Uncovered Interest Parity in High Frequency

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Abstract

We study violations of uncovered interest parity (UIP) at daily and intraday frequencies, carefully accounting for settlement conventions. While we reject the expectations hypothesis (EH) during the intraday period, we cannot do so overnight. Equivalently, returns to the forward premium portfolio (a trading strategy that exploits violations of the EH) are overwhelmingly accrued during the intraday period. The same is true for returns to the traditional carry as well as the dollar carry strategy. The positive carry returns over the sample period are almost exclusively earned during the day as high interest rate currencies appreciate against low interest rate currencies while excess returns overnight are virtually zero. On FOMC and macro announcement days, the forward premium and the dollar carry portfolios drop in value, while they generate positive returns on average on all other days. In contrast, the carry as well as the dollar portfolio exhibit the opposite pattern: They appreciate in value on announcement days value but depreciate on all other days on average. That is, while the strategies exhibit similar return patterns intraday vs. overnight, they behave very differently on announcement vs. non-announcement days.

Keywords: foreign exchange, uncovered interest parity, carry trade, high-frequency returns, macro announcements.

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A vast literature in international finance studies the forward premium puzzle and the carry trade anomaly, which both reflect failures of uncovered interest parity (UIP). Previous empirical studies mostly focus on horizons ranging from one week to one quarter, documenting robust evidence for violations of the UIP condition, manifested either through the failure of the expectations hypothesis or through significantly positive carry returns. In addition, the extant literature provides some evidence that the expectations hypothesis (and, thus, UIP) holds at longer horizons.[1] However, a detailed analysis of UIP violations at very short-term horizons is missing. We fill this gap.

In this paper, we consider very short horizons and study violations of UIP using both regression- as well as portfolio-based methods. We document three novel empirical facts: First, regression-based tests of UIP violations deliver opposite results when confronted with overnight and intraday periods. While the expectations hypothesis cannot be rejected during the overnight period, it strongly is rejected during the day. Second, and relatedly, portfolio-based methods display different patterns of UIP violations throughout the day. During the overnight period, carry trade risk premia are essentially zero, whereas the carry portfolio appreciates significantly during the day. Other strategies related to UIP violations such as the dollar carry trade or the forward premium trade also earn a dominant fraction of their overall returns during the intraday period. Third, trading strategies exhibit distinctly different return papers on FOMC and macro announcement days. Abstracting from the interest rate differential, returns to the carry portfolio are positive on average for announcement days and negative on average on all other days, mirroring the pattern for the dollar portfolio that goes long a basket of foreign currencies. In contrast, for the dollar carry and the forward premium portfolios, the majority of returns are earned on non-announcement days while announcement day returns are significantly negative. That is, while the strategies exhibit similar patterns when decomposed into intraday versus overnight periods, they differ distinctly when studied on announcement versus non-announcement days.

We establish these findings by building a dataset consisting of high-frequency spot and forward rates that allows us to carefully account for conventions in the FX market. Indeed, the high-frequency nature of our empirical framework does not follow from a straightforward application of traditional lower frequency tests. Daily and intraday analyses require taking into account that interest on currency positions is paid at 17:00 Eastern Time as a lump sum covering the whole 24-hour period. That is, the total interest is paid every day at the beginning of what we define as

[1] See, e.g., Engel (2014) for a survey of the literature.

the overnight period, whereas no interest is charged on positions that are open and closed within the day. Moreover, FX spot transactions are not settled immediately but generally with a two-day lag. Thus, the FX spot data used in the existing literature is not suitable to study the relationship between interest rates (or forward discounts) and exchange rate changes at higher frequencies. In order to correctly calculate daily excess currency returns, we need to use data on overnight, tomorrow-next and spot-next forwards that are not commonly used in the academic literature. In doing so, we are able to construct daily and intraday FX excess returns for a cross-section of the G9 currencies over the period from January 1999 to December 2023. Contrary to the existing literature, this then allows us to study for example Fama (1984) regressions or the Hassan and Mano (2018) decomposition in high frequency.

First, we study high frequency Fama (1984) regressions and show that UIP deviations, viewed from the perspective of a U.S. investor, are driven by intraday spot dynamics. The slope coefficient of conventional UIP regressions estimated at daily frequency switches from a positive value of 1.32 (not statistically different than the UIP prediction of unity) during the overnight hours, to -1.28 during the intraday period for the panel of G9 currencies vis-à vis the U.S. dollar.[2] This pattern is a robust feature of the data, with our sample spanning over 25 years of high-frequency data and currencies that collectively represent more than 75% of the daily average trading volume. We find the switch in the coefficient estimate for all currencies in the sample individually, as well as when running panel regressions. The stylised fact is also robust for different subsample periods and is also obtained when using differences in short-term deposit rates to calculate interest differentials instead of using forward discounts.

