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Uncertainty, Currency Excess Returns, and Risk Reversals

Abstract

In this paper we provide strong evidence that heightened uncertainty in the U.S. real economy or financial markets significantly raises excess returns to the currency carry trade. We posit that this works through the influence of uncertainty on global investors' risk preferences. Macro and financial uncertainty also lower foreign exchange risk reversals, an effect that is particularly strong for high interest rate portfolios. Our results are consistent with the idea that an increase in uncertainty regarding the U.S. economy or financial markets increases investors' risk aversion, which in turn drives up the expected returns and the cost of protection against crash risk in the FX market.

Keywords: Exchange rates, uncovered interest parity, uncertainty

JEL Classification: F41

1 Introduction

The failure of uncovered interest parity and profitability of the carry trade in currencies are inherently linked concepts, and represent a fundamental puzzle in international finance. The currency carry trade is an investment strategy whereby an investor borrows funds in a low interest rate currency in order to lend in a high interest rate currency. If uncovered interest rate parity (UIP) held, the investor would expect to make zero profits on average, because the interest rate differential would reflect the expected depreciation of the high interest rate currency against the low interest rate currency. Contrary to what the UIP condition predicts, however, on average high interest rate currencies tend to appreciate against low interest rate currencies, making the carry trade profitable. In the literature this is often referred to as the "forward premium puzzle".

The violation of UIP has been widely studied (Engel, 2014), and crash risk in investment currencies has been recently proposed as a candidate explanation (e.g. Brunnermeier, Nagel, and Pedersen, 2009, Farhi and Gabaix, 2015). It is reasonable to conjecture that uncertainty in the real economy and financial markets could affect both the quantity of crash risk and the degree of investors' risk aversion that drives the price of risk. However, the role of uncertainty in understanding violations of UIP has been largely unexplored, partly due to lack of appropriate uncertainty measures.

Recently, stemming from the macroeconomics and finance literature, there has been a surge of interest in constructing measures of uncertainty. For example, Baker, Bloom, and Davis (2015) develop an index of overall economic policy uncertainty (EPU), including fiscal, monetary, trade, health care, national security, and regulatory policies, based on the occurrence of certain keywords in newspaper coverage. Jurado, Ludvigson, and Ng (2015) construct an econometric estimate of macroeconomic uncertainty, measuring whether the economy has become less or more predictable. Using the same approach, Ludvigson, Ma, and Ng (2016) construct a broad-based measure of financial uncertainty. In addition to these, market-based proxies for uncertainty abound, including the VIX (Bloom, 2009) and implied volatility measures derived from interest rate swaptions (Carlston and Ochoa, 2016). Husted, Rogers, and Sun (2016) construct a news-based measure of monetary policy uncertainty that has several appealing features, including its similarity to survey-based uncertainty measures and its attenuation from enhanced Fed communication strategy.

In this paper we use several of these recently-developed measures of uncertainty to investigate their role in explaining carry trade excess returns. We conjecture that increased uncertainty in the U.S. economy and financial markets can increase investors' risk aversion, which in turn requires higher carry trade payoffs to compensate investors for bearing currency risk. This idea is consistent with our findings that our measure of currency carry trade returns are positively associated with macroeconomic uncertainty and financial uncertainty. In addition, we find that risk reversals on these same portfolios are negatively associated with macroeconomic and financial uncertainty. As the price of the risk reversal is negative (positive) if the risk-neutral distribution of the exchange rate is negatively (positively) skewed, our pattern suggests that investors are willing to pay a higher cost of buying protection on currency positions against crashes in response to heightened macroeconomic and financial uncertainty in the United States.

Given the close link between currency markets and monetary policy, we also examine whether U.S. monetary policy uncertainty affects carry trade excess returns. We expect an increase in monetary policy uncertainty to raise excess returns, as uncertainty increases investors' expectation of future exchange rate volatility, thus increasing the perceived riskiness of their short position in the dollar. Combined with the effect that any form of uncertainty can have on investors' risk aversion, we also expect the risk reversal to decline in monetary policy uncertainty. Using measures of monetary policy uncertainty available in the literature, we find some evidence that U.S. monetary policy uncertainty raises returns to the carry trade and makes risk reversals more negative. Furthermore, we confirm findings in the literature that TED spreads, which measure liquidity funding constraints, are positively linked to excess returns, even after controlling for uncertainty. This pattern is consistent with models that highlight the role of investors' funding constraints, in which TED spreads lead to tighter funding liquidity, forcing unwinding of carry trade positions, thus making the returns higher going forward (Gabaix and Maggiori, 2015).[1]

The vast literature on UIP violations focuses on mean returns. Bacchetta and van Wincoop (2007) attribute the failure of UIP to infrequent revisions of investor portfolio decisions. There is a substantive debate about whether carry trades are exposed to risk factors. Burnside, Eichenbaum, Kleshchelski and Rebelo (2011) argue that they are not, but many others find exposures to a variety of risk factors. For example, Lustig and Verdelhan (2007) argue that the returns on currencies with high interest rates have greater loadings on consumption growth risk. Rafferty (2012) relates carry trade returns to a skewness risk factor in currency markets. Dobrynskaya (2014) and Lettau, Maggiori, and Weber (2014) argue that large average returns to high interest rate currencies are explained by their high conditional exposures to the market return in the down state. Jurek (2014) demonstrates that the return to selling puts, which has severe downside risk, explains carry trade profitability. Bakshi and Panayotov (2013) include commodity returns as well as foreign exchange volatility and liquidity in their risk factors. Menkhoff, Sarno, Schmeling and Schrimpf (2012) find that the large average carry trade payoffs are compensation for exposure to global FX volatility risk. Christiansen, Ranaldo, and Soderlind (2011) further show that the level of FX volatility also affects the risk exposure of carry trade returns to stock and bond markets. Finally, Brunnermeier, Nagel, and Pedersen (2009) document that returns to carry trades have negative skewness and suggest that carry trade speculators face funding liquidity constraints. Relatedly, Farhi and Gabaix (2015) propose the possibility of rare but extreme disasters as an important determinant of risk premia in asset markets. Burnside (2012) provides a review of the literature.

Our analysis is also related to the recent papers that examine the implications of

[1]TED spread is the difference between the interest rates on interbank loans and on short-term U.S. government debt ("T-bills"). TED is an acronym formed from T-Bill and ED, the ticker symbol for the Eurodollar futures contract.

monetary policy for currency excess returns. Alvarez, Atkeson, and Kehoe (2009) build a general equilibrium monetary model to exposit a mechanism through which monetary policy affects asset market segmentation, which in turn affects risk premia in the currency market. Backus, Gavazzoni, Telmer and Zin (2010) model the role of monetary policy for exchange rates using Taylor representations. Benigno, Benigno, and Salvatore (2012) present empirical evidence that following an increase in monetary policy uncertainty, the dollar exchange rate appreciates in the medium run. Rogers, Scotti, and Wright (2016) assess the relationship between monetary policy, foreign exchange risk premia and term premia at the zero lower bound, and find that identified U.S. monetary policy shocks have a significant effect on premia. Mueller, Tahbaz-Salehi, and Vedolin (2016) find significantly larger excess returns on days with scheduled Federal Open Market Committee (FOMC) announcements, that these excess returns are higher for currencies with higher forward premia vis-á-vis the U.S., and that monetary policy uncertainty has a large effect on FOMC day excess returns. Our analysis differs from theirs in that we use more broad and continuous measures of monetary policy uncertainty, we also look at all days and not only scheduled FOMC meeting days, and we find that TED spreads have significantly larger effects on FOMC day excess returns than monetary policy uncertainty has.

