A} - \beta_1) = 0$. Figure 9 shows that both nulls are strongly rejected with p-values of 0.24% and 2.44%, respectively, thus yielding statistical support for our main economic mechanism.

A second robustness check is to mitigate the concern that our second-stage regression employs potentially weak estimated regressors from the first stage. Table 8 reports the first-stage estimates for the 6 Fama & French equity portfolios. Since these equity portfolios have a strong association with the overall equity market, the betas are very precisely estimated even for the downstate. We then use the prices of risk estimated using only these equity portfolios to fit the cross section of currencies. Panel B of Table 9 reports that the DR-CAPM can still explain 67% of the observed variation in currency returns. The estimated price of downside risk is 1.27, statistically significant, and consistent with the estimate of 1.41 obtained on the joint sample of currencies and equities.

In Table 10 we verify that our results are not altered by reasonable variations in the

[9]We employ a smoothed bootstrap scheme consisting of resampling empirical residuals and adding zero centered normally distributed noise using 20,000 iterations.

threshold for the downstate. We vary our benchmark threshold for the market return of 1 standard deviation below its sample mean to 0.5 and 1.5 standard deviations. In both cases we observe a consistent performance of the model.

Finally, we verify the sensitivity of our results to different thresholds for excluding currencies with high inflation. We vary the inflation threshold from our benchmark of 10% above the annualized inflation of the US to 5% and 15%. Table 11 shows that the lower threshold produces higher but noisier estimates of the price of risk compared to the higher threshold. In both cases, however, the prices of risk are statistically significant and the R^2 are around 80%.

Further robustness checks are provided in the separate appendix.

V Factor Structure and PCA Based Models

To further investigate the common factor structure in the joint cross-section of currencies, equities, and commodities we perform a principal component analysis (PCA) both on each asset class separately and on their joint returns. This analysis allows us to compare the DR-CAPM to the asset-class-specific PCA-based models that are prevalent in the literature.

A. Currency PCA Model

For currencies, the PCA analysis leads to the model of Lustig et al. (2011). Consistent with their work, we report in Table 12 that the first two principal components account for 87% of the time series variation of the interest-rate-sorted currency portfolios. The loadings of the first principal component reveal that it can be interpreted as a level factor because it loads on the returns of all currency portfolios similarly. Analogously, the loadings of the second principal component reveal that it can be interpreted as a slope factor because it loads on the differential return when going from portfolio 1 to portfolio 6. Intuitively, these two principal components can be approximated by two portfolios: an equally weighted portfolio of all currencies in the sample against the dollar and a carry trade portfolio created by a long position in portfolio 6 and a short position in portfolio 1. We refer to these two portfolios as the dollar and carry portfolios, and denote their returns by RX_{cur} and HML_{cur} respectively. To confirm the intuition, Table 13 reports in the top left panel that the correlation between the first principal component and the dollar portfolio is 100% and the correlation between the second principal component and the carry portfolio is 95%.

Table 14 and Figure 10 present the estimates of both the PCA-based linear model of Lustig et al. (2011) and the DR-CAPM on the cross-section of currency returns. The LRV model explains 64% of the cross sectional variation in currency returns. The estimated price of risk is statistically significant for the carry portfolio but not for the dollar portfolio. The model is statistically rejected by the χ^2 test on the pricing errors with a p-value of 0%. Notice that it is the slope factor, the carry portfolio, that carries most of the information relevant for the cross section. A model that only includes the first principal component, the level factor or dollar portfolio, generates a R^2 of only 4%. Similarly to the DR-CAPM, the largest individual pricing error (-0.2%) for the LRV model is for the low-yield currency portfolios (portfolio 1).

The DR-CAPM captures the information contained in the principal components that is relevant for this cross section. Intuitively, the DR-CAPM summarizes the two principal components because the unconditional market return acts as a level factor while downside risk acts as a slope factor. To confirm this intuition, recall from Table 8 that the unconditional market betas are relatively similar across currency portfolios, so that all portfolios load similarly on the market. In contrast, the downside betas are more strongly increasing going from portfolio 1 to portfolio 6, thus providing a slope factor. The top two panels in Table 13 confirm that the second principal component (or the carry portfolio) is more highly correlated with the market portfolio in downstates (28% correlation), thus loading on downside risk, than it is unconditionally (9% correlation). The DR-CAPM produces a R^2 of 73% and RMSPE of 0.10% that are similar to the R^2 of 64% and RMSPE of 0.12% of the LRV model.

B. Equity PCA model

The PCA on the cross-section of equities provided by the 6 Fama & French portfolios sorted on size and book-to-market leads to the three factor model of Fama and French (1992). Table 15 shows that the first three principal components account for 98% of the time series variation of the size and book-to-market sorted portfolios. The loadings of the first principal component reveal that it can be interpreted as a level factor because it loads on the returns of all equity portfolios similarly. The loadings of the second and third principal components reveal that they can be interpreted as two slope factors. The second principal component mainly loads on the differential return when going from small portfolios (1 to 3) to big portfolios (4 to 6). The third principal component mainly loads on the differential return when going from growth portfolios (1 and 4) to value portfolios (3 and 6). However, notice that the interpretation is not as clear as it is for currencies (nor as it is for commodities below). For example, the third principal component does not affect portfolio 2 and 5 in a way consistent with its interpretation as a factor affecting the value-growth trade-off in returns.

We approximate the first principal component with the market return and the next two principal components by the Fama & French factors: the small-minus-big portfolio and the high-minus-low portfolio. We denote the returns of these two portfolios as SMB and HML_{ff}, respectively. Table 13 shows in the bottom left panel that the first principal component is highly correlated with the market (95% correlation), the second principal component is mainly related to the SMB return (80% correlation), and the third principal component is mainly related to the HML_{ff} return (82% correlation). However, HML_{ff} and SMB returns are themselves correlated and therefore do not correspond exactly to the two principal components that are by construction orthogonal to each other. Correspondingly, we find that HML_{ff} is also correlated with the second principal component and SMB is correlated with the third principal component.[10]

Table 16 and Figure 11 present the estimates of both the PCA-based linear model of Fama and French (1992) and the DR-CAPM on the cross section of equity returns. The Fama & French three factor model explains 68% of the cross sectional variation in returns. The estimated prices of risk are significant for the market and HML_{ff} but not for SMB. The model is statistically rejected by the χ^2 test on the joint pricing errors with a p-value of 0%. Notice that the cross-sectional performance of the model is driven by the third principal component, which is approximated by the HML_{ff} factor. A model based only on the first two principal components, which are approximated by the market and SMB returns, generates a R^2 of -4%.

The DR-CAPM is unable to match the small-growth equity returns of portfolio 1 (pricing error of -0.45%) and therefore produces a lower R^2 (33%) than the Fama & French three-factor model. As noted by Campbell and Vuolteenaho (2004), it is typical in the literature to find that models cannot correctly price portfolio 1 and a number of papers (Lamont and Thaler (2003); D'Avolio (2002); Mitchell, Pulvino, and Stafford (2002)) have questioned whether its

[10] The correlation between HML_{ff} and SMB helps to rationalize why the interpretation of the equity principal components in terms of mimicking portfolios is not as clear as it is for currencies or commodities. In the case of currencies and, as will shortly be illustrated, in the case of commodities, the proxy portfolios of the two principal components are themselves almost uncorrelated. For example, the correlation between RX_{cur} and HML_{cur} is only 0.07.

return is correctly measured. In the last column of Table 16 we show that once we remove portfolio 1 from the 6 Fama & French portfolios the DR-CAPM performance improves: the R^2 increases to 90% and the hypothesis of zero joint pricing errors cannot be rejected by the χ^2 test at the 5% confidence level.

C. Commodity PCA model

The PCA on the cross-section of commodities leads to the model of Yang (2010). Consistent with his work, we report in Table 17 that the first two principal components account for 75% of the time series variation of the basis-sorted commodity portfolios. The loadings of the first principal component reveal that it can be interpreted as a level factor because it loads on the returns of all commodity portfolios similarly. Analogously, the loadings of the second principal component reveal that it can be interpreted as a slope factor because it loads on the differential return when going from portfolio 1 to portfolio 5. Intuitively, these two principal components can be approximated by two portfolios: an equally weighted portfolio of all commodities contained in the sample and a basis trade portfolio created by a long position in portfolio 1 and a short position in portfolio 5. We refer to these two portfolios as the commodity and basis portfolios and denote their returns by RX_{com} and HML_{com}, respectively. To confirm this intuition, the middle left panel of Table 13 shows that the correlation between the first principal component and the commodity portfolio is 100% and the correlation between the second principal component and the basis portfolio is 95%.

Table 18 and Figure 12 present the estimates of both the PCA-based linear model of Yang (2010) and the DR-CAPM on the cross-section of currency returns. The Yang model explains 87% of the cross sectional variation in expected returns. The estimated price of risk is statistically significant for both the commodity and basis portfolios. The hypothesis of zero joint pricing errors cannot be rejected by the χ^2 test with a p-value of 50%. Notice that it is the slope factor, the basis portfolio, that carries most of the information relevant for the cross section. A model that only includes the first principal component, the level factor or commodity portfolio, generates a R^2 of only 10%.

The DR-CAPM captures the information contained in the principal components that is relevant for this cross section. Intuitively, the DR-CAPM summarizes the two principal components because the unconditional market return acts as a level factor, while downside risk acts as a slope factor. To confirm this intuition, recall from Table 8 that the unconditional market betas are similar across commodity portfolios, so that all portfolios load similarly on the market, while the downside betas are decreasing when going from portfolio 1 to portfolio 5, thus providing a slope factor.[11] The middle two panels in Table 13 confirm that the second principal component (or the basis portfolio) is more highly correlated with the market portfolio in down states (19% correlation), thus loading on downside risk, than it is unconditionally (-0.5% correlation). The DR-CAPM produces a R^2 of 82% and RMSPE of 0.12% that are similar to the R^2 of 87% and RMSPE of 0.10% of the Yang model. The hypothesis that the DR-CAPM pricing errors are jointly zero cannot be rejected by the χ^2 test with a p-value of 66%.

Having investigated the factor structure of each asset class separately, we conclude that for each asset class the DR-CAPM has similar explanatory power to the PCA-model that is specifically designed for that asset class.[12] We emphasize that the underlying reason is that in each asset class the factor structure is composed of level and slope factors that the DR-CAPM picks up with the market and downside risk factors, respectively.

D. PCA models across asset classes

We now turn to investigate the factor structure of the joint cross section of currencies, equities, and commodities. Figure 13 plots together the loadings of the principal component analysis performed on each asset class separately. The left panel suggests that the first principal component in each asset class represents a joint level factor. The right panel shows that the subsequent principal components of each asset class are common slope components.

Tables 19 and 20 explore the predictive power of the PCA-based models analyzed above and the DR-CAPM across asset classes. Table 19 estimates the models using the proxy portfolios discussed above, while Table 20 employs directly the principal components. Each of the asset-class-specific models is unable to price the joint cross section. Both the LRV model and the Yang model have negative R^2 (-15% and -35%, respectively) and the Fama & French model has a modest R^2 of 35%. The LRV model estimates a significant price of risk for the carry portfolio and the estimate increases to 0.99 from the 0.47 estimate obtained when using only currency portfolios as test assets. The price of risk of the dollar portfolio

[11] Notice that for commodity portfolios the unconditional betas are almost increasing when going from portfolio 1 to portfolio 5, but the effect is quantitatively small and dominated by the more strongly decreasing downside betas.

