An emprical analysis of exchange rates, interest rates, and excess returns before and after the global financial crisis

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1 Introduction

Uncovered interest parity (UIP), a foundational topic of international finance providing a link between international interest rates and exchange rates between country pair, boasts a large and growing body of associated literature. When UIP holds the expected returns are equivalent across countries leading to a no-arbitrage condition. The common conditions required for UIP to hold include a) risk neutral investors, b) the free mobility of capital, and c) equivalent default risks across investments. Commonly cited reasons for deviation from UIP include risk premiums (Bekaert et. al (1997)[2] and Backus et. al (2001)[1] and liquidity premiums (Engel 2016)[7].

The conventional UIP regression, (1), should yield $\beta = 1$ and $a = 0$ when UIP holds. Deviations from the null hypothesis was demonstrated empirically by Fama (1984)[8], later referred to as the "Fama puzzle." In fact, per research conducted by Burnside et. al (2006)[4] regarding currency pairs relative to the United Kingdom's pound, β was observed to always be significantly less than one and regularly significantly less than zero when considering data between 1976 and 2005. Recent work by Bussiere, Chinn, Ferrara, and Heipertz (2019)[5] offers evidence of a "new" Fama puzzle. They find $\beta > 0$ when narrowing their sample data down to post global financial crisis (GFC) through 2018[1].

$$s_{t+1} - s_t = a + \beta(i_t - i_t^*) + u_{s,t+1} \tag{1}$$

I update a selection of the original empirical results conducted by Engel (2016), with the intent to investigate the robustness of his findings[2]. G7 countries are included (Canada, France, Germany, Italy, United Kingdom, Japan, and the United States) as well as a G6, trade-weighted composite. Similar to the literature, all foreign exchange rates are relative the U.S. dollar. I find, similar to Bussiere, Chinn, Ferrara, and Heipertz (2019), the Fama puzzle is still present when regressing over 1979 through 2020[3]. There is more variation in the sign of the regression coefficients when constricting the data set to 2010 through 2020. Additionally, I find that the clear transition of the ex ante return regression coefficients from positive to negative do not hold for more recent

[1]Interestingly, when looking at a longer time horizion (1991 - 2018) they find a regression coefficients that are less than one for most countries included in their analysis, with the exception of Canada.

[2]The original data set used by Engel included monthly data from June 1979 through October 2009.

[3]Bussiere, Chinn, Ferrara, and Heipertz (2019) generally find slope coefficients indicative of excess returns positively correlating with foreign-home interest rate differentials; however, with a different data set, I find positive correlation for all six countries and the G6.

dates following the GFC. This is even more apparent when looking at the ex post return regression coefficients.

The remainder of this paper is organized as follows: section two provides a summary of the data that is analyzed; section three briefly discusses the two exchange rate puzzles discussed by Engel (2016); section four provides empirical findings with brief discussion points; finally, section five provides concluding remarks.

2 Data Summary

I use monthly data for this analysis, covering June 1979 through May 2020. Results are considered for the entire time frame as well as a subset: March 2010 through May 2020. This is done to observe if the original empirical approach, estimation of vector error-correction models (VECMs), is viable over a longer time span and within a different time period. Data is gathered from the same databases as Engel (2016) to mitigate any unnecessary variation. Foreign exchange rates are taken from the Federal Reserve (2020) historical database[4]. Price level data is updated for the entire series using consumer price indexes (CPIs) obtained from the Organization for Economic Cooperation and Development (OECD) CPI database[5]. Monthly nominal interest rate data for each country is pulled from Thomson One[6].

Following Engel, I construct composite G6 data series in addition to individual country data. As noted throughout the literature, the averaging appears to smooth out monthly fluctuations seen in individual country data. The G6 exchange rate, price index, and nominal interest rate is computed using equations (2), (3), and (4), respectively.

$$S_{G6} = \prod_{i=1}^{6} S_i^{weight_i} \tag{2}$$

$$P_{G6} = \prod_{i=1}^{6} P_i^{weight_i} \tag{3}$$

$$I_{G6} = 100 * (\prod_{i=1}^{6} (1 + \frac{I_i}{100})^{weight_i} - 1) \tag{4}$$

Country weights are the yearly sum of a specific country imports and exports relative to the sum of all six countries imports and exports. The weights used are the arithmetic average of 1978 and 2008 yearly weights and can be seen in Table 1. I compare the weights used by Engel (2016) to data out to 2018. The International Monetary Fund (IMF) Direction of Trade Statistics (DOTS) database is leveraged for trade data[7].