The rest of the paper is organized as follows. In Section 2 we describe the data and empirical properties of returns to the carry trade and risk reversals. In Section 3, we discuss the effects of macroeconomic and financial uncertainty. In section 4, we analyze the effects of monetary policy uncertainty. Section 5 provides a discussion of the implications of unconventional monetary policy and scheduled FOMC announcements. A final section concludes.

2 Data and Summary Statistics

We use daily data on spot exchange rates and 3-month Treasury bill yields for the United States and the following 20 countries: Australia, Belgium, Brazil, Canada, France, Germany, Hungary, India, Israel, Italy, Japan, Mexico, the Netherlands, Norway, New Zealand, South Africa, Sweden, Switzerland, Thailand, and the United Kingdom. All data comes from Bloomberg and Haver. We use the NY 4 p.m. closing quotes. For most currencies, the beginning of the sample is April 2002 and the end of the sample is December 2015, thus covering the entire ZLB period in the United States.

We denote the logarithm of the nominal exchange rate (foreign currency per dollar) by s_t, the U.S. interest rate by i_t, and the foreign interest rate i_t^*. For carry trade portfolio returns, we follow Lustig and Verdelhan (2007), Brunnermeier et al. (2009), and Burnside et al. (2011) among others, and construct portfolios that are long foreign bonds on the basis of the foreign less U.S. 3-month interest rate differential. In particular, we construct five portfolios sorted in increasing order of the interest differential.[2] The first consists of the four lowest interest rate countries, the second portfolio for the next four lowest interest rate currencies, and so on. Portfolios are rebalanced every quarter (65 business days) in a way that maintains the ascending order of interest differentials throughout the sample period. We calculate daily excess returns, in dollars, over corresponding-maturity U.S. interest rates on these portfolios. We then compute and use in our analysis the unconditional mean of the excess returns, by portfolio at monthly frequency.

Figure 1 shows the percentage of time a country spends in each portfolio. Some countries, like Switzerland and Brazil, lie at the extreme of being almost all of the sample in one portfolio (1 and 5, respectively), but in general countries shift between portfolios often.

Generically, denote the return on an investment in the foreign currency financed by

[2] Verdelhan (2015) introduces an alternative, "dollar-neutral" measure of carry trade, which defines the carry trade as going long \$1 in the equally weighted portfolio of risky countries and going short \$1 in the equally weighted portfolio of safe countries. He separates a "dollar factor" and a "carry factor" in the cross-section of currency excess returns, where the dollar factor is the average exchange rate expressed in dollars and the carry factor is the average exchange rate of high- versus low- interest rate currencies. He finds that the dollar factor is a considerably more important driver of movements in the currency market. With our focus on the U.S. uncertainties, we instead study portfolios that are short in dollars and long foreign currencies, as in Lustig and Verdelhan (2007), Brunnermeier et al. (2009), and Burnside et al. (2011) among others.

borrowing in the domestic currency by

$$z_{t+1} \equiv (i_t^* - i_t) + \Delta s_{t+1},$$

where $\Delta s_{t+1} \equiv s_{t+1} - s_t$ is the depreciation of the home currency. It is a measure of exchange rate return in excess of the prediction by uncovered interest parity because under UIP, $E[z_{t+1}] = 0$ should hold.

More specifically tailored to our daily data set, denote the price of an m-year zero coupon bond with face value F, as $Fexp(-i_t m)$, and calculate the "Hold One Quarter" (HOQ) excess returns over corresponding-maturity U.S. interest rates (daily) as

$$(m - 0.25)i_{t+65} - mi_t - [(m - 0.25)i_{t+65}^* - mi_t^*] + S_{t+65} - s_t.$$

With the three-month bill ($m = 0.25$) data that we use, the measure of excess returns for each foreign country paired with the U.S. is thus,

$$0.25(i_t^* - i_t) + s_{t+65} - s_t.$$

We display the monthly time series of excess returns by portfolio in Figure 2. These are annualized HOQ returns, in percent, equally-weighted across the four currencies in the portfolio. Clearly, excess returns are large and volatile, and for all but portfolio 1 plummeted amid the onset of the global financial crisis in the second half of 2008.

We also use data for these same currencies (averaged within portfolio) on 25Δ three-month risk reversals. These are also daily, obtained from Bloomberg beginning in January 2005. A risk reversal is an options-implied measure of skewness in the foreign exchange market. It is the difference between the implied volatility of an out-of-the-money foreign currency call option (against U.S. dollars) and the implied volatility of an out-of-the-money put option. Buying a risk reversal provides insurance against foreign currency appreciation, financed by providing insurance against foreign currency depreciation, and hence is a measure of "crash risk". If the exchange rate is symmetrically distributed under the risk-neutral measure, then the price of the risk-reversal is zero since the value of being long the call exactly offsets the value of being short the put. On the other hand, if the risk-neutral distribution of the exchange rate is negatively (positively) skewed, the price of the risk-reversal is negative (positive). Hence, the risk reversal measures the combined effects of expected skewness and a skewness risk premium.

For illustration, we display in Figure 3 the daily three-month ahead dollar-pound risk reversal. For this figure, the sample includes the June 23, 2016 referendum on Brexit. Notice the very sharp decline on March 23, the first day that investors could use this instrument to insure against a crash in the pound following the vote. As the vote and consequent crash in the pound itself materialized, less money was put into insuring against further crashes: the risk reversal reversed direction.

As noted above, we are interested in investigating the effect of uncertainty on excess returns and risk reversals. We use five different measures: U.S. macroeconomic uncertainty, U.S. financial uncertainty, and three different proxies for U.S. monetary policy uncertainty. These are displayed in Figure 4. To proxy for macroeconomic uncertainty and financial uncertainty, we use the monthly econometric estimate of uncertainty (one year ahead) constructed in Jurado, Ludvigson, and Ng (2015) and Ludvigson, Ma, and Ng (2016), respectively. We use three measures of monetary policy uncertainty: (1) the implied volatility of options on swap rates constructed in Carlston and Ochoa (2016), (2) the newspaper-based monetary-policy subindex of Economic Policy Uncertainty in Baker, Bloom, and Davis (2015), which we denote MPU-BBD, and (3) a refined newspaper-based monetary policy index in Husted, Rogers, and Sun (2016), denoted MPU-HRS.[3]

Table 1 presents summary statistics for excess returns and risk reversals, by portfolio. We depict the monthly mean returns in pre-ZLB (Apr 2002-Jun 2008) and ZLB (Jan 2009-

[3]Comparisons of these measures are discussed in Husted, Rogers, and Sun (2016). As noted there, the swaptions measure essentially reflects uncertainty about the Fed Funds interest rate. Furthermore, MPU-HRS is much more narrowly-focused on the Federal Reserve than is MPU-BBD. Compared to the estimation-based measures of macro and financial uncertainty, the monetary policy uncertainty measures are considerably less smooth. We return to examine the inter-relatedness of all five uncertainty measures below.