[12] With the exception of the small-growth equity portfolio.

remains statistically insignificant. The Yang model estimates a significant price of risk for the commodity portfolio but not for the basis portfolio. The Fama & French model estimates a significant price of risk only for the HML_{ff} portfolio. The point estimates for the prices of risk of the market, SMB, and HML_{ff} portfolios are 0.28, 0.23, and 0.57, respectively; these point estimates are overall comparable to the 0.36, 0.19, and 0.49 estimates obtained when using only the equity portfolios as test assets. The failure of asset-class specific models to price other asset classes has induced a search for segmented theoretical models that could explain why different stochastic discount factors are needed to price different asset classes. We view our DR-CAPM results as suggesting that a unified view of risk markets is still possible.

To obtain an explanatory power similar to the DR-CAPM, the PCA analysis suggests using between 4 and 8 principal components.[13] A naive approach that simply adds principal components leads to using the first 8 principal components. The first two columns in Table 20 show that the resulting model must be discarded as many of the estimated prices of risk are not statistically significant.

A better model can be built using the information gleaned from the factor structure of each asset class. Since most of the explanatory power for the cross-section of each asset class comes from a slope factor, it is intuitive to suggest a model that only includes the slope factors of each asset class and a common level factor. The third and second to last columns in Tables 19 and 20 show that a model that uses the first and third principal components of the equity portfolios, the second principal component of the currency portfolios and the second principal component of the commodity portfolios or, alternatively, their mimicking portfolios (i.e. the market, HML_{ff}, carry and basis portfolios) performs similarly to the DR-CAPM. The estimated prices of risk are statistically significant for all slope component, or for their mimicking portfolios, but not for the level component or market return. This PCA-based model generates a R^2 of 59% and RMSPE of 0.19 when using the principal components and a R^2 of 69% and RMSPE of 0.16 when using the mimicking portfolios. The DR-CAPM offers a similar performance with a R^2 of 74% and RMSPE of 0.15 and is once again able to jointly summarize the information contained in all of these principal components in the market and downside risk factors.

[13] We refer here to the principal components obtained by performing the PCA on the joint returns of currencies, equities, and commodities. Details of this PCA are reported in the appendix.

E. Other Factor Structures

While the DR-CAPM is able to price returns in many important asset classes, it is not universally successful. In this section we present results for asset classes for which the DR-CAPM is not successful: momentum portfolios, corporate bonds and US Treasuries. Rather than estimating the full model, we plot the relationship of the downside risk beta with average returns in the bottom panels of Figure 14, while the top panels show the relationship of average returns with the standard CAPM beta.

The left panels of Figure 14 show results for equity portfolios sorted on momentum.[14] While the returns of these portfolios appear to be unrelated to beta, they are broadly positively associated with downside beta with the exception of the first momentum portfolio, which consists of small firms with very low recent returns. However, the association with downside beta is not sufficiently strong for the DR-CAPM to fully capture the returns of the momentum portfolios.

The middle panel shows results for US corporate bonds.[15] While both CAPM beta and the downside beta are positively associated with these portfolio returns, the spread in average returns is too small compared to the spread in downside betas.

The right panels in Figure 14 show that the DR-CAPM performs worst on returns of US Treasuries of various maturities.[16] While bond returns are positively associated with their unconditional beta, they are actually negatively related to their downside beta. Cochrane and Piazzesi (2005) have documented that the cross section of average bond returns is in fact driven by a single factor that is not strongly associated with market returns. Figure 14 shows that the bond factor is also not driven by downside market risk.

[14] We use the 6 US equity portfolios sorted on size and momentum by Fama & French and available on Ken French's website. The sample period is from January 1974 to March 2010.

[15] We use the monthly returns on the five corporate bond portfolios sorted annually on their credit spread by Nozawa (2012). The sample period is from October 1975 to March 2010. Portfolio 1 is composed of the lowest credit spread bonds, portfolio 5 is composed of the highest credit spread bonds. The 5 portfolios are obtained by equally weighting the 10 portfolios in the benchmark analysis of Nozawa (2012) into five baskets.

[16] We use the monthly bond returns in the Fama bond file of CRSP. The sample period is from January 1974 to March 2010. Portfolios 1-5 are formed with bonds with maturities less than or equal to one to five years, respectively. Portfolio 6 is formed with bonds with maturities less or equal than 10 years and portfolio 7 with bonds with maturities greater than 10 years.

VI Conclusion

We find that currency returns are associated with aggregate market risk, thus supporting a risk-based view of exchange rates. However, we find that the unconditional CAPM cannot explain the cross section of currency returns because the spread in currency beta is not sufficiently large to match the cross sectional variation in expected returns. The downside risk CAPM (DR-CAPM) explains currency returns because the difference in beta between high and low yield currencies is higher conditional on bad market returns, when the market price of risk is also high, than it is unconditionally.

We also find that the DR-CAPM can jointly explain the cross section of currencies, equity, commodities and sovereign bond returns. We view these results as not only confirming the empirical performance of the model but also as a first step in reconciling discount factors across asset classes. The performance of the model across asset classes contrasts with the failure of models designed for a specific asset class in pricing other asset classes.

Our results open new avenues for future research. Given its demonstrated empirical relevance, it is important to gain a deeper theoretical understanding of the sources and time variation of downside risk. It remains an open question whether downside risk comes from preferences or from micro-founded constraints.

References

Ang, A., J. Chen, and Y. Xing (2006). Downside risk. *Review of Financial Studies 19*(4), 1191–1239.

Asness, C., T. Moskowitz, and L. H. Pedersen (2012). Value and momentum everywhere. *Journal of Finance, forthcoming.*

Bansal, R. and M. Dahlquist (2000). The forward premium puzzle: different tales from developed and emerging economies. *Journal of International Economics 51*(1), 115–144.

Barro, R. J. (2006). Rare disasters and asset markets in the twentieth century. *The Quarterly Journal of Economics 121*(3), 823–866.

Borri, N. and A. Verdelhan (2011). Sovereign risk premia. *Unpublished manuscript, MIT*.

Brunnermeier, M. K., S. Nagel, and L. H. Pedersen (2008). Carry trades and currency crashes. *NBER Macroeconomics Annual* (23), 313–348.

Burnside, C. (2011a). Carry trades and risk. *National Bureau of Economic Research Working manuscript Series No. 17278.*

Burnside, C. (2011b). The cross section of foreign currency risk premia and consumption growth risk: Comment. *American Economic Review 101*(7), 3456–3476.

Burnside, C., M. Eichenbaum, I. Kleshchelski, and S. Rebelo (2011). Do peso problems explain the returns to the carry trade? *Review of Financial Studies 24*(3), 853 –891.

Burnside, C., M. Eichenbaum, and S. Rebelo (2009). Understanding the forward premium puzzle: A microstructure approach. *American Economic Journal: Macroeconomics 1*(2), 127–154.

Burnside, C., M. Eichenbaum, and S. Rebelo (2011). Carry trade and momentum in currency markets. *Annual Review of Financial Economics 3*(1), 511–535.

Burnside, C., B. Han, D. Hirshleifer, and T. Y. Wang (2011). Investor overconfidence and the forward premium puzzle. *The Review of Economic Studies 78*(2), 523 –558.

Caballero, R. and J. B. Doyle (2013). Carry trade and systematic risk: Why are FX options so cheap? *Unpublished manuscript, MIT and Cornerstone Research.*

Campbell, J. and T. Vuolteenaho (2004). Bad beta, good beta. *American Economic Review 94*(5), 1249–1275.

Christiansen, C., A. Ranaldo, and P. Soederlind (2011). The time-varying systematic risk of carry trade strategies. *Journal of Financial and Quantitative Analysis 46*(4), 1107–1125.

Cochrane, J. H. (2005). *Asset Pricing:* (Revised ed.). Princeton University Press.

Cochrane, J. H. (2011). Presidential address: Discount rates. *The Journal of Finance 66*(4), 1047–1108.

Cochrane, J. H. and M. Piazzesi (2005). Bond risk premia. *American Economic Review 95*(1), 138–160.

D'Avolio, G. (2002). The market for borrowing stock. *Journal of Financial Economics 66*(2), 271–306.

Dobrynskaya, V. (2013). Downside market risk of carry trades. *Unpublished manuscript, London School of Economics*.

Fama, E. and K. French (1992). The cross-section of expected stock returns. *Journal of Finance 47*(2), 427–465.

Fama, E. F. and J. D. MacBeth (1973). Risk, return, and equilibrium: Empirical tests. *Journal of Political Economy 81*(3), pp. 607–636.

Farhi, E. and X. Gabaix (2008). Rare disasters and exchange rates. *Unpublished manuscript, Harvard and NYU*.

Frazzini, A. and L. H. Pedersen (2012). Betting against beta. *Journal of Financial Economics, forthcoming*.

Gorton, G. B., F. Hayashi, and K. G. Rouwenhorst (2013). The fundamentals of commodity futures returns. *Review of Finance 17*(1), 35–105.

Gul, F. (1991). A theory of disappointment aversion. *Econometrica 59*(3), 667–686.

Koijen, R., T. Moskowitz, L. H. Pedersen, and E. Vrugt (2012). Carry. *Unpublished Manuscript, University of Chicago and NYU*.

Lamont, O. and R. Thaler (2003). Can the market add and subtract? Mispricing in the tech stock carve-puts. *Journal of Political Economy 111*(2), 227–268.

Lustig, H., N. Roussanov, and A. Verdelhan (2011). Common risk factors in currency markets. *Review of Financial Studies, forthcoming*.

Lustig, H. and A. Verdelhan (2007). The cross section of foreign currency risk premia and consumption growth risk. *American Economic Review 97*(1), 89–117.

Lustig, H. and A. Verdelhan (2011). The cross-section of foreign currency risk premia and consumption growth risk: Reply. *American Economic Review 101*(7), 3477–3500.

Maggiori, M. (2012). A note on currency returns. *Unpublished manuscript, UC Berkeley*.

Menkhoff, L., L. Sarno, M. Schmeling, and A. Schrimpf (2012). Carry trades and global foreign exchange volatility. *The Journal of Finance 67*(2), 681–718.

Mitchell, M., T. Pulvino, and E. Stafford (2002). Limited arbitrage in equity markets. *The Journal of Finance 57*(2), 551–584.