[4]See https://www.federalreserve.gov/releases/h10/Hist/ for a listing of daily rates.

[5]Engel (2016) CPI data referenced 2005 as the index year for CPIs but this is updated in the OECD database with 2015 as the new index, hence the change in values over the entire data set.

[6]Series codes utilized are ECCAD1M (Canada), ECFFR1M (France), ECWGM1M (Germany), ECITL1M (Italy), ECJAP1M (Japan), ECUKP1M (United Kingdom), and ECUSD1M (United States).

[7]See https://data.imf.org/regular.aspx?key=61013712

Table 1: Weights

Country	Weight: 1978 and 2008	Weight 1978 and 2018
Germany	0.2945	0.3018
Japan	0.1843	0.1788
France	0.1599	0.1531
UK	0.1399	0.1419
Italy	0.1230	0.1194
Canada	0.0984	0.1049

Table 1 Notes: Due to similarities in weights over different time periods, original weights are used to reduce additional variation in analyses. Updated weights are based on the author's calculations. Source: IMF DOTS.

3 The puzzles

International finance literature has documented two puzzles between exchange rates and interest rates, known as i) the Fama puzzle and ii) the excess volatility in levels puzzle. Upon further examination, these two puzzles appear to offer contradictory conclusions (Engel, 2016).

3.1 The "Fama" puzzle

As described above, the Fama puzzle raises the question of why high-interest rate countries' currencies appreciate, leading to excess returns. UIP suggests that there should be no arbitrage opportunities with excess returns equal to zero. However, since Fama (1984) empirical investigations into the conventional UIP regressions have demonstrated the opposite. We can express this in Engel's notation as $cov(\rho_{t+1}, r_t^* - r_t) > 0$.

3.2 Excess level volatility puzzle

Put plainly, the excess volatility puzzle examines the empirical finding that exchange rates tend to be more volatile than the Dornbusch (1976)[6] model implies. Expressed mathematically, this puzzle can be represented as $cov(E_t \sum_0^\infty \rho_{t+j+1}, r_t^* - r_t) < 0$.

It can be seen that these two finding point in opposite directions, with one saying the high-interest rate currency is more risky while the other implies it is less risky. This is the issue Engel (2016) attempts to overcome with the development of his model, which implies that at some point the covariance must switch signs. More formally, at $j > 0$, the $cov(E_t \sum_0^\infty \rho_{t+j+1}, r_t^* - r_t)$ must switch from positive to negative. This model seemed to work quite well for the time period prior to 2010, when considering real and nominal interest rates. My findings, when considering only 2010 and later, seem to contradict these original findings.

4 Empirical results

I begin to investigate the noted puzzles by running two Fama regressions, using the notation of Engel (2016). The first regression considers the entire data set, 1979:6 through 2020:5, while the second only considers 2010:3 through 2020:5. The intent is to investigate whether $\beta < 0$ or $\beta > 0$. Engel's regression, expressed in (5), provides an understanding of the ex post excess return on a foreign security.

$$\rho_{t+1} = \zeta_s + \beta_s(i_t^* - i_t) + u_{s,t+1} \tag{5}$$

Regression coefficients and 90% confidence intervals[8] for the entire data set are reported in Table 2. For each country currency, including the G6 rate, the estimate of β is positive. France and Italy are the only two countries whose 90% confidence interval does not lie entirely above zero. These results are marginally different from Engel's findings over a shorter time period.

Similarly, a Fama regression is run for 2010:3 through 2020:5, with results reported in Table 3. Estimates of β are heterogeneous, with some below zero, some above, and many near zero. Results for France, Germany, and Italy are nearly identical, which makes some intuitive sense given the are on the same currency over the entire time frame. Estimates for Canada and Japan are both less than negative 2, suggesting a negative correlation between excess returns on their respective currencies and the foreign-home interest rate differential. The United Kingdom (U.K.) is the only currency with an estimated coefficient greater than one. All 90% confidence intervals are wider when compared to the results in Table 2, with all including zero.

A vector error correction model is relied upon to generate expected inflation and ex ante excess returns. Bootstrap distributions of the estimates of $g_{11} - g_{21}$ are built to investigate if there is real exchange rate reversion to the mean. Results for the whole time span are reported in Table 4 and results from 2010:3 through 2020:5 in Table 5.

