The Cross-Section of Foreign Currency Risk Premia and Consumption Growth Risk: A Reply

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- Web Appendix -

NOT FOR PUBLICATION

This separate appendix complements the paper "The Cross-Section of Foreign Currency Risk Premia and Consumption Growth Risk: A Reply". We report additional results on:

- Durable consumption growth betas of returns and exchange rates: see Table VII and VIII;
- Estimation on dollar-neutral portfolios: see GMM estimates in Table IX and FMB estimates in Tables X and XI (with and without a constant);
- Estimation of linear factor models without a constant but with an additional factor: see Table XII;
- GLS estimation of linear factor models: see Table XIII and XIV;
- FMB estimation of linear factor models and preference parameters: see Table XV;
- Principal components of currency portfolio returns: see Table XVI;
- Estimation of the CAPM and conditional CAPM: see Table XVII.

This separate appendix first details our data in Section A. We focus on the quantity of risk and report in Section B additional regression results on durable consumption growth betas. This additional evidence addresses Burnside's first claim. We then turn to the market prices of risk in Section C. We address Burnside's second claim and presents robustness checks on the model's estimation. We show how to extract risk factors from exchange rates at quarterly frequency in Section D. Finally, we report evidence on time-varying equity prices of risk in Section E.

A Appendix: Data

Deutsche Bank Carry Trade Return Index The Deutsche Bank G10 Currency Harvest Index consists of long futures contracts on the three G10 currencies associated with the highest interest rates and short futures contracts on the three G10 Currencies associated with the lowest interest rates. This index re-evaluates interest rates quarterly and, based on the evaluation, reweights the futures contracts it holds. Immediately after each reweighting, the index will reflect an investment on a 2 to 1 leveraged basis in the three long futures contracts and in the three short futures contracts. The index is available online at *http://www.dbfunds.db.com/Dbv/index.aspx* and starts in 1993. The PowerShares DB G10 Currency Harvest Fund (symbol: DBV), which replicates the Deutsche Bank index, has been listed on the NYSE since 18 September 2006. As a result, the recent returns and losses that we report were accessible to many investors.

LRV Carry Trade Returns Lustig, Roussanov, and Verdelhan (2008) use monthly data on one-month forward and spot exchange rates to construct currency portfolio returns. We have updated these data through June 2009. Lustig, Roussanov, and Verdelhan (2008) construct portfolios of currencies sorted by their forward discounts. We construct six portfolios on the entire set of currencies, five for the developed currencies.

Monthly Consumption Data The U.S. National Income and Product Accounts (NIPA) has recently begun constructing monthly consumption series. We use the growth rate in real total consumption expenditures. Because we do not have monthly data on the stock of durable consumption goods, we cannot construct durable consumption growth. However, we check our results on the growth rate of durable consumption expenditures. The monthly consumption data is from Table 2.8.1. (Percent Change from Preceding Period in Real Personal Consumption Expenditures by Major Type of Product, Monthly). Line 1 is Personal Consumption Expenditures; we call this total consumption growth. Line 2 is Durable goods; we call this durable expenditures. Line 3 is nondurables; we call this nondurable consumption. We do not divide these series by the number of households. The monthly stock return is the real return on the CRSP-VW index.

Crises Dates for the Tequila crisis and the Long Term Capital Management crisis were taken from Kho, Lee, and Stulz (2000). Dates for the less-developed-country crisis are from the FDIC web site, available at `http://www.fdic.gov/bank/historical/history/191_210.pdf`.

Annual Consumption Data The annual personal consumption expenditures in dollars are obtained from Table 2.3.5. (Personal Consumption Expenditures by Major Type of Product), and the price series are obtained from Table 2.3.4. (Price Indexes for Personal Consumption Expenditures by Major Type of Product). The nondurable consumption series is constructed as the sum of nondurable goods (line 6) deflated by its price index (line 6 in Table 2.3.4), services (line 13) deflated by its price (line 13), housing services (line 14) deflated by its price (line 14), and clothes and shoes (line 8) deflated by its price (line 8).

What enters the average investor's utility function is the service flow provided by the stock of durables, not the expenditures on durable consumption goods. The stock is our measure of the service flow provided by the durables. Following Yogo (2006), we measure durable consumption growth as the change in the stock of consumer durables D. Instead of constructing our own measure (using the perpetual inventory method) to extend the sample, we simply used the fixed asset tables, which are available only at annual frequency. For the 1953–2002 sample, our measure is very close to Yogo's. We use two different measures of durable consumption growth.

Our baseline measure of durable consumption growth, denoted Δd_1, is the log change in the deflated current cost stock of consumer durables (line 13 from Fixed Assets Table 1.1: Current-Cost Net Stock of Fixed Assets and Consumer Durable Goods) divided by the number of U.S. households. We also use a second measure, Δd_2; it is the log change in the quantity index for consumer durable goods (line 13 from Fixed Assets Table 1.2: Chain-Type Quantity Indexes for Net Stock of Fixed Assets and Consumer Durable Goods). We divide these series by the number of households.

Return Factors SMB and HML are obtained from Kenneth French's web site. These are listed as Fama-French factors. SMB goes long in a basket of small stocks and short in a basket of large stocks. The momentum factor is also obtained from Kenneth-French's web site; it goes long in a portfolio of winners and short in a portfolio of losers.

B Appendix: Durable Consumption Growth Betas of Returns and Exchange Rates

In this section, we focus on the quantity of risk. Table VII reports durable consumption growth betas of returns on currency portfolios. Durable consumption growth betas are higher for higher interest rate currencies.

What is the source of this covariance between currency returns and consumption growth: interest rates or exchange rates? We can disentangle the contribution of changes in exchange rates and interest rates to the factor loadings of returns that we have reported. To do so, we run a simple time-series regression of the annual exchange rate changes in portfolio j (averaged over all the currencies in this portfolio) on durable consumption growth. The results of this time-series regression are reported in Table VIII. For developed currencies, all of the consumption exposure is a consequence of the exchange rate exposure; for less developed currencies, some of the exposure is due to interest rates. High interest rate currencies depreciate when U.S. durable consumption growth is low and appreciate when consumption growth is high.