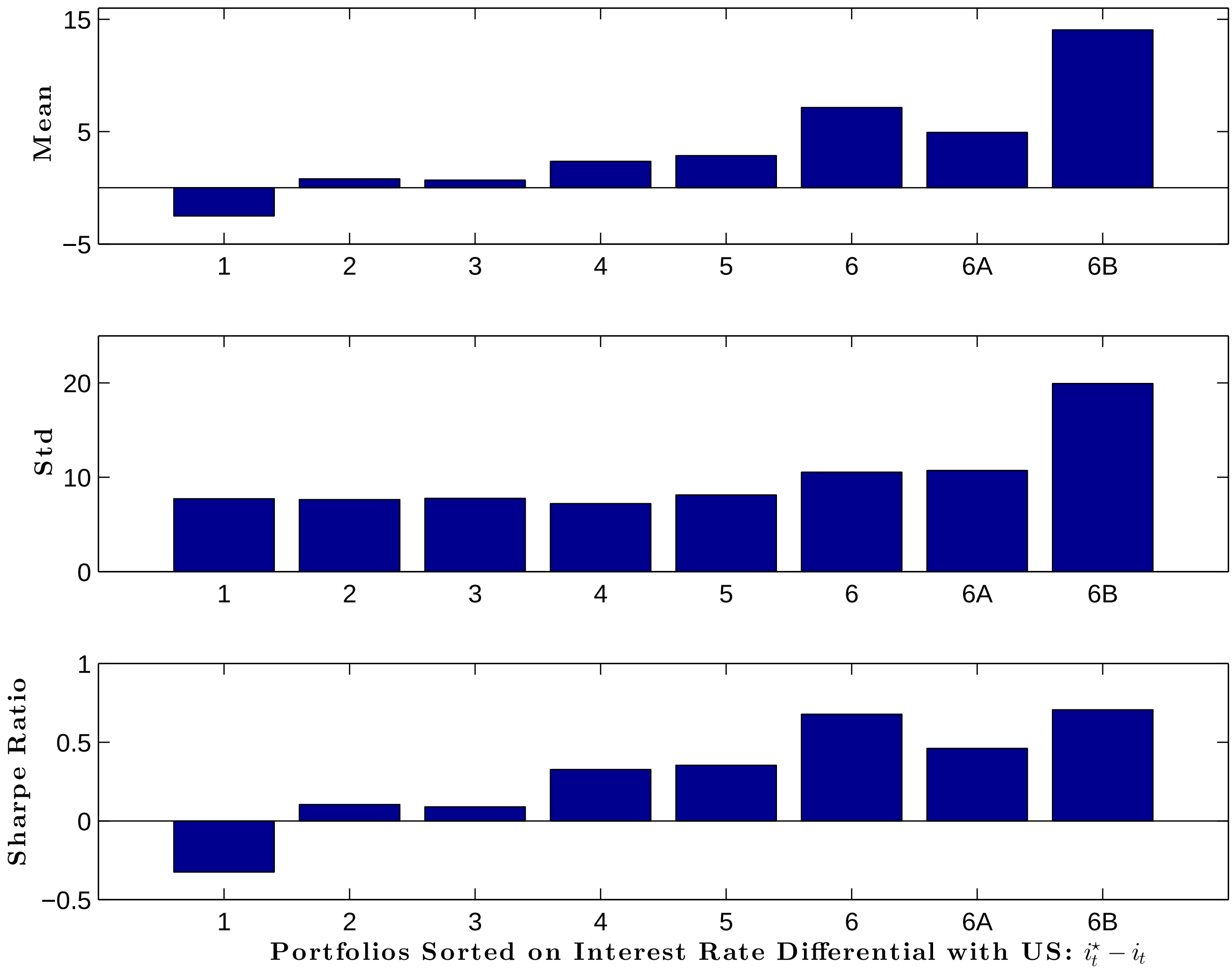
Mueller, P., A. Stathopoulos, and A. Vedolin (2012). International correlation risk. *Unpublished Manuscript, LSE and USC*.

Nozawa, Y. (2012). Corporate bond premia. *Unpublished manuscript, The University of Chicago*.

Routledge, B. and S. Zin (2010). Generalized disappointment aversion and asset prices. *The Journal of Finance 65*(4), 1303–1332.

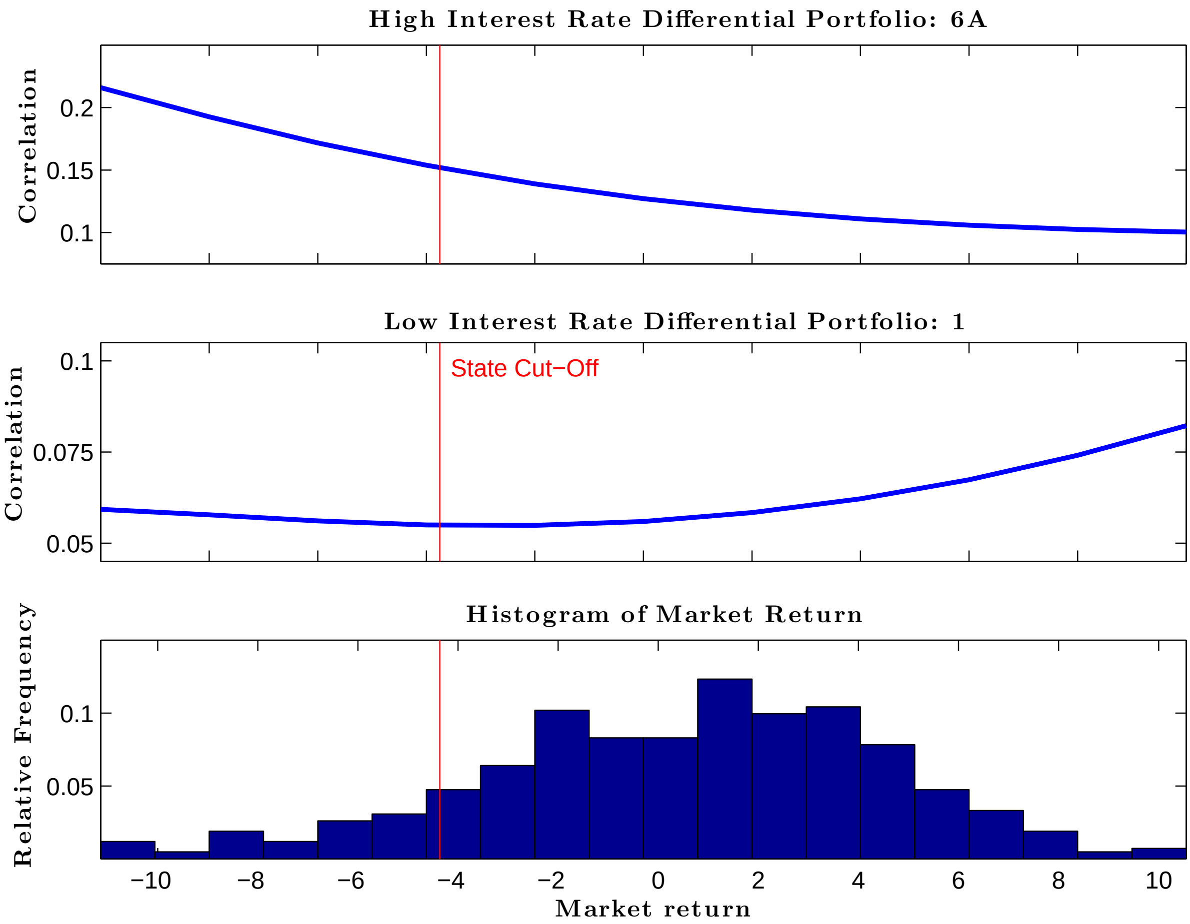
Yang, F. (2010). Investment shocks and the commodity basis. *Unpublished manuscript, Hong Kong University*.

Figure 1: **Characteristics of the 6 Currency Portfolios**



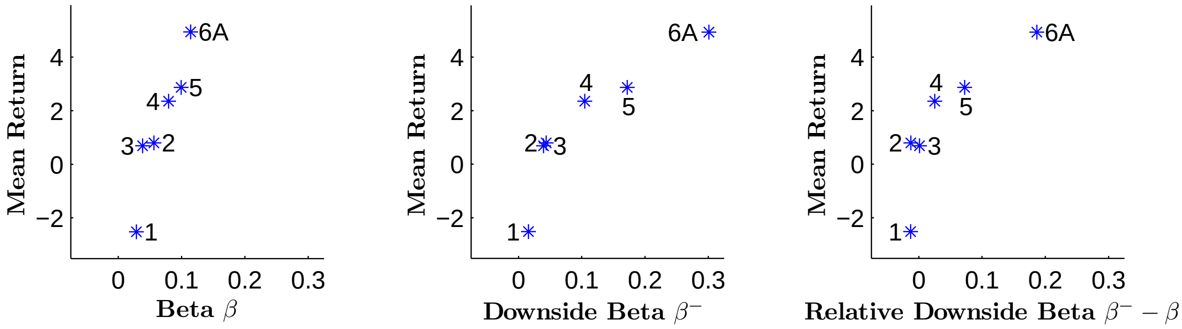
Annualized mean excess-returns, standard deviations and Sharpe ratios for six currency portfolios, monthly re-sampled based on the interest rate differential with the US. The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the sixth portfolio are subdivided into basket 6B. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation.

Figure 2: **Kernel-Smoothed Conditional Correlation**



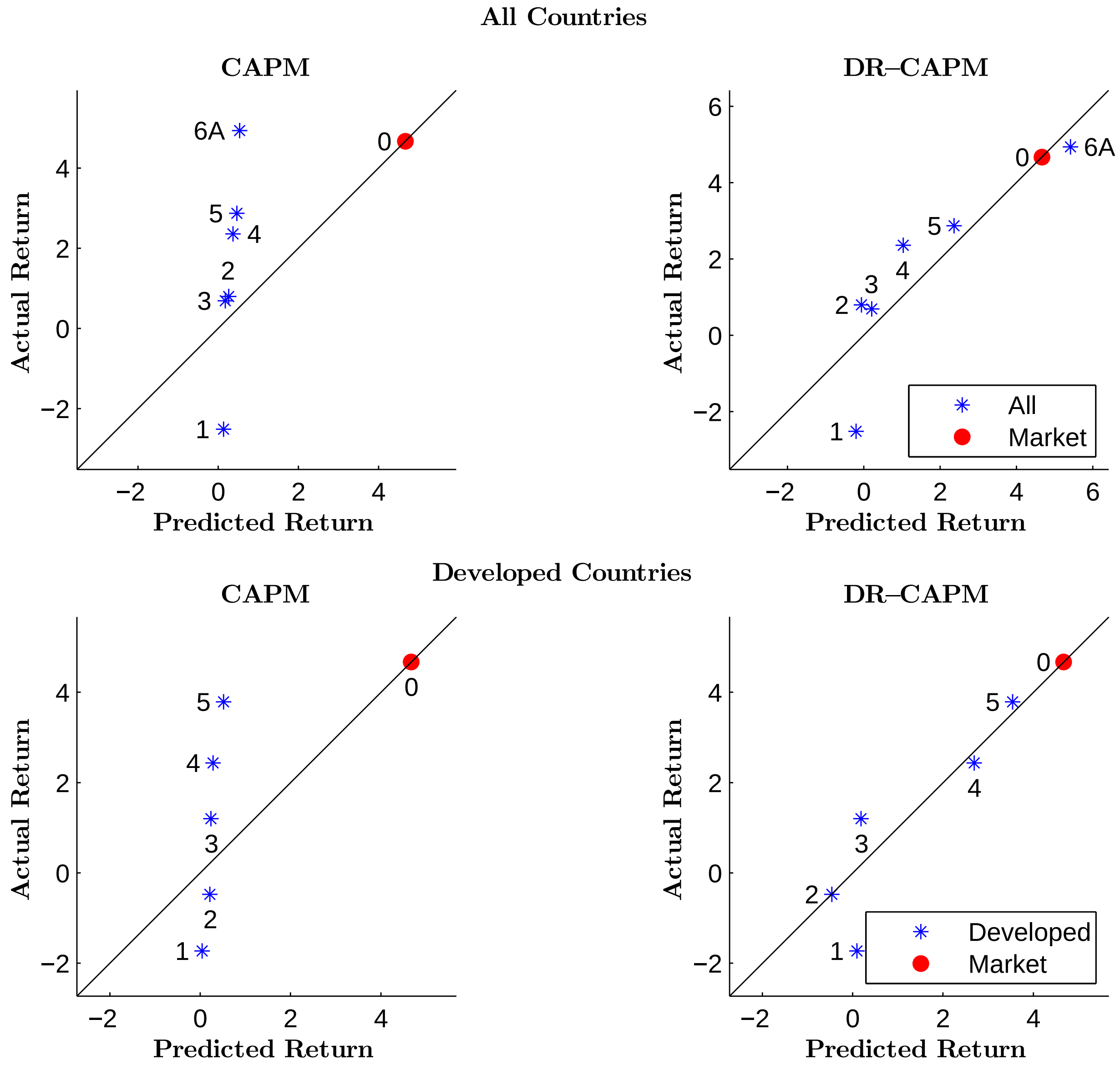
Kernel smoothed estimate of the correlation between different currency portfolios and the CRSP value-weighted (market) excess-return conditional on the market excess-return using a normal kernel. Top panel: correlation of the market excess-return with the high interest rate currencies (portfolio 6A). Middle panel: correlation of the market excess-return with the low interest rate currencies (portfolio 1). Bottom panel: empirical distribution of market excess-returns. The red line indicates the state cut-off in the empirical analysis of one standard deviation below the mean of the market excess-return. The graphs have been cut on the left and right at -/+10% monthly market excess-return. The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation.