Dec 2015) sub-periods, respectively. We omit the latter half of 2008 from these calculations so that we can characterize the data apart from the unusually large movements depicted in Figure 2. We observe in Table 1 a pattern in the pre-ZLB data that echoes findings in the literature: a general rise in the mean return as we move from the low to high interest rate currencies. However, such a pattern is not so evident during the ZLB period. Table 1 also illustrates that portfolio excess returns declined considerably during the ZLB period. In addition, risk reversals become considerably more negative during the ZLB, indicating that investors were willing to pay a higher cost for insurance against crashes in the currency market then. These summary statistics motivate us to study both the full sample and the ZLB sub-period in what follows.

Table 2 reports the correlations between, alternatively, excess returns (ER) and risk reversals (RR) and each of our uncertainty measures. We report these correlations by portfolio and separately for the pre-ZLB and ZLB sub-periods. Excess returns and uncertainty are almost always positively correlated: greater uncertainty is typically associated with larger payoffs to the carry trade. The two exceptions to this pattern are the small, negative correlations between ER and (1) macro uncertainty during the pre-ZLB sub-period and (2) MPU-HRS during the ZLB period. Examining the rows labelled RR, we see that risk reversals are negatively correlated with uncertainty, an effect that is especially large for the high-interest-rate portfolios. We also note that in all cases these negative correlations became smaller in magnitude (less negative) during the ZLB.

The summary statistics point to a clear relationship between uncertainty and currency excess returns. One might wonder, however, whether this is driven by fundamental differences across portfolios that lead to differences in both their interest rate and their currency risk. To control for portfolio-specific effects, our analysis to follow includes time-series evidence with portfolio fixed effects.

3 Financial uncertainty and macro uncertainty

We first analyze whether and how U.S. financial uncertainty (Ludvigson, Ma, and Ng (2016)) and macroeconomic uncertainty (Jurado, Ludvigson, and Ng (2015)) affect currency excess returns. Exposure to uncertainty (imperfect knowledge of the state) has been shown to increase individuals' risk aversion (e.g., Mengel, Tsakas, and Vostroknutov, 2016). Heightened uncertainty in the U.S. real economy or financial markets can thus affect global investors' risk preferences, which in turn, has an effect on carry trade payoffs. In this section, we analyze the effect of U.S. financial and macroeconomic uncertainty over the full sample.

In Table 3 we present monthly regressions of HOQ excess returns on U.S. financial uncertainty, the interest rate differential (foreign less U.S.), TED spread, and monthly crisis dummies that equal 1 for July-December 2008 and zero otherwise,

$$HOQ_{t+1} = b_0 + b_1 * \text{financial uncertainty}_t + b_2 * \text{TED}_t + b_3(i_t^* \quad i_t) + d * \text{crisis} + \epsilon.$$

We control for the interest rate differential because of its well-established (positive) relationship with excess returns, and include the dummies because of the sharp drop in ER in the latter half of 2008 (Figure 2). We display results by portfolio in columns (1)-(5) of the table and for the panel regression with portfolio fixed effects in column (6). We are thus examining within-portfolio time variation. We hypothesize that b_1 and b_2, the coefficients on financial uncertainty$_t$ and TED$_t$, will be positive.

The results consistently show that financial uncertainty raises carry trade excess returns. This suggests that uncertainty arising in the U.S. financial market leads global investors to demand a higher premium for their currency positions. The positive and significant estimates on TED$_t$ indicate that tightened funding liquidity forces reductions in carry trade positions and leads to higher excess returns going forward.

Excess returns to the carry trade have been rationalized as compensation for crash risk in the currency market (Brunnermeier et al., 2009). In Table 4, we examine the relationship between financial uncertainty and the risk reversal, the cost of protection against crashes in the FX market. In particular, we run a monthly regression of risk reversals on the same set of regressors as above,

$$RR_t = c_0 + c_1 * \text{financial uncertainty}_t + c_2 * \text{TED}_t + c_3(i_t^* - i_t) + d * \text{crisis} + \epsilon.$$

As seen in Table 4, heightened financial uncertainty makes risk reversals more negative, implying that it becomes more costly to insure against currency crashes. The effects are especially strong for high-interest-rate portfolios, which is consistent with the idea that crash risk tends to be present in investment currencies, i.e. those with a high interest rate differential (Brunnermeier et. al., 20009).

In Table 5 and Table 6, we present the analogous set of regression results for macroeconomic uncertainty in place of financial uncertainty. The patterns are broadly similar, the one difference being that the effects of macroeconomic uncertainty on excess returns, positive and significant for both uncertainty measures, are strongest for high-interest-rate portfolios. In addition, macro uncertainty has a smaller effect on risk reversals than financial uncertainty.

Finally, note that we estimated the effects of macroeconomic and financial uncertainty on the realized *skewness* of our carry trade portfolios. By and large, the effects were small and statistically insignificant. We conjecture that U.S. macroeconomic and financial uncertainty can have a measurable effect on global investors' risk preferences but probably do not affect the likelihood of crashes in the FX market (for which *local* uncertainty may matter). Therefore, we interpret the results in Tables 3-6 as reflecting the effects U.S. uncertainty has on global investors' risk aversion, which drives up the cost of insurance against crashes and thus also expected returns demanded by investors.

4 Monetary policy uncertainty

Given the close link between currency markets and monetary policy, we continue our investigation by exploring the role of U.S. monetary policy uncertainty. Such measures are more narrowly focused than our two measures from the previous section. We expect an increase in monetary policy uncertainty to raise currency excess returns, as uncertainty about investors' currency demand or interest rates increases investors' expectation of future exchange rate volatility, thus increasing the perceived riskiness of their short position in the dollar (Mueller, Tahbaz-Salehi, and Vedolin, 2016).

We first use the monetary policy subindex of Economic Policy Uncertainty constructed in Baker, Bloom, and Davis (2015), denoted MPU-BBD. Table 7 shows the results of regressions analogous to those above, but now with MPU-BBD on the right-hand side. The estimates show that carry returns increase in monetary policy uncertainty, consistently across portfolios, supporting the notion that monetary uncertainty raises the perceived riskiness in traders' currency positions and hence requiring a higher payoff. TED spreads are once again positive and significant.