Table VIII reports durable consumption growth betas of exchange rates. We start with developed currencies. The top panel reports the results for long positions in each portfolio. The bottom panel reports the results for short positions in the first portfolio and long positions in the other portfolios. For Δd^1, the loadings of exchange rate changes increase from .03 on the first portfolio to 1.74 on the seventh portfolio; the loadings on the last portfolio is 1.62. These loadings are statistically different from zero at the 5 % level, except for the loadings on portfolio 1 and portfolio 4. For Δd^2, the loadings of exchange rate changes increase from .21 on the first portfolio to 1.52 on the seventh portfolio; the loadings on the last portfolio is 1.26. We also tested whether these loadings differ significantly across portfolios by looking at the loadings of zero-cost portfolios of currencies that go long in the high interest rate portfolio and short in the low interest rate portfolio. For the first factor Δd^1, the loadings are significantly different from zero at the 10 % level for all portfolios except for portfolios 3, 4 and 5. The loadings are larger in the post-Bretton-Woods sample, as one would expect. When we include the less developed currencies, the loadings on the higher interest rate portfolios are less precisely estimated. Moreover, they sometimes are smaller for the higher interest rate portfolios. For these currencies, the interest rates themselves contribute significantly to the loadings of returns on durable consumption growth (i.e., higher interest rate differences with the US when US durable consumption growth is high).

C Appendix: Prices of Currency Risk

In this section, we focus on the prices of aggregate risk. We first focus on Burnside's second claim and then report several robustness checks on the model's estimation that were left out from our main paper.

A What Is the Price of Dollar Risk?

We start with Burnside's second claim. Burnside stresses that the constant in the second stage of our regression is large and negative. He then argues (a) that a risk-based explanation can be discounted because our model overpredicts the returns on all eight currency portfolios and (b) that our R^2 overstates the fit of the model because it includes this constant.

The constant measures the risk price of variations in the dollar (relative to all other currencies) that cannot be attributed to consumption growth. In Section D below, we show that the first principal component of currency returns is a dollar factor. All currency portfolios have essentially the same loadings on this factor.[10] As a result, our cross-section of currency portfolios is not informative about the price of dollar risk. In order to estimate the price of dollar risk, currencies need to be sorted by their exposure to the dollar risk factor, not by interest rates.

The constant in the second stage of our regression (λ_0) is -2.9% for the benchmark *EZ-DCAPM* model. This implies that a zero-beta asset yields a negative excess return of 290 basis points. In other words, the model overpredicts the returns on all eight currency portfolios by 290 basis points. The uncorrected standard error on the intercept is 80 basis points. The Shanken-corrected standard error is 220 basis points, but in this case Burnside highlights only the uncorrected standard errors. In the bootstrapping exercise, we find a standard error of 175 basis points. This clearly shows that the intercept is not significantly different from zero.

To confirm that the constant actually measures the price of dollar risk, we test the model's performance on currency carry trade strategies that go long in the high interest rate currency portfolios and short in the first low interest rate portfolio. The returns on this strategy are given by the return on the high interest rate currency portfolio less the return on the lowest interest rate portfolio: $R_t^j - R_t^1$. The Euler equations should also be satisfied for these zero-cost strategies, but the returns are not affected by the fluctuations in the dollar. If our interpretation of the constant is correct, we should observe a smaller intercept λ_0.

[10] It is important to note that this is typically *not* true for stock portfolios and the loadings on the market return.

GMM Estimation In Table IX we report the GMM estimates obtained on these seven test assets. The factors are de-meaned. The consumption risk prices are 2.8 and 4.8, respectively, and these values are statistically significant. Again, the benchmark *EZ-DCAPM* model explains about 80% of the cross-section.

FMB Estimation As a robustness check, Table X reports the results for the Fama–MacBeth (1973) estimation of the linear factor models using these test assets. In the benchmark *EZ-DCAPM* (column 5), the constant λ_0 drops 350 basis points (from 290 to -60 basis points), and is not significantly different from zero. The R^2 is 81%. This measure is based on the regression *with* a constant, yet *without* a constant is (the case considered in the next paragraph) the R^2 "drops" to 79 %. The risk prices of consumption are estimated precisely. The *DCAPM* in column 3 also has a small intercept (λ_0) of about 60 basis points. This model accounts for 60% of the variation in the returns across these portfolios, and we find similar results for the second subsample. Once you eliminate the effect of swings in the dollar by going long in high and short in low interest rate currencies, the intercept is essentially zero.

Measures of Fit Finally, Burnside argues that our definition of the cross-sectional regression's R^2 overstates the fit of the model because we include the constant, even though this is the standard measure reported in the literature. So let us turn again to those test assets that go long in high interest rate currency portfolios and short in the first portfolio. We redo the estimation *without a constant*, and hence use Burnside's preferred measure of fit. Table XI reports the results. The price of nondurable and durable consumption risk are significantly different from zero, and the model accounts for 79% of the variation in these returns. Figure 2 compares the models estimated with and without the constant plotting the benchmark model's predicted excess return (horizontal axis) against the realized excess return for these seven test assets. On the left panel, we include a constant; on the right panel, we do not. There is hardly any difference in the fit. The pricing errors on the first and seventh portfolios are close to zero in both cases.

Dollar Factor Another way to avoid this "dollar problem" is to include the average excess return on all eight portfolios as a separate factor and then estimate the model on all eight portfolios. This additional factor RX_{FX} absorbs the effect of the dollar variation in returns; there is no variation in the betas of this factor across portfolios, because all have the same dollar exposure. In this case, the model can be estimated on all eight test assets without a constant. The resulting risk price estimates are much like the ones we obtained on the same test assets without this additional factor but including a constant. These results are reported in Table XII.

As a result, the *EZ-DCAPM* model overpredicts the average (dollar) excess return on foreign currency investments in our sample, but it has no trouble explaining the spread between high and low interest currency returns. This is what the forward premium puzzle and our previous paper are about. Our paper is not about dollar risk. We agree with Burnside that consumption risk does not explain the average returns earned by U.S. investors on a basket of all foreign currencies, and we have never claimed that it did. Our focus is on the returns obtained by going long in high interest rate currencies and short in low interest rate currencies for this is how the carry trade is defined.

B Robustness checks

Having checked the quantities of risk and the role of the constant, we turn now to the prices of carry risk. We now compare the evidence in Lustig and Verdelhan (2007) on risk price estimates against Burnside's claim. In our previous paper we report bootstrapped standard errors, Shanken-corrected standard errors, and GMM standard errors. In this appendix, we first review the findings reported in Lustig and Verdelhan (2007) and then report additional estimates obtained using Generalized Least Squares (GLS).