Figure 3: **Risk-Return Relations: Currencies**



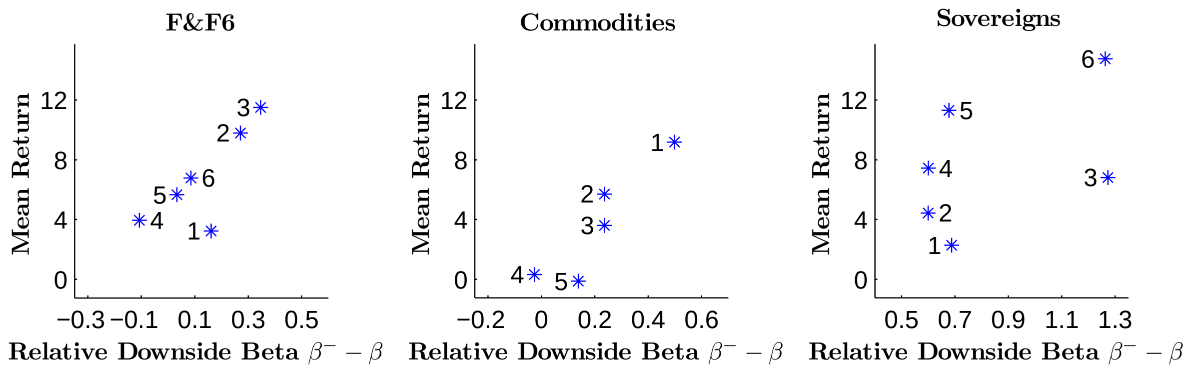
Risk-return relations for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. From left to right, the panels plot the realized mean excess-return versus the CAPM betas (β), the downside betas (β^-) and the relative downside betas ($\beta^- - \beta$). The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 4: **Model Performance: Currencies**



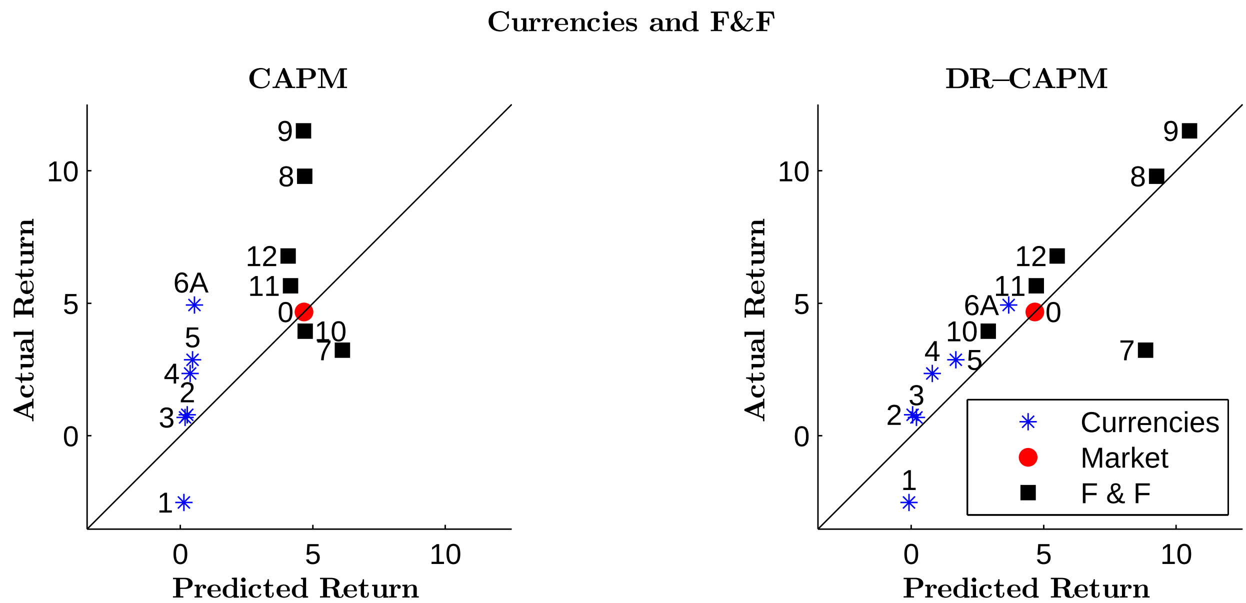
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels. In the top panel, test assets are six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. In the bottom panel, test assets are five currency portfolios of developed countries. The market excess-return is included as a test asset (0). The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 5: **Risk-Return Relations: Other Asset Classes**



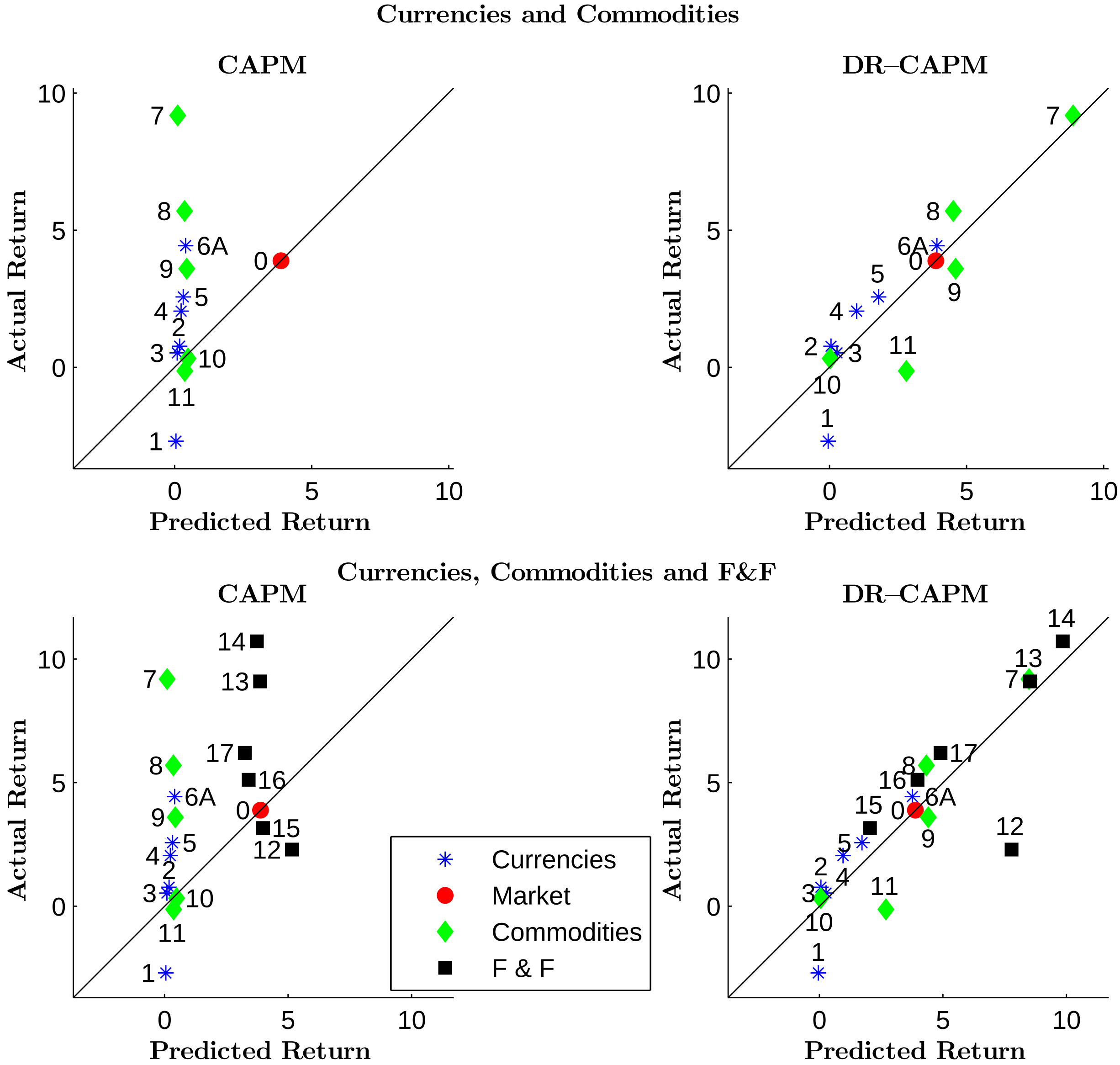
Risk-return relations for six Fama & French equity portfolios sorted on size and book to market (left panel), five commodity futures portfolios monthly re-sampled based on basis (middle panel), and six sovereign bond portfolios monthly re-sampled based on their probability of default and bond beta (right panel). The panels plot the realized mean excess-return versus the relative downside betas ($\beta^- - \beta$). The sample period is January 1974 to March 2010 for a total of 435 observations for the equity portfolios, January 1974 to December 2008 for a total of 420 observations for the commodity portfolios, and January 1995 to March 2010 for a total of 183 observations for the sovereign bond portfolios.