Similar to Engel (2016), Canada's dollar does not exhibit any indication of cointegration in both time periods considered. Using data only from 2010 onward, the Canadian dollar is the only positive estimate of $g_{11} - g_{21}$. Two currencies are critical at the 5% level and three at the 10% level when the data is from 1979:6 to 2020:5. The G6 composite currency is nearly significant at the 5% level. When looking at 2010:3 to 2020:5 six of the currencies are significant at the 5% level, with Canada being the only currency that does exhibit signs of cointegration.

Next, I run Fama regressions in real terms with results reported in Table 6 and Table 7. Slope coefficient estimates, β_q, and 90% confidence intervals are provided. Table 6 considers the entire time span while Table 7 only considers data from 2010:3 through 2020:5.

My results match closely with Engel (2016) when considering the entire time span. All slope coefficient estimates are greater than zero, indicating that high real interest rate currencies tend to have high excess returns. The 90% confidence interval lies above zero for Japan, the U.K., and the G6 currency.

Table 7, which considers the later time frame, shows different results altogether with most slope coefficient estimates less than zero, with the exception of Japan. Zero is only included in two of the 90% confidence intervals while the remainder are completely less than zero. The G6 estimated slope coefficient is close to negative 2[9].

Figure 1, which considers data from 1979:6 through 2020:5, illustrates the central empirical finding of the "puzzle squared", the seemingly contradictory finding that $cov(E_t\rho_{t+1}, r_t^* - r_t) > 0$ and $cov(E_t \sum_0^\infty \rho_{t+j+1}, r_t^* - r_t) < 0$. This implies that there must be some j that where the sign of the covariance switches from positive to negative. With the exception of Canada, I find that all slope estimates transition from positive to negative after approximately 12 months. The estimates

[8] Confidence intervals throughout are based on Newey-West standard errors.
[9] Engel (2016) found this estimate to close to positive two.

for Canada's slope coefficients appear to start positive, quickly head negative, and revert back to a positive slope where it exhibits behavior similar to all other currencies after the initial oscillation.

I conduct a similar exercise, but only considering data from 2010:3 through 2020:5, and depict my results in Figure 2. It is evident that the original findings are not generalizable to this later time period. Estimated slope coefficients appear to be quite noisy over the first 12 months with most of slope coefficients starting out negative. The longer term trend of negative coefficients slowly trending toward an asymptote around zero appears is present.

Slope coefficient estimates are then compared using nominal interest rates. Figure 3 shows the estimates over 120 months using data from the entire sample, this time only for the G6 currency. It can be seen that this yields a similar result as estimates involving the real interest rate. The slope coefficient transitions from positive to negative between 13 to 24 months when considering the 90% confidence interval. The magnitude of the negative slope coefficients appear to be less than those when considering real interest rates.

Figure 4 depicts the same regression for the G6 currency, but only considers 2010:3 through 2020:5. The slope coefficient oscillates around zero initially and has a wider 90% confidence interval range overall. It appears that the coefficient estimate approaches negative one at its peak, nearly double of that when considering the entire time span. The estimated slope coefficients do not appear to approach zero as quickly in the long run.

In Figures 5 through 8 I transition from ex ante regressions to looking at ex post regressions of varying forms. The G6 currency is plotted for each of these figures. Figures 5 and 6 include real interest rates while figures 7 and 8 are concerned with nominal interest rates. Given that these are ex post regressions, VECM forecasts are not relied upon for this portion of the analysis.

Estimated slope coefficients from the ex post return regression using real interest rates from 1979:6 through 2020:5 can be seen in Figure 5. A similar trend can be seen when compared to the ex ante regression results in the previous figures that considered the same time frame; initially starting positive, transitioning to negative slope coefficients estimates after a short time, and trending back towards zero over a longer time span. The results appear to have more noise due to the regression type. Also, the 90% confidence interval range is much wider over all the estimates.

Figure 6 illustrates the results from a similar exercise as used in constructing Figure 5, but considers data from 2010:3 through 2020:5. There is no longer the clear trend noticed in the figures above. The output is quite noisy and appears to ring around zero throughout. The estimation involved in calculating the real interest rates may help explain the excessive volatility.

In Figure 7 the nominal interest rate replaces the real interest rate in the ex post return regression. Data used covers 1979:6 through 2020:5 and G6 composite results are displayed. Again, there is the clear trend with a transition from positive to negative slope coefficient estimates, crossing at anywhere from 25 to 37 months, and a reversion back towards zero at the longer end of the time horizon. The confidence interval range is wider than the ex ante regressions, similar to those seen in Figure 5.