Notation For the reader's convenience, we briefly review the notation and methodology of our previous paper. We keep the same notation in this reply. Starting from the Euler equation, one can derive a linear factor model whose factors are nondurable U.S. consumption growth Δc_t, durable U.S. consumption growth Δd_t, and the log of the U.S. market return r_t^m. The U.S. investor's unconditional Euler equation (approximately) implies a linear three-factor model for the expected excess return on portfolio j:

$$E[R^{j,e}] = b_1 cov\left(\Delta c_t, R_t^{j,e}\right) + b_2 cov\left(\Delta d_t, R_t^{j,e}\right) + b_3 cov\left(r_t^w, R_{t+1}^{j,e}\right). \tag{1}$$

Our benchmark asset pricing model, denoted *EZ-DCAPM*, is described by equation (1). This specification nests as special cases the *CCAPM* with Δc_t as the only factor, the *DCAPM* with factors Δc_t and Δd_t, the *EZ-CCAPM*, with factors Δc_t and r_t^m, and the *CAPM*. This linear factor model can be restated as a beta pricing model, where the expected excess return $E[R^{j,e}]$ of portfolio j is equal to the factor price λ multiplied by the amount of risk β^j:

$$E[R^{j,e}] = \lambda' \beta^j, \tag{2}$$

where $\lambda = \Sigma_{ff} b$, and $\Sigma_{ff} = E(f_t - \mu_f)(f_t - \mu_f)'$ is the variance-covariance matrix of the factors. The classic estimation proceeds in two stages. In the first stage, we estimate the betas (β^j) by running a time-series regression of returns on the factors. In the second stage, we estimate the market prices of risk for all the factors (λ) by running a cross-sectional regression of average returns on the betas.

Bootstrap In panel B of Table 14 of Lustig and Verdelhan (2007), we report the standard errors in braces $\{\cdot\}$ obtained by bootstrapping the whole estimation. These standard errors take into account the uncertainty in the first stage of the estimation as well as the small sample size. They were generated by running the estimation procedure on 10,000 samples constructed by drawing with replacement both from the observed returns and factors under the assumption that returns and factors are not predictable. The first column reports the results with only currency portfolios as test assets. The market price of risk associated with consumption growth in durables is highly significant for currency portfolios. The point estimate is 4.7, and the standard error is 1.7 (panel B, first column). If currency returns and consumption growth are independent, as Burnside claims, then the bootstrapping exercise would have revealed this. Instead, it confirms that our results are significant.

Shanken correction Table 14 of Lustig and Verdelhan (2007) also reports the Shanken-corrected standard errors in parenthesis $(\cdot)$. The Shanken correction (see Jay Shanken 1992), which is only valid asymptotically, produces substantially larger standard errors than the ones we generated by bootstrapping. Ravi Jagannathan and Jiang Wang (1998) show that the uncorrected Fama and MacBeth (1973) standard errors do not necessarily overstate the precision of the factor price estimates in the presence of conditional heteroskedasticity. We show in section III of our previous paper that conditional heteroskedasticity is the key to understanding these currency betas.

Generalized Method of Moments In addition, panel A of Table 14 in Lustig and Verdelhan (2007) reports the two-stage linear GMM estimates obtained on the same test assets. These standard errors also reflect the estimation uncertainty for these betas. Again, the price of nondurable consumption risk is significant (2.4 with a standard error of 0.9); likewise, the price of durable consumption risk is positive and significant (3.4 with a standard error of 1.2). Burnside also discards the GMM evidence because he insists on estimating the mean of the factors; adding three separate moments, he obtains different point estimates. This means that his GMM estimates of the factor means differ from the sample means, which is not an appealing outcome. Yogo (2006) encounters a similar problem and adjusts the weighting matrix to deal with it, as he explains in an appendix (p. 575). Because of these issues, our approach of *not* estimating the mean of the factors is actually more standard.[11]

Generalized Least Squares In Table XIII of this paper, we report the GLS estimates that were left out of the previously published version. We remark that GLS estimators are more efficient than OLS estimators because they put more weight on the more informative moment conditions.[12] Clearly, for the *D-CAPM* and the *EZ-DCAPM*, the market price of durable consumption risk is significant at the 5% level, even when we use the asymptotic Shanken correction upon which Burnside insists. The price of nondurable consumption risk is about 3.0, with a Shanken-corrected standard error of 1.8 and bootstrapped errors of about 1.2. The price of durable consumption risk is approximately 5.15, with a Shanken-corrected standard error of about 2.4 and bootstrapped errors of about 1.6. The measures of fit are lower because GLS does not simply minimize the squared pricing errors; it minimizes the weighted sum. Table XIV reports similar results for the post–Bretton Woods subsample. Burnside's claim that the risk prices are not statistically different from zero does not hold for that sample either. Table XV reports the FMB estimation of linear factor models and preference parameters. The implied risk-aversion coefficient is large, but in line with estimates of consumption-based asset pricing models of equity excess returns.

[11] For example, Martin Lettau and Sydney Ludvigson (2001) report results from a GMM estimation of their linear factor model, yet do not to estimate the mean of the factors.

[12] For a comparison of estimators for beta pricing models, see Shanken and Zhou (2007).

D Appendix: Extracting Risk Factors from Currency Returns

The current recession provides additional support for a risk-based explanation of exchange rates. The number of recessions, however, remains limited. Not surprisingly, the standard errors on the estimates of macroeconomic factor loadings are typically large. This is a well-known fact in the asset pricing literature. To reduce the estimation uncertainty, an alternative strategy is to construct return-based factors. These are much more precisely measured and thus deliver better estimates of the loadings and the risk prices. The Arbitrage Pricing Theory developed by Stephen A. Ross (1976) provides a theoretical underpinning for this methodology.

In Lustig, Roussanov and Verdelhan (forthcoming), we pursue this approach using monthly currency return data constructed from one-month forward contracts (not T-bills) over the period from 1983.1 to 2009.12. We find that these currency returns exhibit a clear factor structure. The first two principal components of the returns account for most of the time-series variation in the returns on the currency portfolios. All excess returns load approximately equally on the first principal component (PC_1), which is close to the mean of all currency returns. We call this the *dollar* factor. However, loadings on the second principal component (PC_2) increase monotonically with the interest rates. This is why we refer to it as the *slope* factor. Exchange rates of various currencies covary in the right way when we sort these currencies by their interest rates: high interest rate currencies move together, and so do low interest rate currencies. This is a necessary condition for a risk-based explanation.