Figure 6: **Model Performance: Currencies and Equities**



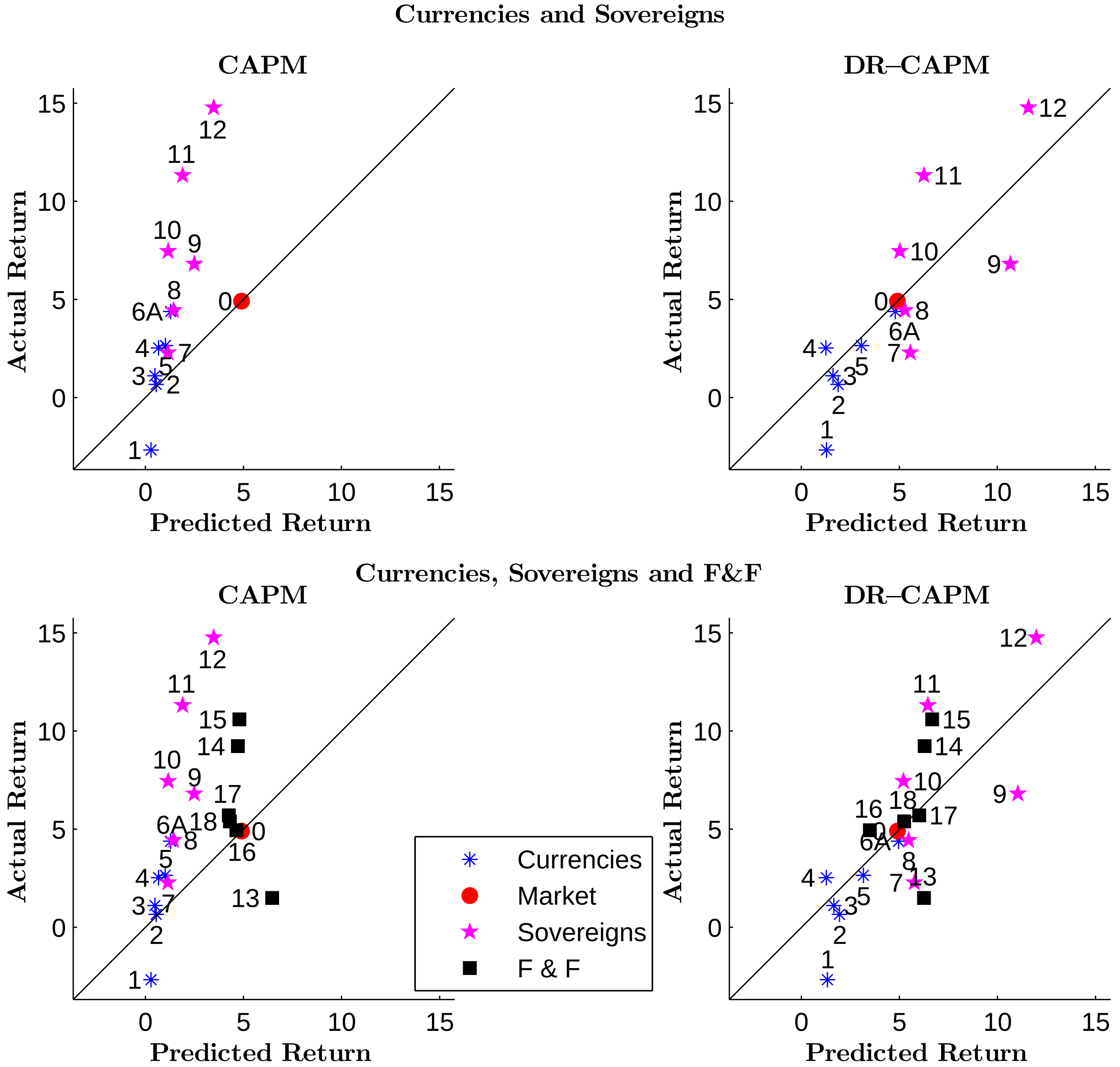
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panel and the downside risk CAPM (DR-CAPM) in the right panel. Test assets are six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US as well as six Fama & French equity portfolios sorted on size and book-to-market (7-12). The market excess-return is included as a test asset (0). The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation.

Figure 7: **Model Performance: Currencies, Equities, and Commodities**



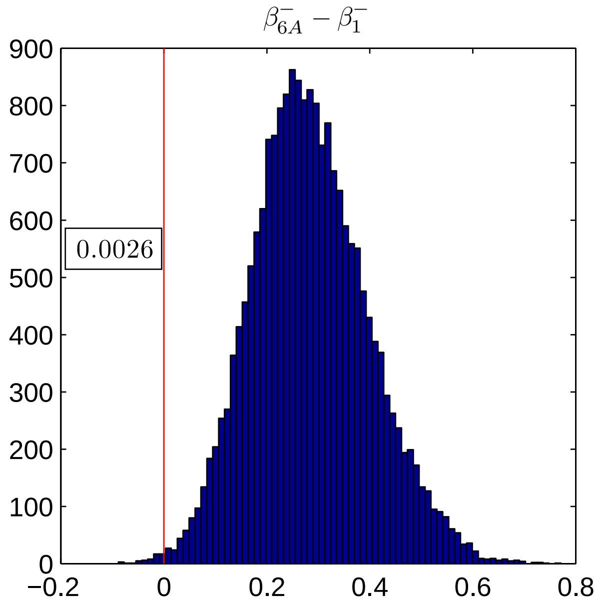
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis (7-11) as well as six Fama & French portfolios sorted on size and book-to-market (12-17). The market excess-return is included as a test asset (0). The sample period is January 1974 to December 2008 for a total of 420 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation.

Figure 8: **Model Performance: Currencies, Equities, and Sovereign Bonds**



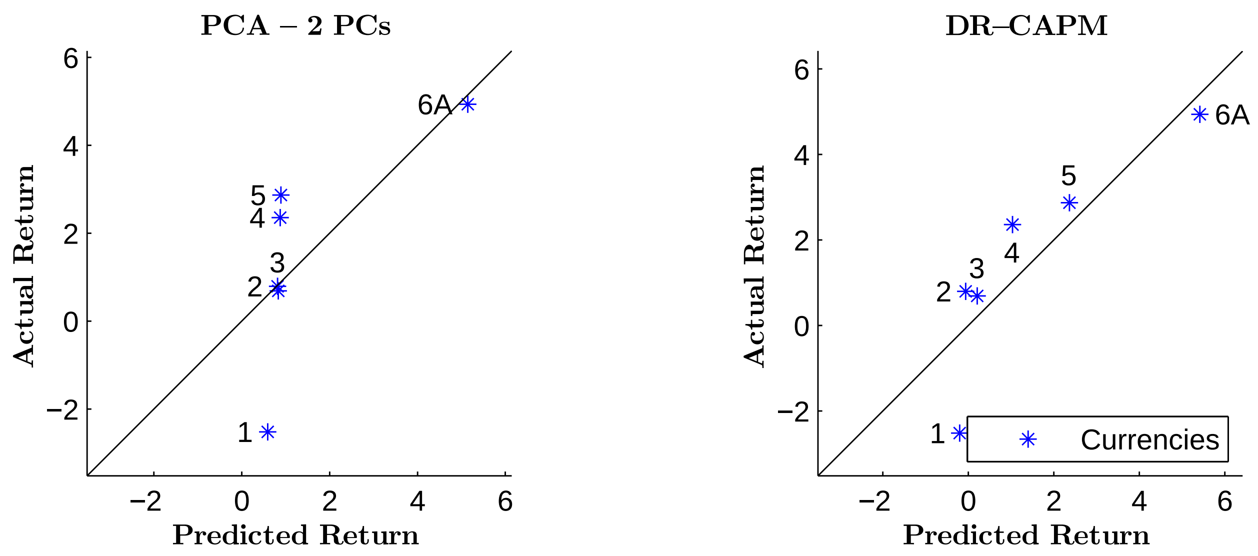
Annualized mean excess-returns versus the predicted excess-returns in percent for the unconditional CAPM in the left panels and the downside risk CAPM (DR-CAPM) in the right panels for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US, six sovereign bond portfolios monthly re-sampled based on their probability of default and bond beta (7-12) as well as six Fama & French portfolios sorted on size and book-to-market (13-18). The market excess-return is included as a test asset (0). The sample period is January 1995 to March 2010 for a total of 183 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than US inflation.

Figure 9: **Bootstrapped Distribution: Relative Downstate Betas**



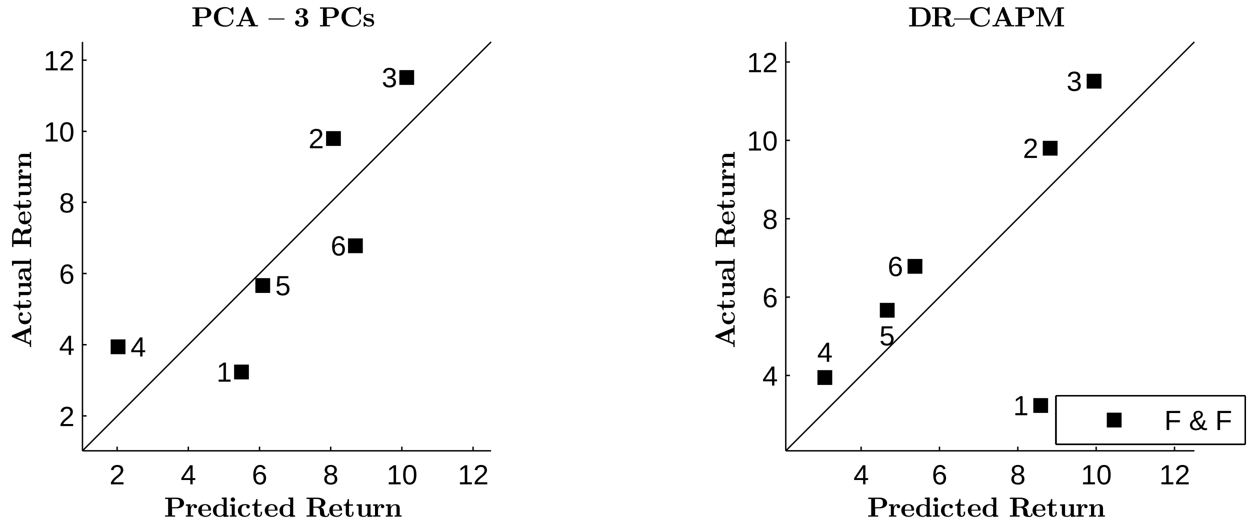
Bootstrapped distribution of the difference in downstate betas of the last and first currency portfolios, $\beta_{6A}^{-} - \beta_{1}^{-}$ *in the left panel, and the difference in downstate minus unconditional betas of the last and first currency portfolios,* $(\beta_{6A}^{-} - \beta_{1}^{-})$ *-* $(\beta_{6A} - \beta_{1})$*, in the right panel. We employ a smoothed bootstrap scheme consisting of resampling empirical residuals and adding zero centered normally distributed noise using 20,000 iterations.*

Figure 10: **Model Performance: PCA Currencies**



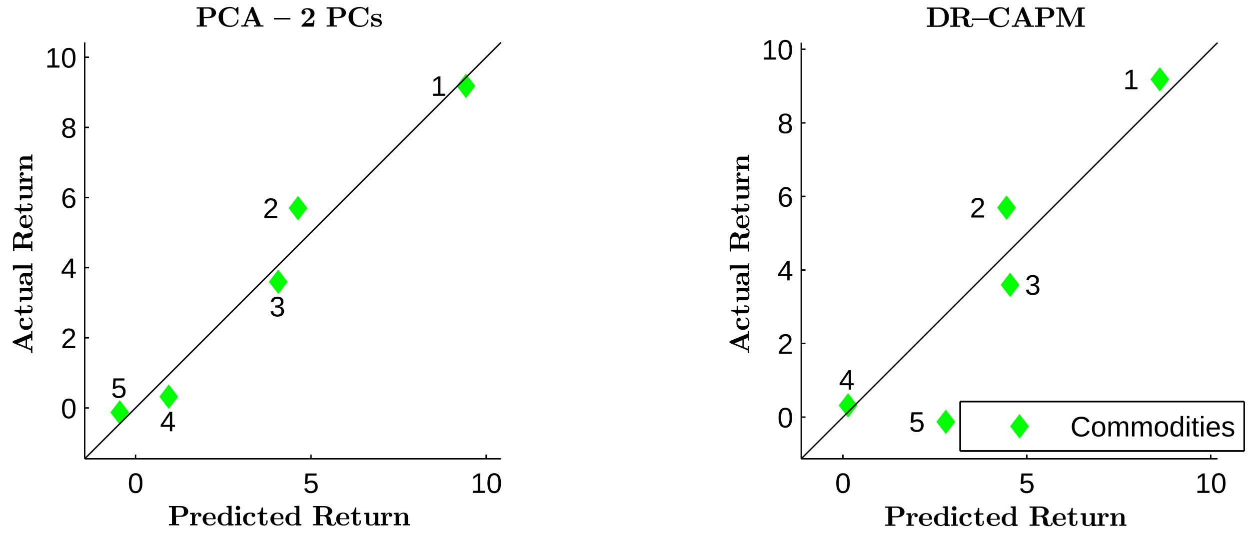
Annualized mean excess-returns versus the predicted excess-returns in percent for a 2 factor model where the factors are the first two principal components of the test assets in the left panel and the downside risk CAPM (DR-CAPM) in the right panel for six currency portfolios (1-6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 11: **Model Performance: PCA Stocks**