Table 8 reports the results from regressions of risk reversals on MPU-BBD with the same set of control variables. Monetary policy uncertainty consistently makes risk reversals more negative, indicating a larger cost of buying protection on a currency position to insure against crashes. The effects are particularly strong for the portfolios with high interest rate differentials, for which we have shown that crash risk in the currency market is especially large. We again interpret this pattern as U.S. monetary policy uncertainty potentially affecting investors' risk preferences, which raises the price investors are willing to pay for protection against crashes.

We next use the market-based measure of monetary policy uncertainty, the implied volatility of options on swap rates (swaptions), from Carlston and Ochoa (2016). The results are very similar to those obtained using MPU-BBD for excess returns (Table 9), but are found to have mostly a positive sign in the risk reversals regressions (Table 10).

Finally, we use the newspaper-based index of monetary policy uncertainty constructed in Husted, Rogers, and Sun (2016). Although the effects of MPU-HRS on risk reversals are mostly negative and significant, just as we found with most of our other uncertainty measures, its effects on carry trade excess returns are insignificant (Table 11 and 12).[4]

The results of this section suggest that the proxy for monetary policy uncertainty matters significantly. A closer examination of MPU-HRS reveals that, for example, it captures a broad notion of U.S. monetary policy uncertainty that incorporates uncertainty regarding the timing and path of policy rate normalization, as highlighted by elevated values during the ZLB when the market-based measures stayed extremely low (Figure 4). This suggests that the latter are primarily measures of uncertainty over the policy interest rate (Husted, Rogers, and Sun (2016)). MPU-HRS also differs from MPU-BBD, in ways we discuss in detail below.

To illustrate the divergence that exists among different measures of U.S. monetary policy uncertainty, we report in Table 13 the correlations among all of our uncertainty measures. Correlations among the monetary policy uncertainty measures are quite low. The correlation between MPU-HRS and the implied volatility of swaptions is *negative* during the ZLB. As argued above, this reflects that there is additional information in MPU-HRS beyond uncertainty about the policy interest rate. In addition, note that the correlation between MPU-HRS and MPU-BBD dropped from .74 to .29 from the pre-ZLB subperiod to the ZLB period. We conjecture that low correlations here are partially driven by the mention of foreign central banks such as ECB, Bank of Japan, and Bank of England in the construction of MPU-BBD, which can in turn influence their respective association with FX market movements.

To push on this last point, we note the non-trivial differences in the keyword searches. As explained in Husted, Rogers, and Sun (2016), MPU-HRS is constructed by searching

[4] As above, we analyze only the earlier notion of carry trade (Lustig-Verdelhan, Burnside et. al., Brunnermeier et. al.), leaving analysis of the carry factor and dollar factor (Verdelhan (2015) in driving our results to future research.

for articles containing the triple of (i) “uncertainty” or “uncertain,” AND (ii) “monetary policy(ies)” or “interest rate(s)” or “Federal fund(s) rate” or “Fed fund(s) rate,” AND (iii) “Federal Reserve” or “the Fed” or “Federal Open Market Committee” or “FOMC”. This is a narrow keyword search compared to that of BBD, who search for: (i) “uncertainty” or “uncertain”) AND (2) “economy” or “economic”) AND (3) “congress” or “legislation” or “white house” or “regulation” or “federal reserve” or “deficit”) AND (4) “federal reserve” or “the fed” or “money supply” or “open market operations” or “quantitative easing” or “monetary policy” or “fed funds rate” or “overnight lending rate” or “Bernanke” or “Volker” or “Greenspan” or “central bank” or “interest rates” or “fed chairman” or “fed chair” or “lender of last resort” or “discount window” or “European Central Bank” or “ECB” or “Bank of England” or “Bank of Japan” or “BOJ” or “Bank of China” or “Bundesbank” or “Bank of France” or “Bank of Italy”. Accounting for the effects of these keyword search differences warrants further examination.

5 The ZLB and FOMC meeting days

5.1 Effects of uncertainty during the ZLB

It is reasonable to question at a conceptual level the role of monetary policy uncertainty in explaining carry trade returns when the U.S. policy rate is at the zero lower bound (for very recent work on UIP, monetary policy, and the ZLB, see Chinn and Zhang (2015)). The summary statistics of Table 1 and simple correlation analysis of Tables 2 and 13 gives us caution that our regression results may be different during the period of unconventional monetary policy. We examine this next.

We start with financial and macroeconomic uncertainty. The results, reported in Table A1-A4 of the Appendix, are broadly similar to the full-sample results in that both measures tend to raise carry trade excess returns, and make risk reversals more negative for the high interest rate portfolios. However, judging from the statistical and economic significance, the effects are smaller during ZLB compared to the full-sample. For our monetary policy uncertainty measures, we report regression results for the ZLB period in Table A5-A10 of the on-line Appendix. The patterns are very similar to the full-sample results. Somewhat to our surprise, regression results from the ZLB sub-period are thus not vastly different from the full-sample results (which incorporate dummies for the crisis).

5.2 FOMC meeting days

We take a closer look at the effects of monetary policy uncertainty by examining carry trade returns on regularly-scheduled Federal Open Market Committee meeting days. These meetings have been the Federal Reserve's primary channel to announce its policy decisions, and the market may perceive increased monetary policy uncertainty prior to an upcoming FOMC meeting. Our sample is from April 2002 through December 2015, with 110 FOMC meeting days and 3479 trading days with no scheduled FOMC meetings.

Table 14 displays the summary statistics of excess returns and risk reversals and for the two monetary policy uncertainty measures for which daily data are available. We do this separately on FOMC meeting days and non-FOMC days. The MPU-HRS index is indeed considerably higher on FOMC meeting days, but swaption uncertainty is not. Excess returns are also significantly higher on FOMC meeting days than on non-FOMC days, while risk reversals are not. Thus, in this part of our analysis, we will focus exclusively on excess returns.

We estimate the following regression:

$$H1D_{t+1} = b_0 + b_1 * \text{mpu}_t + b_2 * \text{mpu} * \text{FOMC} + b_3 * \text{crisis} + \epsilon,$$

where monetary policy uncertainty (generically denoted as mpu) is proxied by either MPU-HRS or swaption implied volatility, FOMC is a dummy variable that equals 1 on FOMC meeting days and 0 otherwise, and $H1D$ is the excess return for holding an m-year bond for only one day, which is expressed as

$$H1D_t = (m - (1/260))i_t - mi_{t-1} - [(m - (1/260))i_t^* - mi_{t-1}^*] + s_t - s_{t-1}.$$

This is approximately the daily foreign bond return minus the daily U.S. bond return plus the exchange rate return $-[m(i_t^* - i_{t-1}^*] + s_t - s_{t-1}$. Since we consider three-month bills ($m = 0.25$), these returns are dominated by the exchange rate return.