We show in this paper that our results extends to a longer sample of quarterly returns on the portfolios of foreign T-bills used in Lustig and Verdelhan (2007). The annual series are not as informative about the covariance matrix and the factor structure of exchange rates. Starting either in 1953:I or in 1971:I, a clear factor structure emerges. The second principal component is a slope factor that explains a large share of the cross-sectional variation in average returns on the currency portfolios.[13] There is much less estimation uncertainty when we use return-based factors. The market price of risk has a t-statistic of 3.4. Table XVI reports the estimates we obtained on the currency portfolios. The left-hand side of the table corresponds to our long sample (1953:I–2009:II); the right-hand side corresponds to the post–Bretton Woods sample (1971:I–2009:II). In both cases, the risk factors are the first two principal components of the currency excess returns.

[13]The first principal component loads on all portfolios in the same way. On the 1953:IV–2009:II sample, its loadings are [0.12, 0.12, 0.13, 0.12, 0.12, 0.11, 0.11, 0.11]. The second principal component loads very differently on low and high interest rate portfolios. On the same sample, its loadings are [−0.65, −0.45, −0.10, 0.13, 0.25, 0.22, 0.44, 0.20]. We obtain similar results on the post–Bretton Woods sample.

Cross-Sectional Regressions The top panel of Table XVI reports estimates of the market prices of risk λ, the adjusted R^2, the square root of mean-squared errors $RMSE$, and the p-values of χ^2 tests (in percentage points).

The dollar risk factor, PC_1, has an estimated risk price of 148 basis points. Its value is not precisely estimated, which is not surprising because all the portfolios have similar betas with respect to this dollar factor. As a result, this factor explains none of the cross-sectional variation in portfolio returns. Although the dollar factor does not explain any of the cross-sectional variation in expected returns, it is important for the level of average returns; it mimics a constant in the cross-sectional regression because all of the portfolios have the same exposure to this factor.

This is the same issue mentioned in Section C. The intercept measures the price of that component of dollar risk not explained by our risk factors (consumption growth and the market return). Why do we call it "dollar risk"? The first principal component of all currency excess returns has the same loadings on all currency portfolios. Hence, in the cross-sectional regression of average returns on factor loadings, the dollar risk loadings behave as a constant. The risk price of this factor is hard to estimate precisely, exactly because it affects all of the currencies in the same way. The cross-section of currency returns is obviously not informative here. Suppose we eliminated the dollar risk factor from the regressions. Then all of the alphas in panel II of Table XVI would increase by 148 basis points, but we would still be explaining 65% of the cross-sectional variation.

The slope factor, PC_2, has a risk price of 293 basis points per annum. This means that an asset with a beta of 1 earns a risk premium of 2.93% per annum.[14] The FMB standard error is 83 basis points. The risk price is more than 3 standard errors removed from zero and thus is highly statistically significant. The lambdas indicate whether risk is priced, and the second principal component clearly captures aggregate risk on currency markets. Overall, the pricing errors are small. The $RMSE$ is around 63 basis points, and the adjusted R^2 is 66%. The null that the pricing errors are zero cannot be rejected, regardless of the estimation procedure. All these results hold also in a smaller sample starting in 1971, as shown on the right-hand side of Table XVI.

Time-Series Regressions The bottom panel of Table XVI reports the intercepts and the slope coefficients obtained by running time-series regressions of each portfolio's currency excess returns on a

[14]Because the factors are returns, the absence of arbitrage implies that the risk prices of these factors should equal their average excess returns. This condition stems from the fact that the Euler equation applies to the risk factor itself, which clearly has a regression coefficient β of 1 on itself. In our estimation, this no-arbitrage condition is automatically satisfied because the two risk factors are orthogonal; in this case, the risk prices exactly equal the factor means.

constant and risk factors. The returns and alphas are in percentage points per annum. The first column reports alpha estimates, which are not statistically significant at the 5% significance level. The null that the alphas are jointly zero cannot be rejected at either the 5% or either the 10% level.

The third column of the same panel reports the estimated betas for the second principal component. These betas increase monotonically from -0.65 for the first portfolio to 0.44 for the seventh currency portfolio, decreasing slightly to 0.20 for the last portfolio. These betas are estimated very precisely. The first three portfolios have betas that are negative and significantly different from 0; the remaining five portfolios have betas that are positive and significantly different from zero. The second column shows that betas for the dollar factor are essentially all equal to 1. Obviously, this dollar factor does not explain any of the variation in average excess returns across portfolios, but it helps to explain the average level of excess returns. These results are comparable to the ones obtained using a shorter sample (reported on the right-hand side of the table).

Return-based risk factors confirm that the cross-section of average currency excess returns align with the covariances of returns and factors, following a simple risk-based logic.

E Appendix: Time Variation in Equity Risk Prices

Finally, we report additional results on the time-variation in equity risk prices.

On a long sample at annual frequency, we report in Lustig and Verdelhan (2007) that the CAPM accounts for less than 5% of the cross-sectional variation in returns. Using monthly returns and a shorter sample leads to more favorable results. But the CAPM is still not a good description of the currency returns. The top panel of Table XVII reports CAPM results with 6 portfolios. The US stock market excess return can account for a large share of the cross-sectional variation in returns. However, the estimated price of US market risk is close to 29 percent, while the actual annualized excess return on the market is only 5.5 percent over this sample. The risk price is more than 5 times too large. The CAPM β's vary from -.03 for the first portfolio to .12 for the last one. Low interest rate currencies provide a hedge, while high interest rate currencies expose US investors to more stock market risk. These β's increase almost monotonically from low to high interest rates, but they are too small to explain these excess returns. Therefore, the cross-sectional regression of currency returns on market β's implies market price of risk that are far too high.

The bottom panel of Table XVII reports results obtained on 12 test assets (the original 6 currency portfolios and the same ones multiplied by the lagged VIX index). Risk factors are the Fama-French value-weighted stock market excess return R^M and $R^M z$, which is R^M multiplied by the lagged value of the VIX index (scaled by its standard deviation). We find that the market price of risk increases significantly in bad times (when the stock market volatility index VIX is high). However, taking into account such time-variation is not enough to justify the CAPM: market prices of risk are still too high.