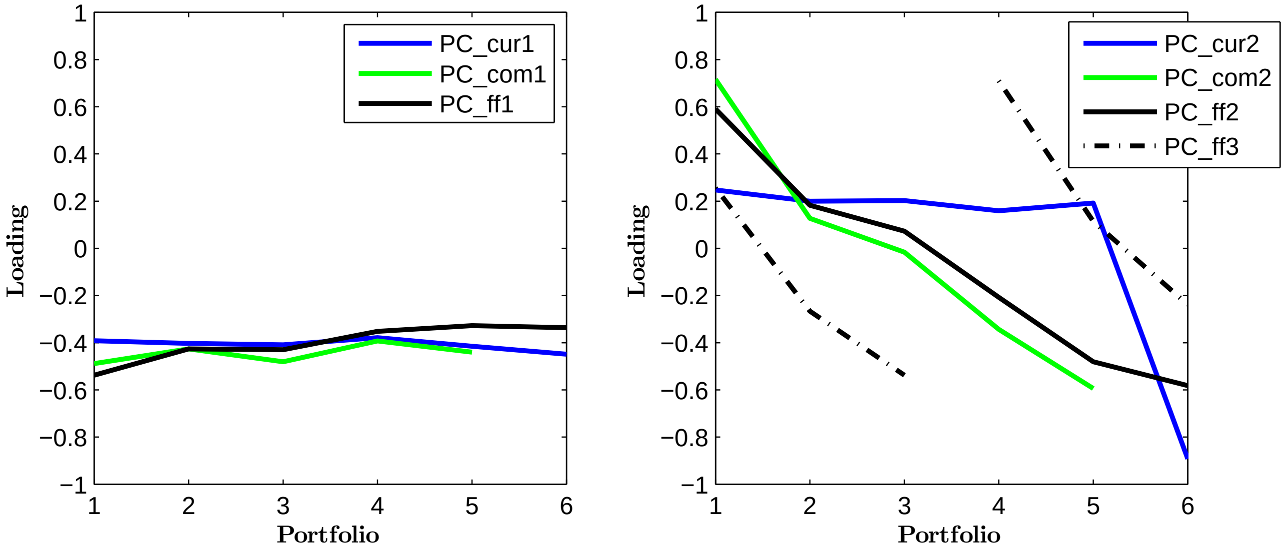
Annualized mean excess-returns versus the predicted excess-returns in percent for a 3 factor model where the factors are the first three principal components of the test assets in the left panel and the downside risk CAPM (DR-CAPM) in the right panel for the six Fama & French portfolios sorted on size and book-to-market. The sample period is January 1974 to March 2010 for a total of 435 observations.

Figure 12: **Model Performance: PCA Commodities**



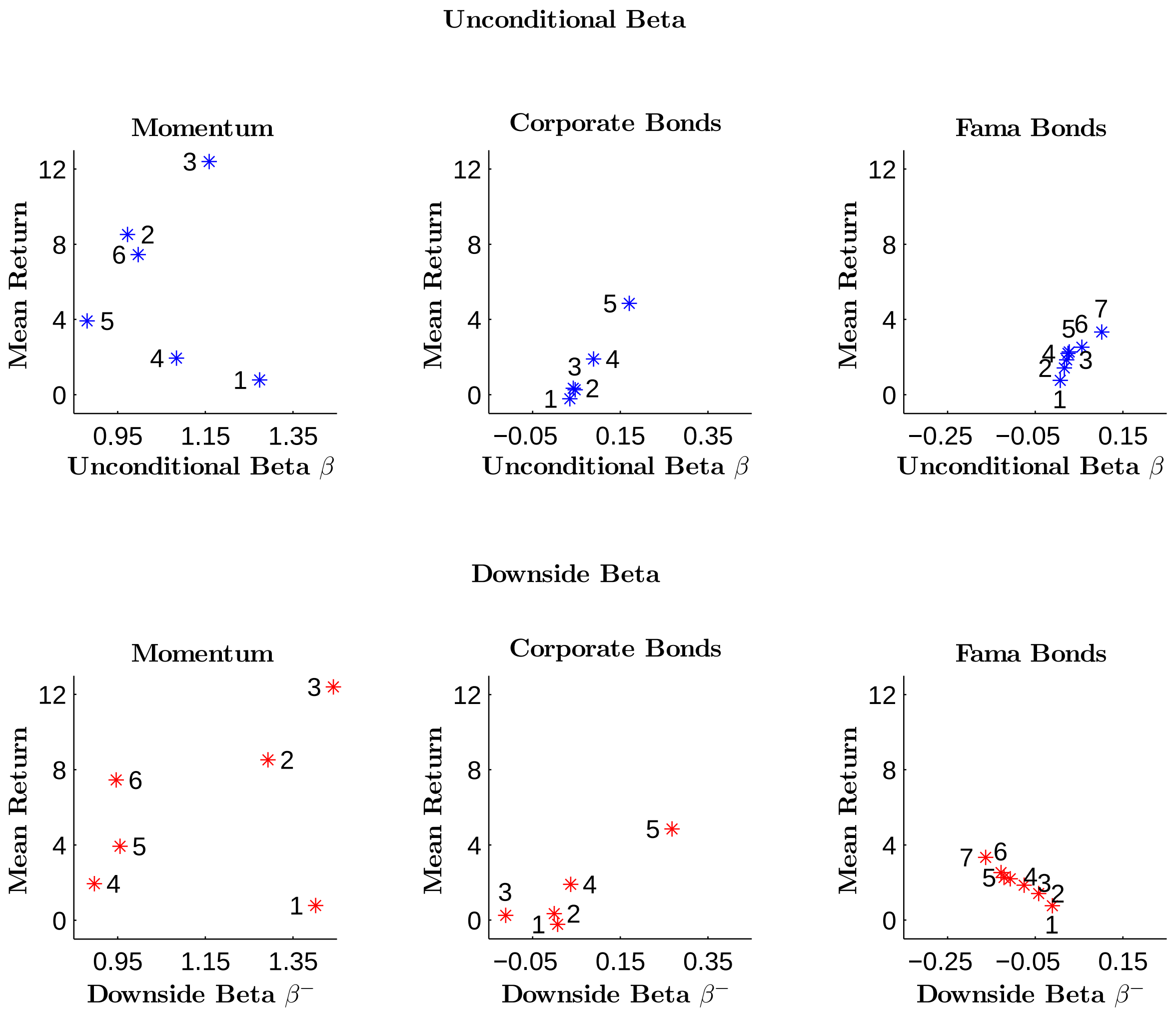
Annualized mean excess-returns versus the predicted excess-returns in percent for a 2 factor model where the factors are the first two principal components of the test assets in the left panel and the downside risk CAPM (DR-CAPM) in the right panel for five commodity futures portfolios monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations.

Figure 13: **PCA Loadings: Currencies, Equities, and Commodities**



The loadings of the principal component analysis for six currency portfolios, monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios monthly re-sampled based on basis as well as the 6 Fama & French portfolios sorted on size and book-to-market. The PCA is performed separately on the portfolios of each asset class. The left panel plots the loadings of the first principal components of each asset class: PC_{cur1}*,* PC_{ff1}*, and* PC_{com1} *for currencies, equities, and commodities respectively. The right panel plots the loadings of the second principal component for currencies (*PC_{cur2}*), the second principal component for commodities (*PC_{com2}*), and the second and third principal components for equities (*PC_{ff2}*,* PC_{ff3}*). The sample period is January 1974 to March 2010 for a total of 435 observations for currencies and equities and to December 2008 for a total of 420 observations for commodities futures. High inflation countries in the last currency portfolio are excluded. A country is considered to have high inflation if it has an annualized monthly inflation of 10% higher than the US.*

Figure 14: **Risk-Return Relations: T-Bills, Equity Momentum, Corporate Bonds**



Risk-return relations for the 6 Fama & French portfolios sorted on size and momentum (left panels), five corporate bond portfolios annually re-sampled based on their credit spread by Nozawa (2012) (middle panels), and seven zero coupon US Treasury bonds (right panels). The top panels plot the realized mean excess-return versus the CAPM beta (β), while the bottom panels employ the downside betas (β^-). The sample period is January 1974 to March 2010 for a total of 435 observations for the equity portfolios, October 1975 to March 2010 for a total of 414 observations for the commodity portfolios, and January 1974 to March 2010 for a total of 183 observations for the US Treasury bond portfolios.

Table 1: **Currency Portfolios**

Annualized sample means, standard deviations and Sharpe ratios for the interest rate differentials, spot exchange rate changes, excess returns and carry trade baskets for six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the sixth portfolio are subdivided into basket 6B. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010, a total of 435 observations.

Portfolio	1	2	3	4	5	6	6A	6B
				Interest Rate Differential: $i^\star - i$				
Mean	-2.79	-0.56	1.11	2.97	5.59	22.01	12.58	36.02
Std	0.62	0.55	0.55	0.63	0.88	7.43	3.76	20.10
				Spot Change: Δs^j				
Mean	-0.27	-1.36	0.42	0.62	2.72	14.87	7.64	21.96
Std	7.63	7.56	7.70	7.19	8.11	10.27	11.30	15.87
				Excess Returns				
Mean	-2.52	0.79	0.69	2.35	2.87	7.14	4.94	14.06
Std	7.73	7.64	7.76	7.21	8.13	10.54	10.73	19.93
Sharpe Ratio	-0.33	0.10	0.09	0.33	0.35	0.68	0.46	0.71
				High minus Low: $rx^j - rx^1$				
Mean		3.31	3.21	4.87	5.38	9.66	7.45	16.14
Std		4.59	5.43	5.30	6.17	10.50	10.31	20.23
Sharpe Ratio		0.72	0.59	0.92	0.87	0.92	0.72	0.80

Table 2: **Stock, Commodity Futures and Sovereign Bond Portfolios**

Annualized sample means, standard deviations and Sharpe ratios for portfolios of stock excess returns, commodity futures and sovereign bond returns. Panel A reports the statistics for the six Fama & French portfolios sorted on size and book-to-market. Panel B reports the statistics for 5 commodity futures portfolios monthly re-sampled based on the commodity basis. Panel C reports the statistics for 6 sovereign bond portfolios monthly re-sampled based on the probability of default and bond beta. The sample period is January 1974 to March 2010 for a total of 435 observations in the upper panel, January 1974 to December 2008 for a total of 420 observations in panel B and January 1995 to March 2010 for a total of 183 observations in the lower panel.