We present the results in Table 15. As indicated in column (1), MPU-HRS does appear to be significantly positively related to excess returns on FOMC meeting days. This is consistent with the findings in a contemporaneous paper by Mueller, Tahbaz-Salehi, and Vedolin (2016). They find that on days with scheduled FOMC announcements carry trade portfolios exhibit larger forward discounts, their proxy for excess returns, and that greater monetary policy uncertainty (proxied by "Treasury Implied Volatility", extracted from 30-year Treasury futures) leads to significantly higher excess returns. Upon further inspection shown in column (3), however, we find clear evidence that it is movements in TED spreads that are driving excess returns on FOMC days. Monetary policy uncertainty has no significant marginal effect. Using swaption implied volatility, a measure that is closer to that of Mueller, Tahbaz-Salehi, and Vedolin than MPU-HRS, produces the same result: greater interest rate uncertainty on FOMC meeting days appears to lead to higher excess returns (column (2)), but once we control for the effect of TED spreads on FOMC days, this result goes away (column (4)). Consistently, our results indicate that it is liquidity funding considerations, rather than monetary policy uncertainty or interest rate uncertainty, that leads to greater excess returns on FOMC meeting days.

Finally, we note that these FOMC meeting day effects are very short-lived. In estimates not shown, we find that the positive effects (of TED or MPU) on excess returns on FOMC meeting days are almost entirely offset the following day. In all cases, they are found to be fully reversed by two days after the meeting.

6 Conclusion

We ontribute to the vast literature on UIP violations by examining the empirical importance of uncertainty on currency carry trade excess returns. We show strong evidence that heightened uncertainty in the U.S. real economy or financial markets significantly raises excess returns. We posit that this works through the influence of uncertainty on global investors' risk preferences, and we show supporting evidence of this. Macro and financial uncertainty also lower the risk reversal, an effect that is particularly strong for high-interest-rate portfolios. Our results are consistent with the idea that an increase in uncertainty regarding the U.S. economy or financial markets increases investors' risk aversion, which in turn, drives up the expected returns and the cost of protection against crash risk in the FX market. We consider this interpretation as broadly consistent with the conventional notion that U.S. uncertainty affects the price of risk, as it affects global investors' risk aversion, while the quantity of risk–that is, the likelihood of crash–is concentrated in investment currencies (i.e., currencies with high interest rate differentials) and perhaps is more likely to be affected by local uncertainties.

We also explore the role of monetary policy uncertainty. In addition to the risk aversion channel, an increase in monetary policy uncertainty can increase investors' expectation of interest rate volatility and thus the perceived riskiness of their currency positions, raising returns to carry trades. Consistent with this idea, we find that some measures of monetary policy uncertainty do indeed raise carry trade excess returns and lower the risk reversal. However, we show that existing measures of monetary policy uncertainty differ significantly in terms of what they reflect, in particular during the ZLB period when the correlations between all of our uncertainty measures fell noticeably. Thus, we do not uncover an unambiguously clear mechanism for how monetary policy uncertainty operates through the currency market.

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Figure 1: Portfolio Allocation by Country