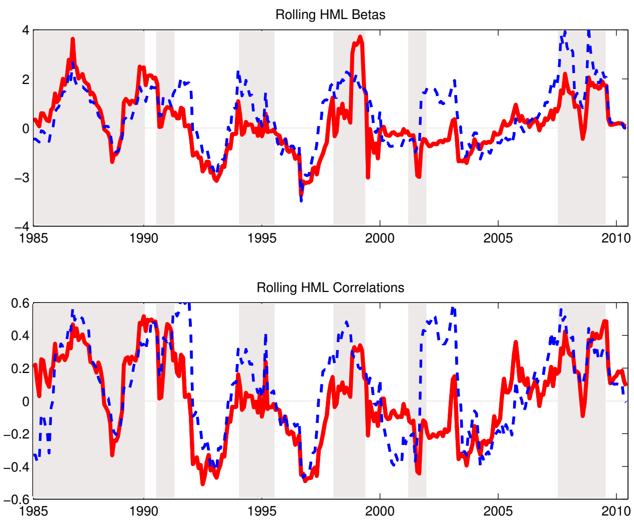

Figure 6: HML Consumption Correlations and Betas

We plot the 18-month nondurable consumption growth betas of HML (upper panel) and 18-month correlations of nondurable consumption growth and HML (lower panel). The red solid line is for all currencies; the blue dotted line is for developed currencies. Monthly currency portfolios from Lustig, Roussanov, and Verdelhan (2008) are updated through May 2010. The shaded areas are NBER recessions and the LDC crisis, the Tequila crisis, and the LTCM crisis.

Table VII: Durable Consumption Growth Betas of Returns

	All Currencies								Developed Currencies							
Portfolios	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
	Panel A: 1953–2008															
Durables (1)	0.37	0.73^{*}	0.91^{**}	1.15^{*}	0.90	1.08^{*}	1.57^{***}	1.12	0.23	1.90^{**}	1.56^{*}	0.62	1.04	1.69^{**}	1.90^{**}	1.85^{**}
	[0.50]	[0.39]	[0.43]	[0.66]	[0.58]	[0.60]	[0.57]	[0.73]	[0.80]	[0.86]	[0.93]	[0.59]	[0.85]	[0.77]	[0.78]	[0.81]
Durables (2)	0.33	0.68^{**}	0.69^{**}	0.90^{*}	0.67	0.91^{**}	1.10^{**}	1.24^{**}	0.31	1.23^{*}	1.02	0.68	0.99	1.11^{*}	1.59^{**}	1.41^{**}
	[0.40]	[0.33]	[0.37]	[0.51]	[0.47]	[0.49]	[0.47]	[0.58]	[0.59]	[0.69]	[0.76]	[0.54]	[0.65]	[0.59]	[0.68]	[0.62]
	Long–Short in 1															
Durables (1)		0.36	0.54	0.78	0.53^{*}	0.71^{*}	1.20^{***}	0.75		1.68^{***}	1.33^{*}	0.39	0.82	1.47^{*}	1.67^{**}	1.62^{***}
		[0.37]	[0.36]	[0.48]	[0.27]	[0.42]	[0.41]	[0.67]		[0.65]	[0.81]	[0.58]	[0.64]	[0.82]	[0.73]	[0.55]
Durables (2)		0.35	0.36	0.56	0.33	0.58	0.77^{**}	0.90^{*}		0.92	0.71	0.37	0.68	0.80	1.28^{**}	1.10^{**}
		[0.29]	[0.31]	[0.35]	[0.27]	[0.36]	[0.37]	[0.52]		[0.56]	[0.65]	[0.48]	[0.51]	[0.66]	[0.61]	[0.48]
	Panel B: 1971–2008															
Durables (1)	0.67	1.11^{*}	1.56^{***}	2.21^{***}	1.66^{**}	1.82^{**}	2.38^{***}	1.22	0.37	2.81^{**}	2.50^{**}	0.99	1.72	2.77^{***}	2.98^{***}	2.85^{***}
	[0.71]	[0.57]	[0.48]	[0.73]	[0.78]	[0.83]	[0.80]	[1.08]	[1.20]	[1.12]	[1.23]	[0.85]	[1.18]	[0.98]	[1.01]	[1.08]
Durables (2)	0.57	0.96^{**}	1.10^{**}	1.52^{**}	1.13^{*}	1.45^{**}	1.53^{**}	1.29^{*}	0.47	1.68^{*}	1.51	0.94	1.52^{*}	1.73^{**}	2.33^{***}	2.06^{***}
	[0.52]	[0.45]	[0.48]	[0.60]	[0.60]	[0.59]	[0.64]	[0.77]	[0.82]	[0.90]	[1.00]	[0.73]	[0.83]	[0.71]	[0.80]	[0.76]
	Long–Short in 1															
Durables (1)		0.44	0.89^{*}	1.54^{***}	0.99^{**}	1.15^{**}	1.71^{***}	0.55		2.44^{***}	2.13^{**}	0.62	1.35	2.40^{***}	2.61^{***}	2.49^{***}
		[0.50]	[0.50]	[0.56]	[0.41]	[0.58]	[0.61]	[0.98]		[0.78]	[1.03]	[0.87]	[0.84]	[0.97]	[0.82]	[0.63]
Durables (2)		0.39	0.53	0.95^{**}	0.56	0.89^{**}	0.96^{*}	0.73		1.21	1.04	0.47	1.06	1.26	1.86^{***}	1.60^{**}
		[0.38]	[0.41]	[0.43]	[0.39]	[0.45]	[0.53]	[0.65]		[0.78]	[0.91]	[0.68]	[0.67]	[0.84]	[0.71]	[0.63]

Notes: Results obtained on annual currency portfolio returns. The returns are from Lustig and Verdelhan (2007), updated through 2008; standard errors are reported in brackets. Following Andrews (1991), we use Newey–West heteroscedasticity-consistent standard errors with an optimal number of lags to estimate the spectral density matrix. We use one asterisk to denote significance at the 10% level, two for 5%, and three for 1%. The first measure, denoted *Durables (1)*, is the log change in the deflated current cost stock of consumer durables; the second measure, *Durables (2)*, is the log change in the quantity index for consumer durable goods. The Data Appendix contains a detailed description of our variables.