	Panel A. Six Fama & French Portfolios					
Portfolio	Small			Big		
	Low	Medium	High	Low	Medium	High
Mean	3.23	9.80	11.51	3.94	5.66	6.78
Std	24.55	18.86	19.53	17.18	15.76	16.64
Sharpe Ratio	0.13	0.52	0.59	0.23	0.36	0.41

	Panel B. Commodity Futures Portfolios				
Portfolio	Low	2	3	4	High
Mean	9.18	5.70	3.59	0.32	-0.13
Std	18.50	15.65	16.38	15.58	17.34
Sharpe Ratio	0.50	0.36	0.22	0.02	-0.01

	Panel C. Sovereign Bond Portfolios					
Portfolio	Low	2	3	4	5	High
Mean	2.28	4.43	6.80	7.45	11.32	14.77
Std	9.51	10.96	16.36	9.27	11.68	19.56
Sharpe Ratio	0.24	0.40	0.42	0.80	0.97	0.75

Table 3: **Conditional Correlations: Carry Trade and Market Returns**

The correlation between the carry trade factor and CRSP value-weighted (market) excess-return. The correlation is computed unconditionally, in the upstate and downstate as well as for various inflation thresholds. Newey-West standard errors are reported in parentheses. The sample period is January 1974 to March 2010 for a total of 435 observations. Downstates are all months in which the market return is more than one standard deviation below its sample mean.

	all	downstate	upstate
all countries	0.12	0.26	0.05
	(0.04)	(0.19)	(0.06)
excl high inflation (5%)	0.08	0.28	0.00
	(0.04)	(0.22)	(0.05)
excl high inflation (10%)	0.14	0.33	0.02
	(0.05)	(0.19)	(0.05)
excl high inflation (15%)	0.15	0.41	0.02
	(0.05)	(0.22)	(0.05)
developed countries	0.23	0.31	0.10
	(0.07)	(0.15)	(0.06)

Table 4: **Estimation of Linear Pricing Models: Currencies**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). In the two left columns, test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. In the two right columns, test assets are five currency portfolios of developed countries. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	All Currencies		Developed Currencies	
	CAPM	DR-CAPM	CAPM	DR-CAPM
λ_{market}	0.39⋆	0.39⋆	0.39⋆	0.39⋆
λ_{-}		2.18		2.34
		(0.77)		(1.05)
χ^2	42.28	24.60	22.36	9.81
p-val	0.00%	0.04%	0.10%	8.09%
RMSPE	0.19	0.09	0.15	0.07
R^2	8.77%	78.74%	34.74%	85.32%

Table 5: **Estimation of Linear Pricing Models: Currencies and Equities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, and the six Fama & French portfolios sorted on size and book-to-market. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	CAPM	DR-CAPM
λ_{market}	$0.39^{\star}$	$0.39^{\star}$
λ_{-}		1.41
		(0.40)
χ^2	114.54	63.39
p-val	0.00%	0.00%
RMSPE	0.26	0.16
R^2	24.31%	71.41%

Table 6: **Estimation of Linear Pricing Models: Currencies, Equities and Commodities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, five commodity futures portfolios, monthly re-sampled based on basis, and the six Fama & French portfolios, sorted on size and book-to-market. The market excess-return is included as a test asset. The sample period is January 1974 to December 2008 for a total of 420 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Currencies and Commodities		Currencies, Equities, and Commodities	
	CAPM	DR-CAPM	CAPM	DR-CAPM
λ_{market}	$0.32^{\star}$	$0.32^{\star}$	$0.32^{\star}$	$0.32^{\star}$
λ_{-}		1.47		1.40
		(0.53)		(0.38)
χ^2	52.66	28.24	128.27	64.48
p-val	0.00%	0.30%	0.00%	0.00%
RMSPE	0.30	0.11	0.31	0.15
R^2	-42.93%	80.69%	-17.38%	73.52%

Table 7: **Estimation of Linear Pricing Models: Currencies, Equities, and Sovereigns**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for the unconditional CAPM and the downside risk CAPM (DR-CAPM). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, six sovereign bond portfolios, monthly re-sampled based on the probability of default and bond beta, and the six Fama & French portfolios, sorted on size and book-to-market. The market excess-return is included as a test asset. The sample period is January 1995 to March 2010 for a total of 183 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Currencies and Sovereigns		Currencies, Equities, and Sovereigns	
	CAPM	DR-CAPM	CAPM	DR-CAPM
λ_{market}	$0.41^\star$	$0.41^\star$	$0.41^\star$	$0.41^\star$
λ_-		0.53		0.56
		(0.21)		(0.21)
χ^2	40.26	39.68	88.31	86.54
p-val	0.01%	0.01%	0.00%	0.00%
RMSPE	0.41	0.22	0.38	0.22
R^2	-20.81%	65.80%	-22.66%	57.10%

Table 8: **Betas of First-Stage Times-Series Regressions: Currencies, Equities and Commodities**

First-stage time series unconditional and downstate betas with OLS standard errors in parentheses and bootstrapped standard errors in brackets for portfolios of currency, stock and commodity (excess-) returns. Panel A reports these statistics for six currency portfolios, monthly re-sampled based on the interest rate differential with the US. Panel B reports the statistics for the six Fama & French portfolios sorted on size and book-to-market. Panel C reports the statistics for 5 commodity futures portfolios monthly re-sampled based on the commodity basis. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations in Panel A and B and January 1974 to December 2008 for a total of 420 observations in Panel C.

	Panel A. Six Currency Portfolios						
Portfolio	1	2	3	4	5	6	6A
β	0.03	0.06	0.04	0.08	0.10	0.10	0.11
SE_{OLS}	(0.02)	(0.02)	(0.02)	(0.02)	(0.02)	(0.03)	(0.03)
SE_{BS}	[0.02]	[0.02]	[0.02]	[0.02]	[0.02]	[0.03]	[0.03]
β^-	0.02	0.04	0.04	0.10	0.17	0.18	0.30
SE_{OLS}	(0.10)	(0.10)	(0.09)	(0.08)	(0.10)	(0.10)	(0.13)
SE_{BS}	[0.10]	[0.09]	[0.09]	[0.08]	[0.10]	[0.09]	[0.13]

	Panel B. Six Fama & French Portfolios					
		Small			Big	
Portfolio	Low	Medium	High	Low	Medium	High
β	1.31	1.01	1.00	1.01	0.89	0.87
	(0.03)	(0.03)	(0.03)	(0.01)	(0.02)	(0.02)
β^-	1.47	1.28	1.34	0.90	0.92	0.96
	(0.11)	(0.12)	(0.14)	(0.05)	(0.08)	(0.13)

	Panel C. Commodity Futures Portfolios				
Portfolio	Low	2	3	4	High
β	0.03	0.09	0.11	0.13	0.10
	(0.06)	(0.05)	(0.05)	(0.05)	(0.05)
β^-	0.53	0.33	0.35	0.10	0.23
	(0.26)	(0.23)	(0.25)	(0.20)	(0.25)

Table 9: **Model Robustness: Currencies. Equities' Prices of Risk**

Prices of risk, Fama&MacBeth standard errors in parentheses, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for a restricted downside risk CAPM (DR-CAPM). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, and the six Fama & French portfolios, sorted on size and book-to-market. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The market prices of risk are estimated based only on the six Fama & French portfolios and the market excess-return. The reported standard errors correspond to this estimation. The estimated prices of risk are then used to fit the six currency portfolios (left column) or the six currency portfolios and the Fama & French portfolios jointly (right column). Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Currencies DR-CAPM	Currencies and Equities DR-CAPM
λ_{market}	$0.39^{\star}$	$0.39^{\star}$
λ_{-}	1.27	1.27
	(0.45)	(0.45)
RMSPE	0.12	0.16
R^2	66.62%	70.99%

Table 10: **Model Robustness: Currencies, Varying State Threshold**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for the downside risk CAPM (DR-CAPM) . Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. In the left (right) column, downstates are all months in which the market return is more than 1.5 (0.5) standard deviation below its sample mean. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Low Threshold DR-CAPM	High Threshold DR-CAPM
λ_{market}	$0.39^{\star}$	$0.39^{\star}$
λ_{-}	1.95	2.72
	(0.49)	(0.84)
χ^2	23.38	16.27
p-val	0.07%	1.24%
RMSPE	0.15	0.09
R^2	47.16%	77.76%

Table 11: **Model Robustness: Currencies, Varying Inflation Threshold**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for the downside risk CAPM (DR-CAPM). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US. The market excess-return is included as a test asset. The sample period is January 1974 to March 2010 for a total of 435 observations. High inflation countries in the last portfolio are excluded. In the left (right) column, a country is considered to have high inflation if it has annualized monthly inflation 5% (15%) higher than US inflation. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	5% threshold DR-CAPM	15% threshold DR-CAPM
λ_{market}	$0.39^\star$	$0.39^\star$
λ_-	2.55	2.13
	(0.94)	(0.60)
χ^2	23.94	25.21
p-val	0.05%	0.03%
RMSPE	0.09	0.09
R^2	80.20%	80.99%

Table 12: **PCA: Currencies**

Loadings (PC1 – PC6) and percentage of the total variance explained by each principal component of a principal components analysis on the covariance matrix of six currencies portfolios (Cur-PF1 – Cur-PF6A), monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010, a total of 435 observations.

	PC1	PC2	PC3	PC4	PC5	PC6
Cur-PF1	-0.39	0.25	0.55	-0.42	0.34	0.44
Cur-PF2	-0.40	0.20	0.37	-0.10	-0.51	-0.62
Cur-PF3	-0.41	0.20	-0.05	0.67	-0.34	0.47
Cur-PF4	-0.38	0.16	-0.15	0.37	0.70	-0.43
Cur-PF5	-0.41	0.19	-0.73	-0.48	-0.13	0.08
Cur-PF6A	-0.45	-0.89	0.04	-0.02	0.00	0.03
Explained	68.78%	17.76%	5.03%	3.47%	2.67%	2.29%

Table 13: **Correlations: Currencies, Equities and Commodities**

Top panel: correlations between market excess return (Mrkt), dollar and carry portfolio returns (RX_cur and HML_cur) and the first two principal components of six currency portfolios sorted on the interest differential (PC_cur1 and PC_cur2). Middle panels: market excess return, commodity and basis portfolio returns (RX_com and HML_com) and the first two principal components of five commodity futures portfolios sorted on basis (PC_com1 and PC_com2). Bottom panels: three Fama & French portfolio returns (Mrkt, SMB and HML_ff) and the first three principal components of six stock portfolios sorted on size and book to market (PC_ff1, PC_ff2 and PC_ff3). The left panels report unconditional correlations while the right panels condition on the downstate. The sample period is January 1974 to March 2010, a total of 435 observations in the top and bottom panels and January 1974 to December 2008, a total of 420 observations in the middle panels.