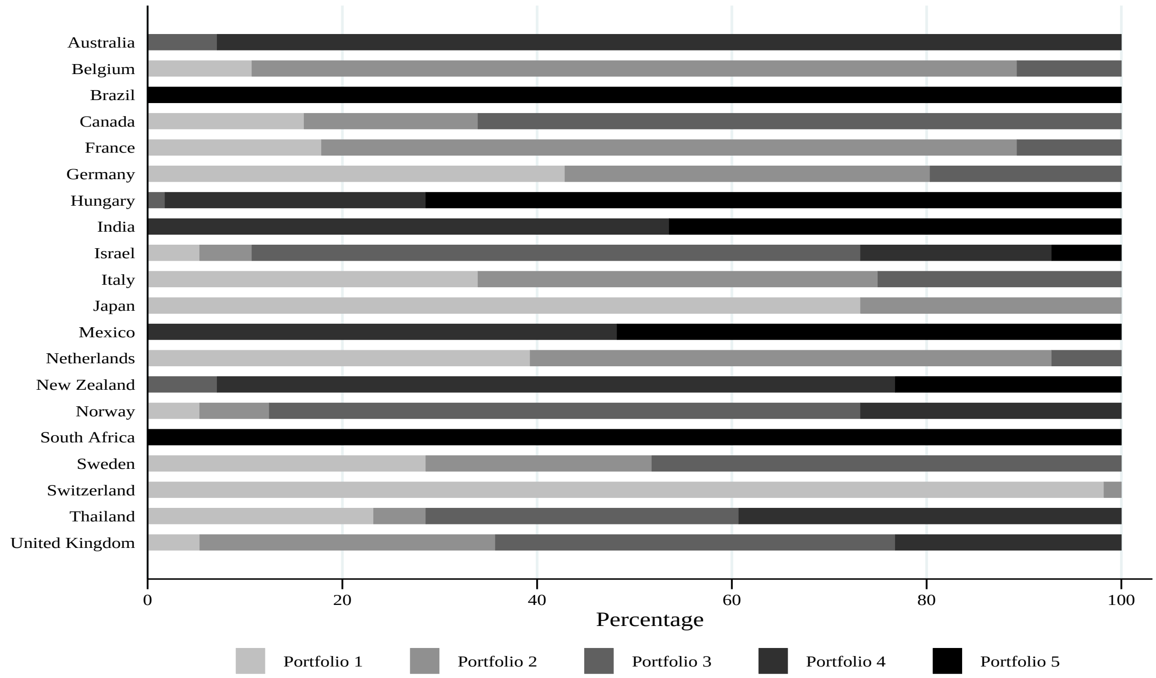


Figure 2: Carry Trade Portfolio Excess Returns

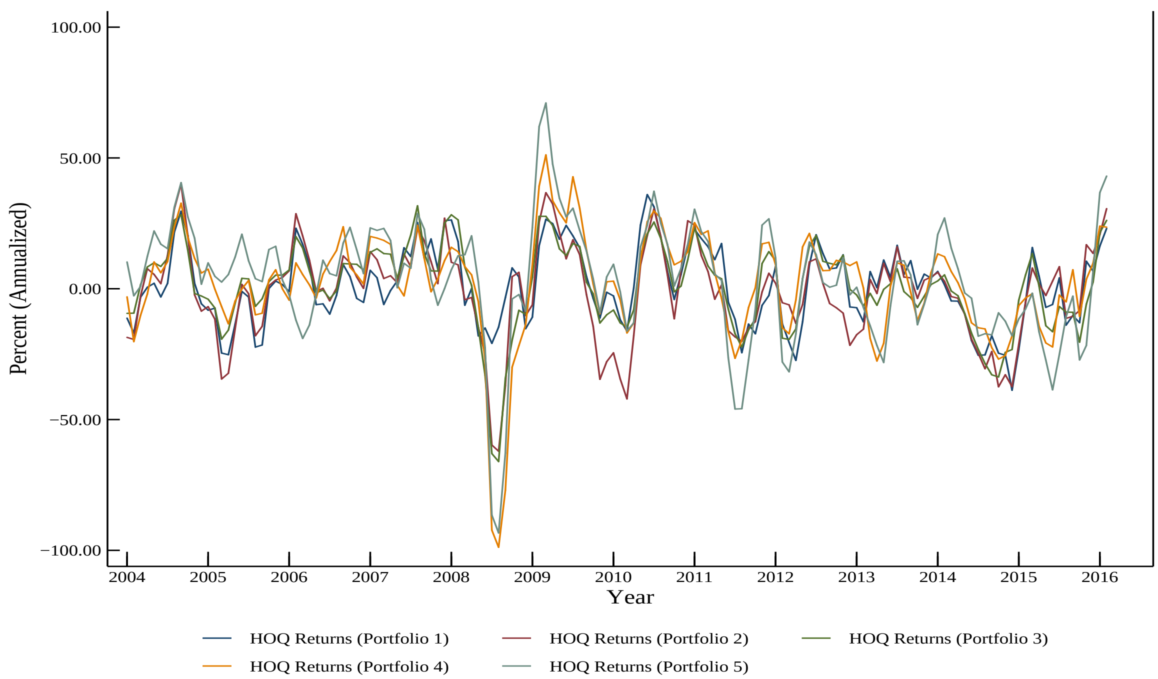


Figure 3: Dollar-Pound 3-month Risk Reversal, 2015-2016

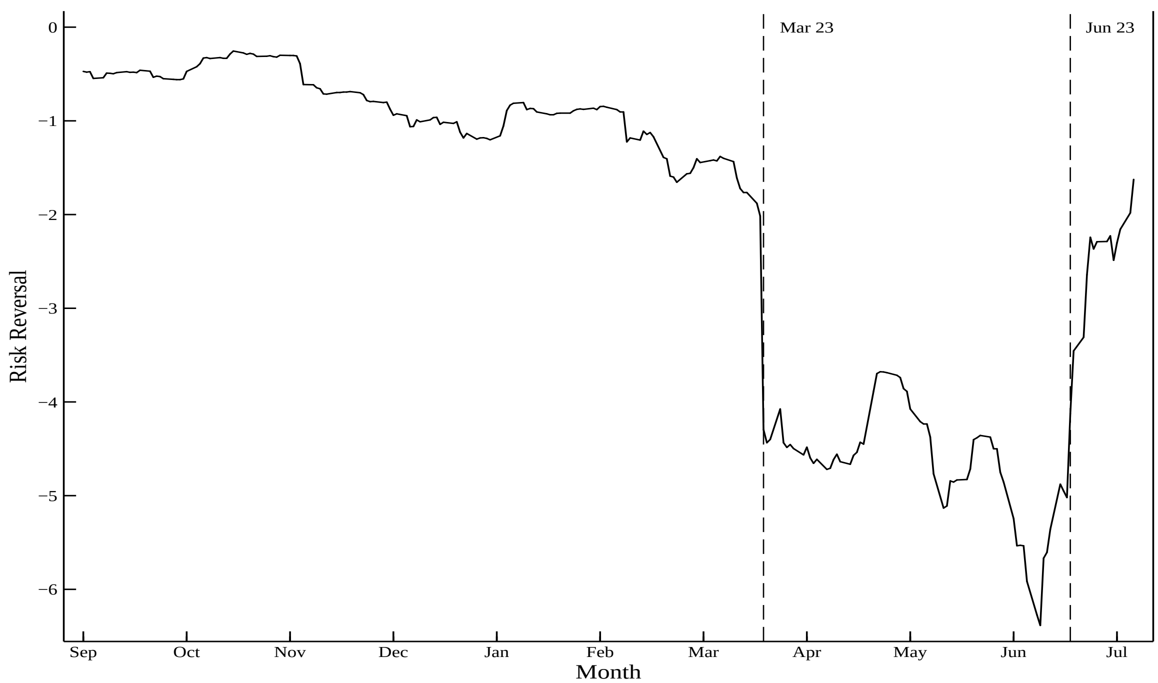
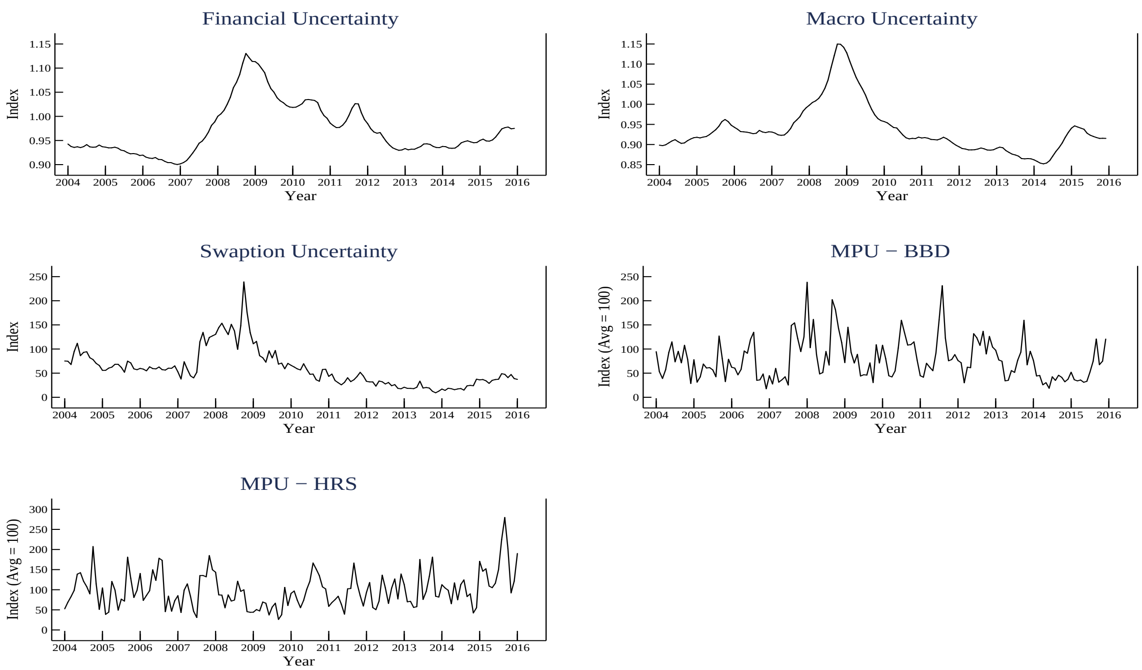


Figure 4: Uncertainty Measures



List of Tables

Table 1: Summary Statistics by Portfolio, Quarterly Holding Period

		(1)	(2)	(3)	(4)	(5)	(Avg)
2002m4 - 2008m6	$i^* - i$	-1.233	0.001	0.886	3.187	7.781	2.125
	Excess Returns	3.780	7.130	9.200	7.445	12.285	7.968
	Risk Reversals	0.542	-0.051	-0.150	-0.883	-2.165	-0.541
2009m1 - 2015m12	$i^* - i$	-0.025	0.252	1.062	2.925	7.226	2.288
	Excess Returns	0.646	-2.794	-0.574	3.135	1.651	0.412
	Risk Reversals	-0.713	-1.121	-1.384	-2.247	-3.595	-1.831