Table VIII: Estimation of Durable Consumption Growth Betas of Exchange Rates

	All Currencies								Developed Currencies							
Portfolios	1	2	3	4	5	6	7	8	1	2	3	4	5	6	7	8
								Panel A: 1953-2008								
								Long								
Durables (1)	−0.03	0.43	0.73**	1.00*	0.36	0.64	0.77	−0.60	0.03	1.74**	1.32*	0.42	0.79	1.57**	1.74**	1.62**
	[0.38]	[0.39]	[0.35]	[0.52]	[0.47]	[0.49]	[0.60]	[0.90]	[0.77]	[0.73]	[0.78]	[0.49]	[0.71]	[0.66]	[0.70]	[0.63]
Durables (2)	0.09	0.50	0.56**	0.71*	0.22	0.58	0.39	−0.51	0.21	1.13**	0.89	0.55	0.84	1.05**	1.52***	1.26**
	[0.33]	[0.35]	[0.28]	[0.43]	[0.37]	[0.43]	[0.53]	[0.84]	[0.58]	[0.57]	[0.62]	[0.45]	[0.55]	[0.50]	[0.58]	[0.51]
								Long-Short in 1								
Durables (1)		0.46	0.76**	1.02**	0.39	0.67	0.80	−0.57		1.72**	1.30	0.39	0.76	1.54*	1.71**	1.59**
		[0.38]	[0.33]	[0.47]	[0.31]	[0.45]	[0.61]	[0.89]		[0.67]	[0.84]	[0.61]	[0.70]	[0.90]	[0.86]	[0.68]
Durables (2)		0.41	0.47	0.62*	0.14	0.49	0.30	−0.60		0.92	0.68	0.34	0.63	0.84	1.30*	1.05*
		[0.30]	[0.30]	[0.37]	[0.28]	[0.39]	[0.55]	[0.77]		[0.61]	[0.67]	[0.50]	[0.54]	[0.72]	[0.72]	[0.58]
								Panel B: 1971-2008								
								Long								
Durables (1)	0.07	0.64	1.22**	1.76***	0.85	1.23*	1.34	−0.05	0.06	2.50***	2.08**	0.65	1.31	2.57***	2.71***	2.55***
	[0.58]	[0.59]	[0.50]	[0.68]	[0.70]	[0.69]	[0.82]	[0.92]	[1.15]	[0.97]	[1.01]	[0.85]	[0.99]	[0.83]	[0.91]	[0.90]
Durables (2)	0.22	0.67	0.85**	1.19**	0.51	1.06**	0.68	0.05	0.32	1.48**	1.27	0.72	1.30**	1.62***	2.20***	1.90***
	[0.46]	[0.50]	[0.36]	[0.53]	[0.51]	[0.51]	[0.70]	[0.93]	[0.80]	[0.73]	[0.81]	[0.67]	[0.70]	[0.60]	[0.71]	[0.62]
								Long-Short in 1								
Durables (1)		0.57	1.14**	1.69***	0.78*	1.16*	1.26	−0.12		2.44***	2.02*	0.59	1.25	2.50**	2.65***	2.49***
		[0.53]	[0.48]	[0.62]	[0.46]	[0.60]	[0.87]	[0.96]		[0.84]	[1.09]	[0.91]	[0.89]	[1.04]	[0.99]	[0.75]
Durables (2)		0.45	0.63	0.97**	0.29	0.84*	0.46	−0.18		1.16	0.95	0.40	0.98	1.30	1.88**	1.58**
		[0.38]	[0.43]	[0.49]	[0.41]	[0.51]	[0.77]	[0.89]		[0.83]	[0.95]	[0.72]	[0.70]	[0.92]	[0.84]	[0.71]

Results obtained on annual currency portfolio returns. The returns are from Lustig and Verdelhan (2007), updated to 2008. The standard errors are reported in brackets. We use Newey-West heteroscedasticity-consistent standard errors with an optimal number of lags to estimate the spectral density matrix following Andrews (1991). We use one asterisk to denote significance at the 10 % level, two for 5%, three for 1%. The first measure, denoted Δd^1, is the log change in the deflated current cost stock of consumer durables. The second measure, Δd^2, is the log change in the quantity index for Consumer durable goods. The Data Appendix contains a detailed description.

Table IX: GMM Estimation: Dollar-Neutral Currency Portfolios, 1953–2002

	CCAPM	*DCAPM*	*EZ-CCAPM*	*EZ-DCAPM*
Factor Prices				
Nondurables	4.073	2.917	3.839	2.757
	[1.785]	[1.363]	[2.031]	[1.306]
Durables		4.886		4.864
		[2.128]		[1.866]
Market			0.171	0.261
			[0.141]	[10.834]
Parameters				
γ	193.44	147.45	514.39	139.53
	[84.77]	[67.01]	[452.25]	[63.22]
σ			-1.912	-0.009
			[2.839]	[0.026]
α		0.626		0.767
		[0.522]		[0.420]
Stats				
MAE	1.654	0.672	1.538	0.451
R^2	-1.392	0.568	-0.916	0.790
p-value	0.962	0.968	0.818	0.674

Notes: This table reports the two-stage GMM estimates of the factor prices (in percentage points) using seven annually rebalanced currency portfolios as test assets. These test assets go long in the nth currency portfolio and short in the first portfolio. The sample is 1953–2002. The data are annual, from Lustig and Verdelhan (2007). In the first stage, we use the identity matrix as the weighting matrix, in the second stage, we use the optimal weighting matrix (no lags). Standard errors are reported in brackets. The factors are de-meaned. The pricing errors correspond to the first-stage estimates. The last two rows report the mean absolute pricing error (in percentage points) and the p-value for a χ^2 test.

Table X: Long in High and Short in Low Interest Rate Currency Portfolios: FMB

	CCAPM	DCAPM	EZ-CCAPM	EZ-DCAPM
Factor Prices				
Constant	2.406	0.694	2.417	−0.641
	[0.901]	[0.869]	[0.845]	[0.848]
	(1.135)	(1.946)	(1.062)	(2.382)
	{0.999}	{1.213}	{1.263}	{1.691}
Nondurables	1.123	1.735	1.116	2.450
	[1.074]	[1.065]	[0.949]	[0.818]
	(1.369)	(2.394)	(1.211)	(2.307)
	{1.305}	{1.398}	{1.434}	{1.542}
Durables		4.129		5.144
		[1.225]		[1.042]
		(2.758)		(2.941)
		{1.819}		{2.217}
Market			1.757	4.699
			[7.978]	[8.190]
			(10.336)	(23.144)
			{12.598}	{12.751}
Parameters				
γ	52.274	90.704	44.392	123.622
	[50.004]	[55.429]	[46.192]	[38.382]
	(90.065)	(121.554)	(57.576)	(104.774)
σ			0.167	−0.035
			[0.887]	[0.035]
			(1.106)	(0.096)
α		1.140		1.124
		[0.613]		[0.487]
		(1.344)		(1.334)
Stats				
MAE	1.699	0.703	1.698	0.348
R^2	0.081	0.620	0.081	0.812
$p - value$	0.038	0.620	0.023	0.510

Notes: This table reports the Fama-MacBeth estimates of the risk prices (in percentage points) using 7 annually re-balanced currency portfolios as test assets. These test assets go long in the n-th currency portfolio and short in the first portfolio. The sample is 1953-2002 (annual data). The factors are demeaned. The OLS standard errors are reported between brackets. The Shanken-corrected standard errors are reported in (). The boostrapped errors are in {}. The last three rows report the mean absolute pricing error (in percentage points), the R^2 and the p-value for a χ^2 test.