The estimated slope coefficients using nominal interest rates, when leveraging data from 2010:3 through 2020:5, are displayed in Figure 8. Again, only the G6 composite is shown for brevity. The results are not nearly as noisy as seen in Figure 6, which observed real interest rates. Interestingly, coefficients are close to zero for approximately the first 25 months with a narrow 90% confidence interval. After this lag it appears that noise is amplified, oscillating around zero with an increasing amplitude. The results resembles a periodic fluctuations after relative stability.

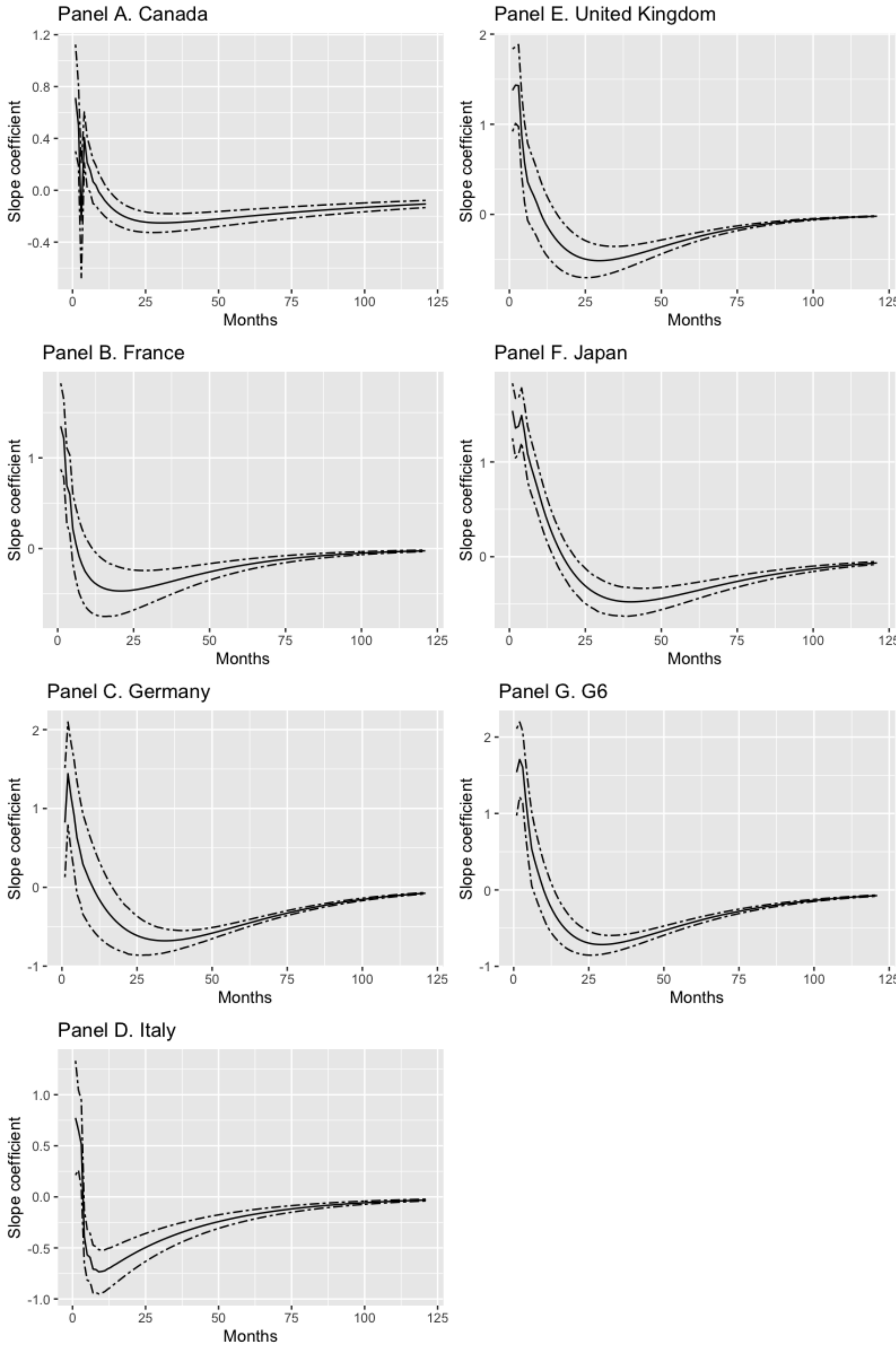

Figure 1: Slope of ex ante return regression: $\hat{E}_t(\rho_{t+j}) = \zeta_j + \beta_j(r_t^* - r_t) + u_t^j$. Notes: Monthly data, 1979:6-2020:5.