Second, we study high-frequency intraday UIP deviations using FX trading strategies. Hassan and Mano (2018) propose a decomposition that maps UIP violations to a set of FX trading strategies that can be adapted to our high-frequency empirical setting. We follow their approach and decompose the unconditional covariance of expected currency returns (or "risk premia") with forward premia into a cross-currency, a between-time-and-currency, and a cross-time component. This allows us to construct high-frequency return series for the carry trade (traditional and static), the dollar carry trade and the forward premium trade that generate average annualised excess returns equal to 3.63%, 5.34%, 4.54% and 2.83%, respectively. With the exception of the static carry strategy, 95% to 186% of the total excess returns are earned during the intraday period. Take the traditional carry strategy for example that invests in high interest currencies while

[2] For a smaller and shorter sample, Chaboud and Wright (2005) find support for UIP over very short windows of data that span the time of the discrete interest payment.

shorting low interest rate currencies. According to UIP, the interest rate differential that is earned should be offset by depreciation of the carry trade portfolio. Over our sample period, the return contribution from the interest rate differential is exactly 3.63%, i.e., the total excess return earned on the strategy. The reason for the positive excess return is that the exchange rate changes in the portfolio result in a 0% change in the portfolio value instead of a loss in value to offset the "carry." Further decomposing the close-to-close returns, we find that the total annualised overnight change in the price of the carry portfolio is −3.45%, almost fully offsetting the interest that is paid at the beginning of the overnight period, and resulting in roughly zero excess return overnight. During the day, however, the carry portfolio exhibits a reversal and appreciates by 3.44% annualised as high interest rate currencies tend to appreciate while low interest rate currencies tend to depreciate.[3]

Third, we further exploit the high-frequency nature of our dataset to study the link between UIP violations and news. To this end, we split our sample into announcement and non-announcement days, and we show that both FOMC announcement days as well as scheduled major U.S. macroeconomic releases are fundamental sources of time-varying currency risk premia.[4] Although these days account for only 17% of our sample, over 60% of total currency excess returns for the traditional as well as the static carry strategy are earned on these days. In fact, focusing only on the appreciation and depreciation of the carry portfolios (i.e., ignoring the interest rate differential), we find that both portfolios on average depreciate on non-announcements days while they strongly appreciate on FOMC and macro announcement days, a result in line with findings for the dollar portfolio. The dollar carry and forward premium portfolios, on the other hand, exhibit very different patterns. Their overall positive excess returns are exclusively earned on non-announcement days. Both exhibit significantly negative average excess returns on announcement days that become even more negative if the positive contribution from the interest rate differential is removed.

Thus, while our results suggest that overnight and intraday periods differ in a systematic way with respect to risk compensation for FX trading strategies, it seems that the different strategies are exposed to macro announcement risks in fundamentally opposite directions. This suggests that multiple sources should be considered to understand origins of UIP violations.

Related Literature: Our paper relates to various strands of the literature. First, an extensive

[3]This empirical result is in line with the model by Lyons and Rose (1995) who show that currencies that are potentially exposed do devaluation risk intraday should appreciate systematically.

[4]Mueller et al. (2017) document that returns to shorting the U.S. dollar are significantly higher on FOMC announcements days and increase with the interest rate differential.

literature studies violations of UIP using both regression- as well as portfolio-based methods.[5] Fama (1984) rejects the expectations hypothesis for currencies and coins the forward discount puzzle showing that high-interest rate currencies subsequently tend to appreciate. Among others, Chinn and Meredith (2005), Chinn (2006), Bacchetta and van Wincoop (2010), and Engel (2016) show that UIP tends to hold over longer horizons. More recently, Albagli et al. (2024) employ an event-study framework and document that long-term bonds and exchange rates tend to move in the direction predicted by UIP following monetary policy shocks. Similarly, there exists a vast literature studying the carry trade. Lustig and Verdelhan (2007) and Lustig et al. (2011) argue that returns to the carry trade are compensation for risk. Lustig, Stathopoulos, and Verdelhan (2019) show that currency carry trade risk premia are decreasing in the maturity of the bonds used to implement the strategy. Lustig et al. (2014) describe the dollar carry strategy that compenstes investors for taking on aggregate risk by shorting the dollar in bad times, when the U.S. price of risk is high. Hassan and Mano (2018) unify the existing methods by providing a framework that maps UIP violations to trading strategy returns. Contrary to the extant literature, we are the first paper to focus on high-frequency data and systematically study UIP violations not only at high frequencies but also for very short maturity instruments. To the best of our knowledge, Lyons and Rose (1995) and Chaboud and Wright (2005) are the only other papers that study UIP violations at comparable frequencies. However, they only do so for a much smaller set of currencies and a much shorter time period. Most importantly, they focus only on the regression-based approach and conclude that results are supportive of the expectations hypothesis over very short windows. We largely confirm their findings but significantly expand the analysis to include an analysis of a range of trading strategies related to UIP violations.