Table 2: Correlation Between Uncertainty and Excess Return/Risk Reversal

Measure	Variable	Period	Portfolio (1)	(2)	(3)	(4)	(5)	(Avg)
Financial	ER	Pre-ZLB	0.163	0.205	0.207	0.064	0.036	0.160
		ZLB	0.306	0.288	0.370	0.517	0.498	0.447
	RR	Pre-ZLB	0.536	-0.793	-0.737	-0.670	-0.606	-0.757
		ZLB	0.632	-0.224	0.116	-0.461	-0.785	-0.309
Macro	ER	Pre-ZLB	-0.026	-0.206	-0.163	-0.224	-0.199	-0.190
		ZLB	0.267	0.256	0.351	0.441	0.465	0.402
	RR	Pre-ZLB	0.460	-0.772	-0.751	-0.707	-0.609	-0.782
		ZLB	0.680	0.051	0.354	-0.213	-0.656	-0.061
Swaption	ER	Pre-ZLB	0.160	0.119	0.154	0.073	-0.038	0.107
		ZLB	0.313	0.275	0.385	0.516	0.497	0.446
	RR	Pre-ZLB	0.613	-0.793	-0.709	-0.862	-0.744	-0.843
		ZLB	0.620	-0.065	0.272	-0.326	-0.706	-0.170
MPU-BBD	ER	Pre-ZLB	0.201	0.236	0.294	0.192	0.317	0.290
		ZLB	0.244	0.176	0.293	0.337	0.196	0.270
	RR	Pre-ZLB	0.344	-0.476	-0.315	-0.725	-0.556	-0.591
		ZLB	0.083	-0.289	-0.170	-0.361	-0.351	-0.322
MPU-HRS	ER	Pre-ZLB	0.029	0.099	0.131	0.054	0.186	0.119
		ZLB	-0.089	-0.029	-0.101	-0.098	-0.211	-0.124
	RR	Pre-ZLB	0.080	-0.024	-0.028	-0.377	-0.251	-0.205
		ZLB	-0.331	-0.075	-0.168	0.003	0.264	-0.027

Pre-ZLB spans 2002m4-2008m6 for ER and 2005m11-2008m6 for RRs; ZLB spans 2009m1-2015m12.

Table 3: Excess Returns and Financial Uncertainty, 2002m4 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
Financial Uncertainty	74.57*	47.99	32.39	94.28**	21.60	48.39**
	(2.37)	(1.25)	(1.09)	(3.26)	(0.58)	(3.31)
TED Spread	5.702	8.011^{+}	9.046*	6.082^{+}	14.75**	8.429**
	(1.53)	(1.82)	(2.48)	(1.70)	(2.93)	(4.54)
$i^{*} - i$, Portfolio i	-119.9	33.43	140.6	-78.86	290.3**	
	(-0.87)	(0.18)	(0.97)	(-0.62)	(3.15)	
$i^{*} - i$, Panel						115.8*
						(2.13)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	165	165	165	165	165	825
Adjusted R^2	0.046	0.153	0.266	0.475	0.330	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 4: Risk Reversals and Financial Uncertainty, 2005m11 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
Financial Uncertainty	9.656**	-3.846*	1.604	-7.821**	-19.21**	-3.059**
	(5.73)	(-2.28)	(1.08)	(-5.47)	(-7.83)	(-2.90)
TED Spread	0.864**	0.838**	0.873**	0.944**	0.161	0.703**
	(4.83)	(4.75)	(5.05)	(5.76)	(0.64)	(6.12)
$i^{*} - i$, Portfolio i	-48.44**	-44.27**	-71.61**	-31.91**	-14.91^{+}	
	(-7.09)	(-4.97)	(-8.66)	(-4.38)	(-1.68)	
$i^{*} - i$, Panel						-45.20**
						(-9.60)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	122	122	122	122	122	610
Adjusted R^2	0.535	0.397	0.478	0.734	0.748	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 5: Excess Returns and Macroeconomic Uncertainty, 2002m4 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
Macro Uncertainty	38.61	17.10	45.98	92.99^{**}	113.7^{**}	62.45^{**}
	(1.22)	(0.45)	(1.49)	(2.99)	(2.83)	(3.98)
TED Spread	4.926	7.680	6.084	-0.0700	5.188	4.530^{*}
	(1.08)	(1.42)	(1.38)	(-0.02)	(0.87)	(2.01)
$i^* - i$, Portfolio i	77.40	180.7	235.7^{*}	151.3	274.2^{**}	
	(0.75)	(1.27)	(2.04)	(1.42)	(3.56)	
$i^* - i$, Panel						200.0^{**}
						(4.43)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	165	165	165	165	165	825
Adjusted R^2	0.022	0.145	0.270	0.470	0.362	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 6: Risk Reversals and Macroeconomic Uncertainty, 2005m11 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
Macro Uncertainty	10.27^{**}	1.427	4.797^{**}	-2.340	-9.869^{**}	1.039
	(7.90)	(0.95)	(3.49)	(-1.56)	(-4.07)	(1.08)
TED Spread	0.347^{+}	0.646^{**}	0.497^{*}	1.057^{**}	0.288	0.527^{**}
	(1.83)	(2.96)	(2.48)	(4.72)	(0.83)	(3.78)
$i^* - i$, Portfolio i	-26.60^{**}	-57.92^{**}	-66.09^{**}	-53.96^{**}	-54.28^{**}	
	(-5.71)	(-8.24)	(-9.85)	(-8.00)	(-7.00)	
$i^* - i$, Panel						-53.93^{**}
						(-14.25)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	122	122	122	122	122	610
Adjusted R^2	0.614	0.374	0.524	0.671	0.660	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 7: Excess Returns and MPU-BBD, 2002m4 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
MPU-BBD	5.171*	5.803*	6.597**	6.697**	4.271	5.637**
	(2.42)	(2.19)	(2.99)	(2.88)	(1.46)	(5.09)
TED Spread	6.419^{+}	7.306^{+}	7.573*	6.052^{+}	13.60**	7.850**
	(1.76)	(1.69)	(2.13)	(1.67)	(2.75)	(4.29)
$i^{*} - i$, Portfolio i	28.00	76.62	84.28	4.428	271.3**	
	(0.26)	(0.52)	(0.68)	(0.04)	(3.25)	
$i^{*} - i$, Panel						132.5**
						(2.78)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	165	165	165	165	165	825
Adjusted R^2	0.048	0.170	0.300	0.468	0.338	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 8: Risk Reversals and MPU-BBD, 2005m11 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
MPU-BBD	-0.0502	-0.366**	-0.117	-0.345**	-0.502*	-0.267**
	(-0.37)	(-3.04)	(-0.95)	(-2.74)	(-2.51)	(-3.35)
TED Spread	1.280**	0.914**	0.964**	0.965**	-0.360	0.733**
	(6.43)	(5.16)	(5.48)	(5.29)	(-1.21)	(6.32)
$i^{*} - i$, Portfolio i	-21.54**	-52.59**	-64.72**	-47.93**	-59.65**	
	(-3.63)	(-7.59)	(-8.74)	(-6.88)	(-7.56)	
$i^{*} - i$, Panel						-50.35**
						(-13.09)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	122	122	122	122	122	610
Adjusted R^2	0.400	0.417	0.476	0.685	0.630	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 9: Excess Returns and Swaption Uncertainty, 2002m4 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
Swaption Uncertainty	9.55*	18.10**	18.10**	16.70**	15.40*	15.40**
	(2.29)	(3.37)	(4.27)	(3.49)	(2.41)	(6.89)
TED Spread	2.659	-1.378	-0.973	-1.434	4.817	0.511
	(0.61)	(-0.26)	(-0.23)	(-0.32)	(0.74)	(0.23)
$i^* - i$, Portfolio i	67.55	-22.65	42.35	-61.04	196.3*	
	(0.64)	(-0.15)	(0.36)	(-0.50)	(2.14)	
$i^* - i$, Panel						87.66^{+}
						(1.83)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	165	165	165	165	165	825
Adjusted R^2	0.044	0.203	0.338	0.480	0.353	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$
Coefficients for Swaption Uncertainty are multiplied by 100.