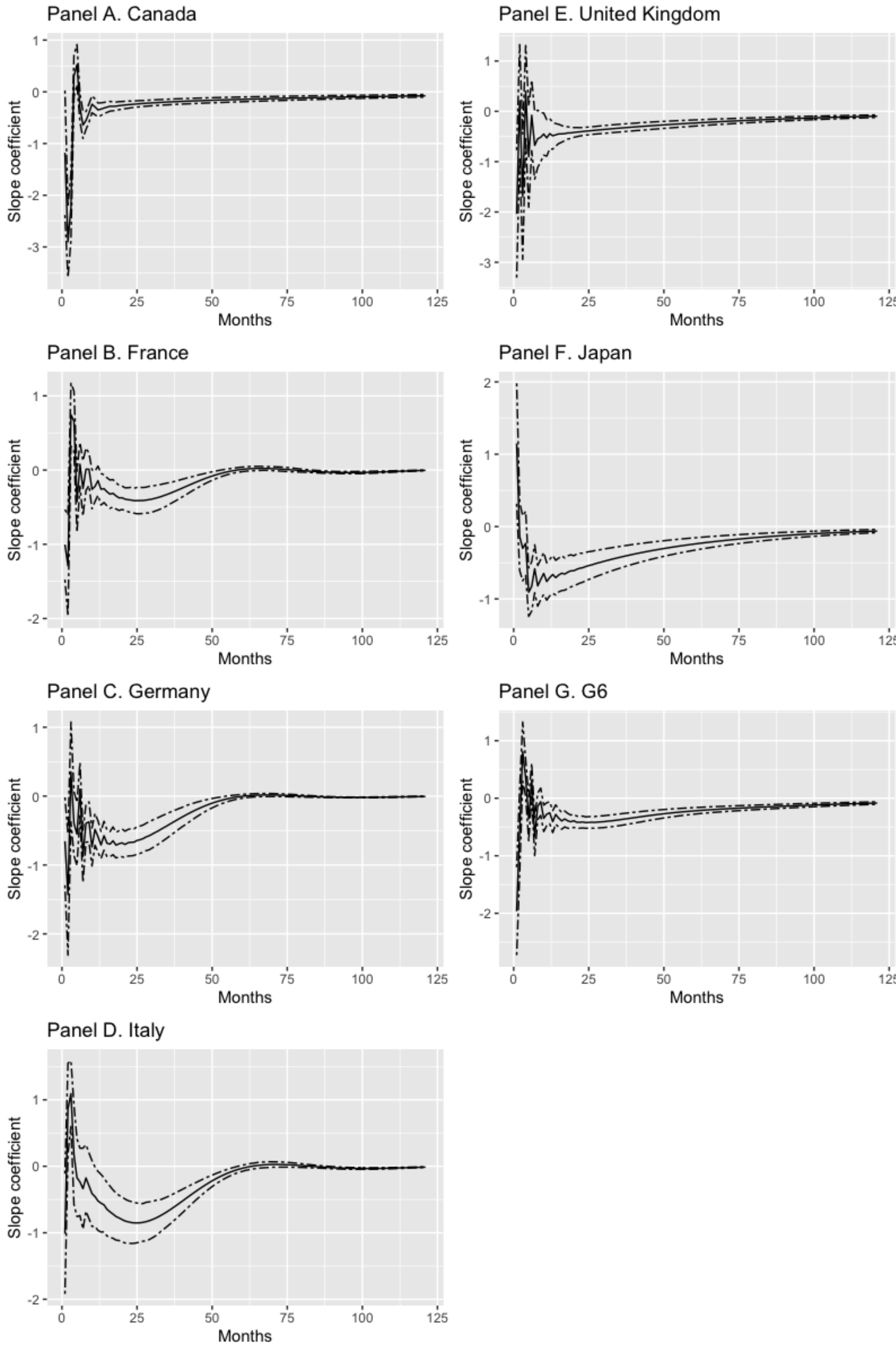

Figure 2: Slope of ex ante return regression: $\hat{E}_t(\rho_{t+j}) = \zeta_j + \beta_j(r_t^* - r_t) + u_t^j$. Notes: Monthly data, 2010:3-2020:5.