Second, our paper relates to a strand of the literature that studies intraday price patterns in the FX market starting with Wasserfallen (1989) and Cornett et al. (1995); followed by Ranaldo (2009) and Breedon and Ranaldo (2013) who document that local currencies depreciate during local working hours. More recently, Krohn et al. (2024) show that FX intraday return dynamics are tightly linked to the publication of foreign exchange benchmark rates, whereby the U.S. dollar appreciates in the run-up to foreign exchange institutional fixes, and depreciates in the hours thereafter. In contrast to these papers, we tie together high-frequency variations in intraday returns to low frequency violations of uncovered interest parity (UIP).

Finally, our paper is related to a literature that studies effects of macroeconomic or FOMC

[5] See Engel (1996) and Engel (2014) for surveys on the literature on UIP deviations.

announcements. For equity markets, Lucca and Moench (2015) show that a sizable fraction of realised stock returns is earned on FOMC announcement days. Similarly, Savor and Wilson (2013) show that the average excess return on U.S. stocks is significantly higher on days when macroeconomic news is scheduled for announcement. In fixed income markets, Peng and Pan (2024) document that returns to long-term U.S. treasury bonds are systematically positive and significant on the day before FOMC announcements, while Hillenbrand (2023) shows that yield dynamics on U.S. monetary policy announcement days substantially contribute to the secular decline in U.S. long-term yields over the last two decades. For currency markets, Mueller et al. (2017) show that long FX positions earn significant positive returns on FOMC announcement days, with returns increasing in the interest rate differential vis-a-vis the U.S. dollar. We complement the latter paper by documenting the importance of FOMC and macroeconomic announcements not only for individual currency excess returns but for a host of currency trading strategies that may have different exposures to currency risk factors.

The remainder of the paper is organised as follows. Section I describes the market conventions for trading currencies at daily and higher frequencies. In addition, we describe how to implement the existing tests for UIP violations to our high-frequency setup. In Section II we describe the data required to implement our high-frequency analysis. The regression-based approach is discussed in Section III while the portfolio-based results are presented in Section IV. Section V then discusses the effects of FOMC and macroeconomic announcements and Section VI concludes.

I. Market Conventions and UIP Tests in High Frequency

In this section, we first clarify the relevant terminology used in FX markets for short-term transactions. In addition, we recast regression- and portfolio-based methods to study UIP violations in high frequency.

A. Spot as Forward Trading

In financial markets, *spot* trading commonly refers to transactions with "immediate" delivery (as opposed to *forward* transactions where delivery happens at a pre-determined point in the future). However, settlement is usually delayed—in FX markets, this usually happens two business days following the spot trade—to give both parties enough time to settle their obligations given time zone differences and bank processing delays.[6] This means that an FX spot trade is not immediate

[6] The exception to this rule is the Canadian dollar which settles one trading day after the transaction date.

but effectively a two-day (or multi-day) forward transaction.[7] In order to establish the exact settlement date, it is important to track business days in both jurisdictions of the currencies to be exchanged, i.e., what matters for settlement are the jurisdictions of the respective currencies and not where the counterparties are located.[8] For example, if the trade date is a Wednesday, the settlement date would normally be a Friday if Thursday and Friday are business days in both jurisdictions. However, if Friday is a holiday in one of the two countries, then settlement will happen on the following Monday, again assuming there is no holiday on this day in either country.

Spot trades are the most frequent transactions in the FX market and the prices are commonly used to calculate FX (excess) returns at different frequencies. While traders routinely take into account that spot transactions involve a two-day settlement lag when managing their currency positions, the settlement lag is largely ignored in academic research as it is irrelevant. Instead, it is generally assumed that spot rates describe the immediate rate of exchange between two currencies. As we focus on higher-frequency transactions, however, the institutional and settlement details become important and there is a need to be very precise with regards to the various rates that are available in the market.

B. Short-Dated FX Transactions

Denote by S_t the spot exchange rate expressed in units of U.S. dollar per foreign currency.[9] A decrease in S_t corresponds to an appreciation of the U.S. dollar relative to the foreign currency. The τ-day domestic and foreign interest rates are i_t^τ and $i_t^{\tau,*}$, respectively. Covered interest parity (CIP) ensures that τ-day outright FX forwards obey

$$F_t^\tau = S_t \left(\frac{1 + i_t^\tau}{1 + i_t^{\tau,*}} \right). \tag{1}$$

FX forwards are quoted in terms of forward points (FP_t^τ), the number of basis points (bps) added to (or subtracted from) the current spot rate to determine the forward rate for delivery on

[7] In addition to the transaction and settlement dates, the value date is important in financial markets. It is the future time at which the value of an account, transaction, or asset becomes effective. In FX markets, the settlement and value date coincide, whereas in bond markets for example, the settlement date must be a business day but the value date can fall on any date of the month from which accrued interest is calculated. In FX, settlement can only happen on what is called an FX trading day.