	All States						**Down States**					
	Mrkt	RX_cur	HML_cur	PC_cur1	PC_cur2		Mrkt	RX_cur	HML_cur	PC_cur1	PC_cur2	
Mrkt	1.00	0.17	0.14	-0.17	-0.09		1.00	0.17	0.33	-0.17	-0.28	
RX_cur	0.17	1.00	0.07	-1.00	0.02		0.17	1.00	0.13	-1.00	-0.06	
HML_cur	0.14	0.07	1.00	-0.09	-0.95		0.33	0.13	1.00	-0.15	-0.97	
PC_cur1	-0.17	-1.00	-0.09	1.00	0.00		-0.17	-1.00	-0.15	1.00	0.08	
PC_cur2	-0.09	0.02	-0.95	0.00	1.00		-0.28	-0.06	-0.97	0.08	1.00	
	Mrkt	RX_com	HML_com	PC_com1	PC_com2		Mrkt	RX_com	HML_com	PC_com1	PC_com2	
Mrkt	1.00	0.11	-0.05	-0.11	-0.08		1.00	0.20	0.19	-0.20	0.21	
RX_com	0.11	1.00	0.05	-1.00	-0.02		0.20	1.00	0.07	-1.00	0.04	
HML_com	-0.05	0.05	1.00	-0.07	0.95		0.19	0.07	1.00	-0.09	0.95	
PC_com1	-0.11	-1.00	-0.07	1.00	0.00		-0.20	-1.00	-0.09	1.00	-0.05	
PC_com2	-0.08	-0.02	0.95	0.00	1.00		0.21	0.04	0.95	-0.05	1.00	
	Mrkt	SMB	HML_ff	PC_ff1	PC_ff2	PC_ff3	Mrkt	SMB	HML_ff	PC_ff1	PC_ff2	PC_ff3
Mrkt	1.00	0.25	-0.33	-0.95	-0.15	0.23	1.00	0.45	0.00	-0.91	0.01	-0.16
SMB	0.25	1.00	-0.23	-0.48	0.80	-0.36	0.45	1.00	0.02	-0.64	0.66	-0.44
HML_ff	-0.33	-0.23	1.00	0.24	-0.51	-0.82	0.00	0.02	1.00	-0.27	-0.66	-0.90
PC_ff1	-0.95	-0.48	0.24	1.00	0.00	0.00	-0.91	-0.64	-0.27	1.00	-0.02	0.49
PC_ff2	-0.15	0.80	-0.51	0.00	1.00	0.00	0.01	0.66	-0.66	-0.02	1.00	0.30
PC_ff3	0.23	-0.36	-0.82	0.00	0.00	1.00	-0.16	-0.44	-0.90	0.49	0.30	1.00

Table 14: **Estimation of Linear Pricing Models: Currencies**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The three leftmost columns present models based on the first three principal components of the test assets (PC1, PC2 and PC3). The fourth column presents the dollar and carry portfolio returns of Lustig and Verdelhan (2007) (RX_{cur} and HML_{cur}). Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US. High inflation countries in the last portfolio are excluded. A country is considered to have high inflation if it has annualized monthly inflation 10% higher than US inflation. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC1	PC2	PC3	LRV	DR-CAPM
PC1	-0.33	-0.33	-0.33		
	(0.23)	(0.23)	(0.23)		
PC2		-0.32	-0.32		
		(0.12)	(0.12)		
PC3			-0.28		
			(0.06)		
RX_{cur}				0.13	
				(0.09)	
HML_{cur}				0.47	
				(0.15)	
λ_{market}					0.39*
λ_{-}					2.18
					(0.77)
χ^2	43.24	36.05	15.96	25.14	24.60
p-val	0.00%	0.00%	0.12%	0.00%	0.02%
RMSPE	0.19	0.14	0.07	0.12	0.10
R^2	4.47%	50.07%	86.21%	63.71%	73.04%

Table 15: **PCA: Equities**

Loadings (PC1 – PC6) and percentage of the total variance explained by each principal component of a principal components analysis on the covariance matrix of 6 stock portfolios (FF-PF1 – FF-PF6), sorted on size and book-to-market. The sample period is January 1974 to March 2010, a total of 435 observations.

	PC1	PC2	PC3	PC4	PC5	PC6
FF-PF1	-0.54	0.59	0.26	-0.18	0.47	0.21
FF-PF2	-0.43	0.18	-0.27	0.25	-0.11	-0.80
FF-PF3	-0.43	0.07	-0.54	0.04	-0.51	0.51
FF-PF4	-0.35	-0.21	0.71	-0.14	-0.55	-0.06
FF-PF5	-0.33	-0.48	0.11	0.70	0.34	0.20
FF-PF6	-0.34	-0.58	-0.24	-0.63	0.29	-0.11
Explained	86.37%	6.98%	4.73%	0.86%	0.81%	0.24%

Table 16: **Estimation of Linear Pricing Models: Equities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The three leftmost columns present models based on the first three principal components of the test assets (PC1, PC2 and PC3). The fourth column presents the three Fama & French portfolio returns (Mr, SMB and HML_ff). Test assets are six stock portfolios sorted on size and book to market. The last column excludes the small growth portfolio. The sample period is January 1974 to March 2010 for a total of 435 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC1	PC2	PC3	F&F	DR-CAPM	*excl port 1* DR-CAPM
PC1	-1.37	-1.37	-1.37			
	(0.60)	(0.60)	(0.60)			
PC2		-0.25	-0.25			
		(0.17)	(0.17)			
PC3			-0.51			
			(0.14)			
Mr				0.36		
				(0.23)		
SMB				0.19		
				(0.15)		
HML_ff				0.49		
				(0.15)		
λ_{market}					0.39*	0.39*
λ_{-}					1.27	1.61
					(0.45)	(0.43)
χ^2	57.69	55.58	42.15	41.77	33.83	9.43
p-val	0.00%	0.00%	0.00%	0.00%	0.00%	5.12%
RMSPE	0.27	0.25	0.14	0.14	0.20	0.07
R^2	-19.95%	-3.57%	67.25%	68.27%	32.93%	90.48%

Table 17: **PCA: Commodities**

Loadings (PC1 – PC5) and percentage of the total variance explained by each principal component of a principal components analysis on the covariance matrix of five commodity futures portfolios (Com-PF1 – Com-PF6A), monthly re-sampled based on basis. The sample period is January 1974 to December 2008, a total of 420 observations.

	PC1	PC2	PC3	PC4	PC5
Com-PF1	-0.49	0.72	0.41	-0.27	-0.03
Com-PF2	-0.43	0.13	-0.46	0.47	-0.61
Com-PF3	-0.48	-0.02	-0.28	0.30	0.78
Com-PF4	-0.39	-0.34	-0.38	-0.76	-0.09
Com-PF5	-0.44	-0.59	0.63	0.20	-0.14
Explained	59.99%	15.08%	10.45%	8.25%	6.23%

Table 18: **Estimation of Linear Pricing Models: Commodities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The three leftmost columns present models based on the first three principal components of the test assets (PC1, PC2 and PC3). The fourth column presents the commodity and basis portfolio returns of Yang (2010) (RX_{com} and HML_{com}). Test assets are five commodity futures portfolios, monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC1	PC2	PC3	Yang	DR-CAPM
PC1	-0.73	-0.73	-0.73		
	(0.41)	(0.41)	(0.41)		
PC2		0.60	0.60		
		(0.20)	(0.20)		
PC3			0.00		
			(0.17)		
RX_{com}				0.31	
				(0.18)	
HML_{com}				0.83	
				(0.28)	
λ_{market}					$0.39^{\star}$
λ_{-}					1.42
					(0.57)
χ^2	9.33	0.68	0.68	2.37	2.42
p-val	5.34%	87.84%	71.25%	49.90%	65.98%
RMSPE	0.27	0.05	0.05	0.10	0.12
R^2	10.41%	96.83%	96.83%	87.14%	81.61%

Table 19: **Estimation of Linear Pricing Models: Currencies, Equities and Commodities (Mimicking Portfolios)**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The leftmost column presents the model based on the dollar and carry portfolio returns of Lustig and Verdelhan (2007) (RX_{cur} and HML_{cur}). The second column presents the model based on the commodity and basis portfolio returns of Yang (2010) (RX_{com} and HML_{com}). The third column presents a model based on the three Fama-French factors (Mrkt, SMB and HML_ff). The next two columns present models based on combinations of the portfolio returns in the previous three columns. Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, 6 Fama & French portfolios sorted on size and book to market and five commodity futures portfolios, monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	Cur_{mim}	Com_{mim}	FF_{mim}	Cur_{mim} Com_{mim} FF_{mim}	Cur_{mim} Com_{mim} FF_{mim}	DR-CAPM
RX_{cur}	0.19			0.10		
	(0.11)			(0.10)		
HML_{cur}	0.99			0.42	0.50	
	(0.37)			(0.15)	(0.16)	
RX_{com}		0.43		0.31		
		(0.19)		(0.18)		
HML_{com}		0.54		0.83	0.91	
		(0.31)		(0.28)	(0.29)	
Mr			0.28	0.31	0.40	
			(0.23)	(0.23)	(0.24)	
SMB			0.23	0.18		
			(0.16)	(0.16)		
HML			0.57	0.49	0.49	
			(0.18)	(0.15)	(0.17)	
λ_{market}						$0.39^{\star}$
λ_{-}						1.40
						(0.38)
χ^2	113.18	120.09	107.48	84.30	87.49	64.48
p-val	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RMSPE	0.32	0.34	0.24	0.12	0.16	0.15
R^2	-14.96%	-35.22%	35.29%	82.37%	69.50%	73.52%

Table 20: **Estimation of Linear Pricing Models: Currencies, Equities and Commodities**

Prices of risk, Fama&MacBeth standard errors in parentheses, χ^2 statistics testing for joint significance of pricing errors, root mean squared pricing errors (RMSPE) and the cross sectional R^2s for various factor models and the downside risk CAPM (DR-CAPM). The two leftmost columns present models based on the first eight principal components of the test assets (PC1 – PC8). The third column presents a model based on the first two principal components of the currency portfolios (PC_cur1 and PC_cur2). The fourth column presents a model based on the first two principal components of the commodity portfolios (PC_com1 and PC_com2). The fifth column presents a model based on the first three principal components of the stock portfolios (PC_ff1 – PC_ff3). The sixth and seventh columns present models based on combinations of the principal components in the previous three columns. Test assets are six currency portfolios, monthly re-sampled based on the interest rate differential with the US, 6 Fama & French portfolios sorted on size and book to market and five commodity futures portfolios, monthly re-sampled based on basis. The sample period is January 1974 to December 2008 for a total of 420 observations. Starred estimates impose the restriction that the market excess-return is exactly priced and consequently no standard errors are reported.

	PC7	PC8	PC_cur	PC_com	PC_ff	PC_cur PC_com PC_ff	PC_cur PC_com PC_ff	DR-CAPM
PC1 / PC_cur1	-1.32	-1.32	-0.55			-0.27		
	(0.60)	(0.60)	(0.28)			(0.24)		
PC2 / PC_cur2	0.55	0.55	-0.73			-0.28	-0.29	
	(0.40)	(0.40)	(0.27)			(0.12)	(0.12)	
PC3 / PC_com1	0.08	0.08		-0.97		-0.72		
	(0.23)	(0.23)		(0.42)		(0.41)		
PC4 / PC_com2	-0.57	-0.57		0.35		0.60	0.59	
	(0.20)	(0.20)		(0.23)		(0.20)	(0.20)	
PC5 / PC_ff1	-0.24	-0.24			-1.26	-1.22	-1.26	
	(0.18)	(0.18)			(0.60)	(0.60)	(0.60)	
PC6 / PC_ff2	0.22	0.22			-0.21	-0.25		
	(0.16)	(0.16)			(0.17)	(0.17)		
PC7 / PC_ff3	0.10	0.10			-0.63	-0.52	-0.58	
	(0.15)	(0.15)			(0.18)	(0.14)	(0.18)	
PC8		-0.60						
		(0.14)						
λ_{market}								$0.39^{\star}$
λ_{-}								1.40
								(0.38)
χ^2	111.56	93.14	123.01	118.39	107.72	91.80	97.69	64.48
p-val	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
RMSPE	0.19	0.12	0.33	0.34	0.24	0.12	0.19	0.15
R^2	59.08%	83.03%	-28.62%	-35.32%	36.07%	83.62%	59.48%	73.52%