5 Conclusion

In this paper I update interest rate, exchange rate, and consumer price index data; reconstruct the research preformed by Engel (2016) by expanding beyond 2009; and compare the various model results over two overlapping time periods: 1979:6 through 2020:5 and 2010:3 though 2020:5. I find that the results hold up consistently well with marginal variation when considering the longer time period, compared to Engel's original results. However, when constrained to the 2010:3 through 2020:5 time period, the results do not appear to hold up as well. I do not obtain results that support the traditional Fama puzzle, but instead may lend support to ongoing research into the "new" Fama puzzle.

The apparent change in results from the model dependent on the time frame considered suggests more research is required in this field. Considering varying time frames to assess model sensitivity may be fruitful. Additionally, including U.S. monetary policy into the regressions may be explanatory. As demonstrated in prior research, central bank monetary policy announcements tends to affect asset prices in advanced economies (Rogers, Scotti, and Wright; 2014[9]) and emerging economies (Bowman, Londono, and Sapriza; 2015[3]). Expansion into exchange rates with other economies outside of the G7, perhaps emerging and developed economies such as Turkey, may yield interesting results.

References

[1] D. K. Backus, S. Foresi, and C. I. Telmer. Affine term structure models and the forward premium anomaly. *Journal of Political Economy*, 84(6):1161–1176, 2001.

[2] G. Bekaert, R. J. Hodrick, and D. A. Marshall. The implications of first-order risk aversion for asset market risk premiums. *Journal of Monetary Economics*, 40(1):3–39, 1997.

[3] D. Bowman, J. M. Londono, and H. Sapriza. U.s. unconventional monetary policy and transmission to emerging market economies. *Journal of International Money and Finance*, 55(c):27–59, 2015.

[4] C. Burnside, M. Eichenbaum, I. Kleshchelski, , and S. Rebelo. The returns to currency speculation. Working Paper 12489, National Bureau of Economic Research, August 2006.

[5] M. Bussiere, M. D. Chinn, L. Ferrara, and J. Heipertz. The new fama puzzle. Working Paper 24342, National Bureau of Economic Research, December 2019.

[6] R. Dornbusch. Expectations and exchange rate dynamics. *Journal of Political Economy*, 84(6):1161–1176, 2015.

[7] C. Engel. Exchange rates, interest rates, and the risk premium. *American Economic Review*, 106(2):436–474, 2016.

[8] E. F. Fama. Forward and spot exchange rates. *Journal of Monetary Economics*, 14(3):319–338, 1984.

[9] J. H. Rogers, C. Scotti, and J. H. Wright. Measuring the reaction of monetary policy to the stock market. *The Quarterly Journal of Economics*, 118(2):639–669, 2014.

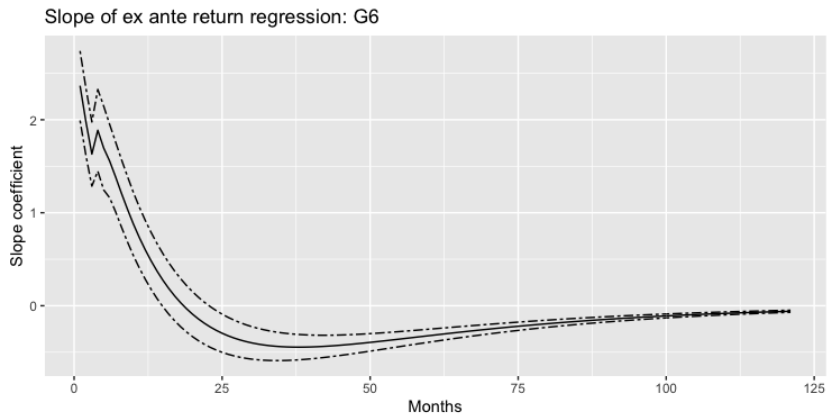

Figure 3: Slope coefficients and 90 percent confidence interval of the regression: $\hat{E}_t(\rho_{t+j}) = \hat{\zeta}_j - \hat{\beta}_j(i_t^* - i_t) + u_t^j$. Notes: Monthly data, 1979:6-2020:5.