Table XI: FMB Estimation: Dollar-Neutral Currency Portfolios, 1953-2002, No Constant

	CCAPM	DCAPM	EZ-CCAPM	EZ-DCAPM
Factor Prices				
Nondurables	4.617	2.302	4.021	2.016
	[1.060]	[0.848]	[1.005]	[0.915]
	(3.509)	(2.325)	(3.103)	(2.233)
	{1.881}	{1.617}	{1.905}	{1.524}
Durables		5.244		4.385
		[1.175]		[1.117]
		(3.221)		(2.729)
		{2.097}		{2.093}
Market			24.470	2.383
			[10.191]	[7.401]
			(31.500)	(18.151)
			{17.883}	{12.965}
Stats				
MAE	1.654	0.672	1.538	0.451
R^2	-0.700	0.578	-0.602	0.792
$p-value$	0.018	0.613	0.012	0.483

Notes: This table reports the FMB estimates of the risk prices (in percentage points) using 7 annually re-balanced currency portfolios as test assets. No constant included. These test assets go long in the n-th currency portfolio and short in the first portfolio. The sample is 1953-2002 (annual data). The factors are demeaned. The OLS standard errors are reported between brackets. The Shanken-corrected standard errors are reported in (). The boostrapped errors are in {}. The last three rows report the mean absolute pricing error (in percentage points), the R^2 and the p-value for a χ^2 test.

Table XII: Estimation of Linear Factor Models: No Constant but Additional Factor

	CCAPM	DCAPM	EZ-CCAPM	EZ-DCAPM
Factor Prices				
Nondurables	1.083	1.166	1.283	1.543
	[0.889]	[0.890]	[0.782]	[0.775]
Durables		4.856		5.267
		[1.221]		[1.144]
Market			11.379	0.057
			[8.143]	[8.071]
RX_{FX}	0.362	0.201	0.359	0.168
	[0.830]	[0.829]	[0.830]	[0.828]
Stats				
MAE	1.287	0.846	1.358	0.560
R^2	0.125	0.600	0.189	0.799
$p-value$	0.000	0.143	0.000	0.087

Notes: This table reports the Fama-MacBeth estimates of the risk prices (in percentage points) using 8 annually re-balanced currency portfolios as test assets. The sample is 1953-2002 (annual data). The factors are demeaned. We did not include a constant in the regression of average returns on β's. RX_{FX} -the additional factor- is the average excess return on all eight portfolios. The OLS standard errors are reported between brackets. The last three rows report the mean absolute pricing error (in percentage points), the R^2 and the p-value for a χ^2 test.

Table XIII: GLS Estimation of Linear Factor Models, 1953–2002

	CCAPM	*DCAPM*	*EZ-CCAPM*	*EZ-DCAPM*
Factor Prices				
Constant	−2.765	−3.414	−2.939	−3.390
	[0.784]	[0.805]	[0.797]	[0.809]
	(1.850)	(2.215)	(1.990)	(2.212)
	{1.521}	{1.656}	{1.691}	{1.996}
Nondurables	3.134	3.004	3.290	2.953
	[0.659]	[0.660]	[0.672]	[0.680]
	(1.570)	(1.829)	(1.691)	(1.871)
	{1.237}	{1.236}	{1.334}	{1.348}
Durables		5.153		5.125
		[0.860]		[0.864]
		(2.384)		(2.382)
		{1.557}		{1.783}
Market			−1.817	−3.650
			[5.907]	[5.933]
			(14.958)	(16.421)
			{11.420}	{11.480}
Stats				
MAE	4.657	0.855	4.449	0.732
R^2	0.110	0.678	−0.033	0.728
p-value	0.561	0.996	0.559	0.991

Notes: This table reports the generalized least squares (GLS) estimates of the risk prices (in percentage points) using eight annually rebalanced currency portfolios as test assets. The sample is 1953–2002. The data are annual, from Lustig and Verdelhan (2007). The factors are demeaned. The OLS standard errors are reported in brackets; the Shanken-corrected standard errors in parentheses, and the boostrapped errors are in braces. The last three rows report the mean absolute pricing error (in percentage points), the R^2, and the p-value for a χ^2 test.

Table XIV: GLS Estimation of Linear Factor Models: 1971-2002

	CCAPM	DCAPM	EZ-CCAPM	EZ-DCAPM
Factor Prices				
Constant	−2.853	−3.251	−2.833	−3.167
	[1.089]	[1.111]	[1.103]	[1.117]
	(2.295)	(2.430)	(2.339)	(2.535)
	{1.852}	{2.016}	{2.108}	{2.336}
Nondurables	3.060	3.043	3.081	3.191
	[0.682]	[0.682]	[0.708]	[0.710]
	(1.467)	(1.520)	(1.529)	(1.638)
	{1.182}	{1.276}	{1.248}	{1.383}
Durables		3.431		3.517
		[0.703]		[0.712]
		(1.576)		(1.653)
		{1.250}		{1.339}
Market			6.895	5.975
			[6.154]	[6.173]
			(13.448)	(14.383)
			{10.182}	{11.045}
Stats				
MAE	5.689	2.452	5.666	1.902
R^2	0.095	0.337	0.117	0.482
$p - value$	0.782	0.931	0.893	0.947

Notes: This table reports the **GLS** estimates of the risk prices (in percentage points) using 8 annually re-balanced currency portfolios as test assets. The sample is 1971-2002 (annual data). The factors are demeaned. The OLS standard errors are reported between brackets. The Shanken-corrected standard errors are reported in (). The bootstrapped errors are in {}. The last three rows report the mean absolute pricing error (in percentage points), the R^2 and the p-value for a χ^2 test.