Table 10: Risk Reversals and Swaption Uncertainty, 2005m11 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
Swaption Uncertainty	2.090**	0.468	1.270**	0.464	-0.853^{+}	0.699**
	(7.36)	(1.45)	(4.43)	(1.42)	(-1.61)	(3.42)
TED Spread	-0.327	0.420	-0.0389	0.514^{+}	0.0470	0.0918
	(-1.24)	(1.42)	(-0.15)	(1.71)	(0.10)	(0.49)
$i^* - i$, Portfolio 1	-24.64**	-58.82**	-67.63**	-54.86**	-62.17**	
	(-5.22)	(-8.39)	(-10.44)	(-8.10)	(-7.92)	
$i^* \quad i$, Panel						-54.28**
						(-14.57)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	122	122	122	122	122	610
Adjusted R^2	0.595	0.381	0.551	0.669	0.618	

Monthly regressions; t statistics in parentheses; $^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$
Coefficients for Swaption Uncertainty are multiplied by 100.

Table 11: Excess Returns and MPU-HRS, 2002m4 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
MPU-HRS	-1.040	1.309	0.256	-1.321	-3.326	-0.700
	(-0.45)	(0.47)	(0.11)	(-0.56)	(-1.12)	(-0.61)
TED Spread	8.308*	9.149*	10.04**	7.951*	15.91**	9.998**
	(2.29)	(2.12)	(2.83)	(2.18)	(3.36)	(5.53)
$i^* - i$, Portfolio i	88.30	184.5	233.1*	159.0	331.0**	
	(0.83)	(1.30)	(2.00)	(1.45)	(4.26)	
$i^* - i$, Panel						217.9**
						(4.79)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	165	165	165	165	165	825
Adjusted R^2	0.013	0.146	0.260	0.440	0.334	

Monthly regressions; t statistics in parentheses; $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 12: Risk Reversals and MPU-HRS, 2005m11 – 2015m12

	(1)	(2)	(3)	(4)	(5)	(6)
MPU-HRS	-0.495**	-0.241+	-0.331*	-0.182	0.515*	-0.152+
	(-3.38)	(-1.70)	(-2.47)	(-1.26)	(2.22)	(-1.67)
TED Spread	1.270**	0.782**	0.931**	0.867**	-0.617*	0.623**
	(7.09)	(4.46)	(5.66)	(4.75)	(-2.17)	(5.59)
$i^* - i$, Portfolio i	-23.66**	-58.70**	-68.10**	-54.54**	-62.40**	
	(-4.31)	(-8.41)	(-9.93)	(-8.07)	(-8.06)	
$i^* - i$, Panel						-53.71**
						(-14.32)
Recession Dummies	Yes	Yes	Yes	Yes	Yes	Yes
Portfolio Dummies	No	No	No	No	No	Yes
Observations	122	122	122	122	122	610
Adjusted R^2	0.455	0.385	0.499	0.668	0.626	

Monthly regressions; t statistics in parentheses; $^+$ $p < 0.10$, * $p < .05$, ** $p < .01$

Table 13: Correlations Between Uncertainty Measures

		MPU-HRS	MPU-BBD	Swaption	Macro	Financial
	MPU-HRS	1.000				
	MPU-BBD	0.737	1.000			
Pre-ZLB	Swaption	0.229	0.452	1.000		
	Macro	0.127	0.239	0.682	1.000	
	Financial	0.126	0.450	0.698	0.606	1.000
	MPU-HRS	1.000				
	MPU-BBD	0.289	1.000			
ZLB	Swaption	-0.349	0.123	1.000		
	Macro	-0.384	0.079	0.911	1.000	
	Financial	-0.312	0.272	0.902	0.853	1.000

Pre-ZLB spans 2003m1-2008m6 and ZLB spans 2009m1-2015m12.

Table 14: Summary Statistics of Key Daily Measures By Portfolio

		(1)	(2)	(3)	(4)	(5)	(Avg)
	3m Yield Spreads	-0.537	0.212	1.053	3.132	7.564	2.285
	Excess Returns	0.938	-0.231	1.909	2.245	4.686	1.909
	Risk Reversals	-.296	-0.873	-1.045	-1.986	-3.381	-1.516
Non-FOMC Day	MPU-HRS						109.793
	Swaption Uncertainty						63.128
	Ted Spreads						0.438
	3m Yield Spreads	-0.528	0.219	1.056	3.152	7.560	2.291
	Excess Returns	32.791	42.831	30.440	42.487	53.960	40.502
	Risk Reversals	-0.274	-0.873	-1.038	-2.005	-3.399	-1.518
FOMC Day	MPU-HRS						163.931
	Swaption Uncertainty						63.189
	Ted Spreads						0.441

Table 15: Excess Returns, Daily Holding Period, 2002m4 – 2015m12

	(1)	(2)	(3)	(4)
MPU-HRS	0.346		0.699	
	(0.81)		(1.55)	
MPUxFOMC	4.185**		-1.851	
	(2.93)		(-1.01)	
Swaption Uncertainty		0.0973**		0.101*
		(3.00)		(2.36)
SwaptionXFOMC		0.517**		0.204
		(5.70)		(1.27)
TED Spread			4.239	-0.558
			(1.21)	(-0.13)
TED SpreadxFOMC			81.16**	49.55*
			(5.26)	(2.30)
3m Yield Spread, Panel			257.9**	171.5+
			(2.94)	(1.82)
Constant	1.679	-3.388	0.692	-2.125
	(0.63)	(-1.10)	(0.22)	(-0.63)
Recession Dummies	Yes	Yes	Yes	Yes
Portfolio Dummies	Yes	Yes	Yes	Yes
Observations	17940	17660	16875	16850

t statistics in parentheses

Daily regressions estimated over 2005m11-2015m12

with daily dummy variables for Jul.-Dec. 2008.

$^{+}$ $p < 0.10$, * $p < .05$, ** $p < .01$