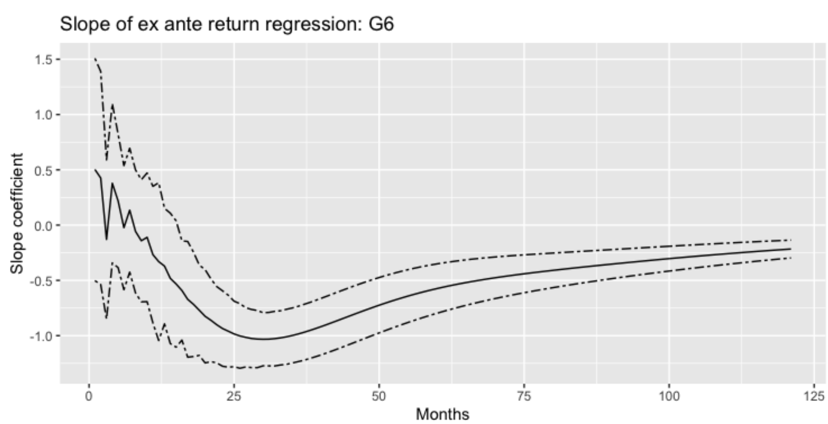

Figure 4: Slope coefficients and 90 percent confidence interval of the regression: $\hat{E}_t(\rho_{t+j}) = \hat{\zeta}_j - \hat{\beta}_j(i_t^* - i_t) + u_t^j$. Notes: Monthly data, 2010:3-2020:5.

Figure 5: Slope coefficients and 90 percent confidence interval of the regression: $\rho_{t+j} = \zeta_j + \beta_j(\hat{r_t^*} - \hat{r_t}) + u_t^j$. Notes: Monthly data, 1979:6-2020:5.

Figure 6: Slope coefficients and 90 percent confidence interval of the regression: $\rho_{t+j} = \zeta_j + \beta_j(\hat{r_t^*} - \hat{r_t}) + u_t^j$. Notes: Monthly data, 2010:3-2020:5.

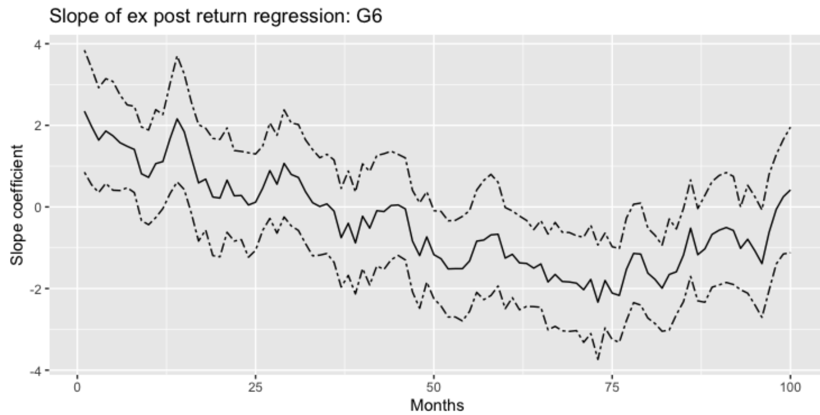

Figure 7: Slope coefficients and 90 percent confidence interval of the regression: $\rho_{t+j} = \zeta_j + \beta_j(i_t^* - i_t) + u_t^j$. Notes: Monthly data, 1979:6-2020:5.

Figure 8: Slope coefficients and 90 percent confidence interval of the regression: $\rho_{t+j} = \zeta_j + \beta_j(i_t^* - i_t) + u_t^j$. Notes: Monthly data, 2010:3-2020:5.

Table 2: Fama Regressions: $s_{t+1} - s_t + i_t^* - i_t = \zeta_s - \beta_s(i_t^* - i_t) + u_{s,t+1}$ 1979:6 - 2020:5

Country	$\hat{\zeta}_s$	90% interval	$\hat{\beta}_s$	90% interval
Canada	-0.084	(-0.252, 0.084)	2.099	(1.089, 3.110)
France	-0.076	(-0.320, 0.167)	1.241	(-0.010, 2.493)
Germany	0.0848	(-0.184, 0.354)	1.894	(0.500, 3.287)
Italy	-0.071	(-0.320, 0.177)	0.507	(-0.378, 1.393)
Japan	0.480	(0.135, 0.826)	2.656	(1.452, 3.860)
UK	-0.323	(-0.574, -0.071)	2.912	(1.139, 4.685)
G6	0.002	(-0.196, 0.200)	2.338	(0.798, 3.877)

Table 2 Notes: Similar to Engel (2016), 90 percent confidence intervals are based on Newey-West standard errors.