Table XV: Estimation of Linear Factor Models and Preference Parameters: 1953-2002

	CCAPM	DCAPM	EZ-CCAPM	EZ-DCAPM
Factor Prices				
	-0.693	-3.057	-0.525	-2.943
	[0.954]	[0.839]	[1.046]	[0.855]
	(1.582)	(2.049)	(1.809)	(2.209)
	{1.538}	{1.659}	{1.743}	{1.751}
Nondurables	1.938	1.973	2.021	2.194
	[0.917]	[0.915]	[0.845]	[0.830]
	(1.534)	(2.245)	(1.476)	(2.154)
	{1.369}	{1.343}	{1.460}	{1.360}
Durables		4.598		4.696
		[0.987]		[0.968]
		(2.430)		(2.518)
		{1.653}		{1.695}
Market			8.838	3.331
			[7.916]	[7.586]
			(13.917)	(19.754)
			{12.336}	{11.216}
Parameters				
γ	90.191	102.778	92.757	111.107
	[42.676]	[54.374]	[41.869]	[38.910]
σ			-0.008	-0.032
			[0.460]	[0.037]
α		1.104		1.147
		[0.530]		[0.555]
Stats				
MAE	2.041	0.650	1.989	0.325
R^2	0.178	0.738	0.199	0.869
$p-value$	0.025	0.735	0.024	0.628

Notes: This table reports the Fama-MacBeth estimates of the risk prices (in percentage points) using 8 annually re-balanced currency portfolios as test assets. The sample is 1953-2002 (annual data). The factors are demeaned. The OLS standard errors are reported between brackets. The Shanken-corrected standard errors are reported in (). The last three rows report the mean absolute pricing error (in percentage points), the R^2 and the p-value for a χ^2 test.

Table XVI: Asset Pricing — Principal Components

	1953:IV–2009:II					1971:IV–2009:II				
					Panel I: Risk Prices					
	PC_1	PC_2	R^2	$RMSE$	χ^2	PC_1	PC_2	R^2	$RMSE$	χ^2
FMB	1.48	2.93	66.54	0.63		1.80	2.82	47.09	0.87	
	[0.98]	[0.86]			9.08	[1.44]	[1.26]			13.58
	(0.98)	(0.86)			11.32	(1.44)	(1.26)			15.54
Mean	1.48	2.93				1.80	2.82			
					Panel II: Factor Betas					
Portfolio	*Intercept*	PC_1	PC_2	R^2		*Intercept*	PC_1	PC_2	R^2	
1	−0.52	1.04	−0.65	87.92		−0.79	1.05	−0.65	88.40	
	[0.47]	[0.04]	[0.05]			[0.68]	[0.04]	[0.05]		
2	0.80	1.06	−0.45	85.69		0.94	1.06	−0.45	86.01	
	[0.55]	[0.05]	[0.06]			[0.78]	[0.05]	[0.06]		
3	−0.24	1.20	−0.10	86.73		0.04	1.20	−0.08	87.43	
	[0.49]	[0.05]	[0.04]			[0.69]	[0.05]	[0.05]		
4	−0.26	1.07	0.13	80.84		−0.24	1.08	0.14	82.18	
	[0.57]	[0.05]	[0.04]			[0.78]	[0.05]	[0.04]		
5	−1.03	1.07	0.25	81.40		−1.67	1.07	0.27	83.08	
	[0.63]	[0.05]	[0.07]			[0.83]	[0.05]	[0.07]		
6	0.45	1.03	0.22	70.74		0.51	1.01	0.14	75.08	
	[0.71]	[0.06]	[0.07]			[0.98]	[0.06]	[0.07]		
7	−0.02	1.03	0.44	84.72		0.15	1.03	0.46	85.97	
	[0.49]	[0.04]	[0.05]			[0.68]	[0.04]	[0.04]		
8	0.94	0.98	0.20	83.93		1.17	0.98	0.20	84.75	
	[0.42]	[0.04]	[0.04]			[0.60]	[0.04]	[0.04]		
All	7.37	49.74%				6.65	57.47%			

Notes: Panel I reports results from GMM and Fama–MacBeth asset pricing procedures. Market prices of risk λ, the adjusted R^2, the square root of mean-squared errors $RMSE$, and the p-values of χ^2 tests on pricing errors are reported in percentage points. Excess returns used as test assets and risk factors take into account bid–ask spreads. All excess returns are multiplied by 4 (annualized). Shanken-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure. Panel II reports OLS estimates of the factor betas. The R^2s and p-values are reported in percentage points. The standard errors in brackets are Newey and West (1987) standard errors computed with the optimal number of lags according to Andrews (1991). The χ^2 test statistic $\alpha' V_{\alpha}^{-1} \alpha$ tests the null that all intercepts are jointly zero. This statistic is constructed from the Newey–West variance-covariance matrix (one lag) for the system of equations (see Cochrane 2001, p. 234). Data are quarterly, from Global Financial Data. The sample includes only developed countries. Portfolios are rebalanced every quarter. The sample period is 1953:IV–2009:II for the left panel and 1971:IV-2009:II for the right panel. The alphas are annualized and reported in percentage points.

Table XVII: Estimation of Linear Factor Model Risk Prices: CAPM

	Market	*Market* $-$ *VIX*	R^2	*RMSE*	χ^2
	Panel A: Unconditional CAPM				
FMB	27.00		70.50	1.08	
	[14.60]				9.80
	(16.21)				18.77
Mean	**5.67**				
	Panel B: CAPM with VIX as conditioning variable				
FMB	29.91	75.46	69.64	2.07	
	[11.75]	[29.51]			25.57
	(13.80)	(34.22)			55.13
Mean	**5.04**	**10.53**			

Notes: This table reports results from Fama-McBeth asset pricing test. Market prices of risk λ, the adjusted R^2, the square-root of mean-squared errors $RMSE$ and the p-values of χ^2 tests are reported in percentage points. In the top panel, the risk factor is the Fama-French value-weighted stock market excess return R^m. In the bottom panel, the risk factors are the value-weighted stock market excess return R^m and $R^m VIX$, which is R^m multiplied by the lagged value of the VIX index (scaled by its standard deviation). The portfolios are constructed by sorting currencies into six groups at time t based on the interest rate differential at the end of period $t-1$. Portfolio 1 contains currencies with the lowest interest rates. Portfolio 6 contains currencies with the highest interest rates. In the bottom panels, we use 12 test assets: the original 6 portfolios and 6 additional portfolios obtained by multiplying the original set by the conditioning variable (VIX). Data are monthly, from Barclays and Reuters (Datastream). The sample is 11/1983–6/2009 for the top panel and 02/1990–6/2009 for the bottom panel. Standard errors are reported in brackets. Shanken-corrected standard errors are reported in parentheses. We do not include a constant in the second step of the FMB procedure.