Table 3: Fama Regressions: $s_{t+1} - s_t + i_t^* - i_t = \zeta_s - \beta_s(i_t^* - i_t) + u_{s,t+1}$ 2010:3 - 2020:5

Country	$\hat{\zeta}_s$	90% interval	$\hat{\beta}_s$	90% interval
Canada	-0.165	(-0.419, 0.090)	-2.665	(-8.124, 2.794)
France	-0.210	(-0.690, 0.270)	0.232	(-2.878, 3.343)
Germany	-0.210	(-0.690, 0.270)	0.232	(-2.878, 3.343)
Italy	-0.210	(-0.690, 0.270)	0.232	(-2.878, 3.343)
Japan	-0.327	(-0.986, 0.333)	-2.076	(-6.212, 2.061)
UK	-0.154	(-0.496, 0.188)	1.950	(-2.636, 6.537)
G6	-0.202	(-0.575, 0.170)	0.209	(-2.599, 3.017)

Table 3 Notes: Similar to Engel (2016), 90 percent confidence intervals are based on Newey-West standard errors.

Table 4: Bootstrapped distribution of $g_{11} - g_{21}$ estimate from VECM, 1979:6 - 2020:5

Country	$g_{11} - g_{21}$ Estimate	Critical Value 5%	Critical Value 10%
Canada	-0.0181	-0.0444	-0.0353
France	-0.0322	-0.0339	-0.0263
Germany	-0.0390	-0.0355	-0.0271
Italy	-0.0283	-0.0365	-0.0269
Japan	-0.0174	-0.0314	-0.0242
UK	-0.0360	-0.0342	-0.0264
G6	-0.0326	-0.0330	-0.0264

Table 4 Notes: I omit g_{11} and g_{21} results for brevity.

Table 5: Bootstrapped distribution of $g_{11} - g_{21}$ estimate from VECM, 2010:3 - 2020:5

Country	$g_{11} - g_{21}$ Estimate	Critical Value 5%	Critical Value 10%
Canada	0.0447	-0.0171	-0.0122
France	-0.0421	-0.0283	-0.0196
Germany	-0.0548	-0.0323	-0.0238
Italy	-0.0501	-0.0332	-0.0257
Japan	-0.0290	-0.0164	-0.0116
UK	-0.0669	-0.0333	-0.0256
G6	-0.0238	-0.0161	-0.0117

Table 5 Notes: I omit g_{11} and g_{21} results for brevity.

Table 6: Fama regressions in real terms: $q_{t+1} - q_t + \hat{r_t^*} - \hat{r}_t = \hat{\zeta}_q - \hat{\beta}_q(\hat{r_t^*} - \hat{r}_t) + u_{q,t+1}$ 1979:6 - 2020:5

Country	$\hat{\zeta}_q$	90% interval	$\hat{\beta}_q$	90% interval
Canada	-0.024	(-0.203, 0.045)	0.713	(-0.749, 2.919)
France	-0.113	(-0.353, 0.074)	1.346	(-0.125, 2.938)
Germany	-0.087	(-0.329, 0.350)	0.822	(-0.473, 3.662)
Italy	-0.039	(-0.253, 0.038)	0.772	(-0.511, 2.533)
Japan	-0.012	(-0.172, 0.115)	1.536	(0.169, 3.364)
UK	-0.114	(-0.375, -0.047)	1.380	(0.092, 3.021)
G6	-0.082	(-0.276, 0.033)	1.540	(0.140, 3.641)

Table 6 Notes: 90% confidence intervals are bootstrapped. The 95% confidence interval is omitted.

Table 7: Fama regressions in real terms: $q_{t+1} - q_t + \hat{r_t^*} - \hat{r}_t = \hat{\zeta}_q - \hat{\beta}_q(\hat{r_t^*} - \hat{r}_t) + u_{q,t+1}$ 2010:3 - 2020:5

Country	$\hat{\zeta}_q$	90% interval	$\hat{\beta}_q$	90% interval
Canada	-0.164	(-0.344, 0.072)	-1.197	(-2.987, 0.409)
France	-0.161	(-0.466, -0.252)	-1.040	(-3.034, -1.161)
Germany	-0.173	(-0.437, -0.260)	-0.644	(-2.782, -0.517)
Italy	-0.168	(-0.434, -0.253)	-1.337	(-4.911, -1.912)
Japan	-0.262	(-0.717, -0.403)	1.163	(-0.655, 2.344)
UK	-0.264	(-0.588, -0.145)	-2.081	(-5.378, -0.071)
G6	-0.200	(-0.511, -0.210)	-1.988	(-4.097, -1.120)

Table 7 Notes: 90% confidence intervals are bootstrapped. The 95% confidence interval is omitted.