[8] Some currencies are not quoted directly against each other but against the U.S. dollar, implying that an FX trading day must be a business day in up to three jurisdictions.

[9] Note that throughout we follow the euro vs. U.S. dollar quoting convention (EURUSD) where the U.S. dollar (our domestic currency) is the "quote currency."

a specific value date $t+\tau$ in the future, i.e.,

$$F_t^\tau = S_t + FP_t^\tau \quad \text{or} \quad FP_t^\tau = S_t \left(\frac{i_t^\tau - i_t^{\tau,*}}{1 + i_t^{\tau,*}} \right). \tag{2}$$

If the domestic interest rate is higher than the foreign interest rate ($i_t^\tau > i_t^{\tau,*}$), we observe a forward premium and forward points are added. Conversely, forward points are subtracted when there is a forward discount ($i_t^{\tau,*} > i_t^\tau$). Either way, imposing equation (1) ensures arbitrage-free pricing for FX forwards. In order to manage FX positions and exposures, traders can use a number of short-dated FX swaps, i.e., agreements to simultaneously borrow one currency and lend another while exchanging the amounts at maturity:

- Overnight (ON): swap today (t) against tomorrow ($t+1$) denoted F_t^{ON}.
- Tomorrow-Next (TN): forward swap agreed today (t) for tomorrow ($t+1$) against the next day ($t+2$) denoted F_t^{TN}.
- Spot-Next (SN): forward FX swap agreed today (t) for the spot date ($t+2$) against the following day ($t+3$) denoted F_t^{SN}.

As a rule, if a trader opens and closes a position during the same business day, the value date of the trades will be identical and the positions will net out during settlement at $t+2$ as intradaily interest is zero and only accrues if a position is held open through 17:00 New York time (see, e.g., Chaboud and Wright (2005)). A TN contract for example can then enable traders to avoid taking physical delivery of spot by simultaneously buying and selling a currency over consecutive business days once they hold an open position. The quoted TN rate adjusts the closing level of positions held at 17:00 ET by prevailing interest rate differentials. Depending on the cost of carry, a broker will adjust the trading account in that a long position in a higher yielding currency will earn a credit while a long position in a lower yielding currency will be charged a debit. Moreover, the contracts listed above allow traders to roll over their positions on a potentially daily basis if desired.

The quotation of FX forwards takes into account that spot transactions settle two business days after the transaction date. Any contracts that settle before or after the standard two-day lag require an adjustment for the interest rate differential in line with equation (1). In particular, this is the case for value today (TOD) and value tomorrow (TOM) trades that settle on the same or the next day, respectively. Thus, ON, TN and spot transactions allow to back out the exchange rate for a TOD trade for example. Define such a cash rate C_t using the logic for the forward rate used in equation (1):

$$S_t = C_t \left(\frac{1 + i_t^{\text{2d}}}{1 + i_t^{\text{2d},*}} \right) \quad \text{or expressed in logs} \quad c_t = s_t - i_t^{\text{2d}} + i_t^{\text{2d},*} = s_t - fp_t^{\text{2d}},$$

where fp_t^{2d} denotes the (log) forward premium, the difference between the domestic and the foreign interest rate for the period from the transaction to the settlement date (usually two days). To back out fp_t^{2d}, we can use the ON and TN contracts that are quoted in terms of forward points. When combining a spot transaction with an ON and a TN transaction, the ON back leg nets out the TN front leg, and the TN back leg nets out the spot trade. The implied cash rate can then be calculated by taking the spot rate and subtracting two days worth of forward points, i.e., $C_t = S_t - FP_t^{\text{ON}} - FP_t^{\text{TN}}$, where FP_t^i refers to the pricing convention of ON and TN FX swaps as per equation (2).

Note, however, that in order to calculate short term currency swap rates F_t^{ON} and F_t^{TN}, we effectively have to discount backwards in time, while for F_t^{SN} we can directly use the expression in equation (1). This for example implies that if $i_t^{\text{TN}} > i_t^{\text{TN},*}$, forward points are subtracted from the spot rate. Conversely, if $i_t^{\text{TN}} < i_t^{\text{TN},*}$, forward points are instead added to the spot rate if FP_t^{TN} is quoted as in equation (2).

To visualise the timing of the FX and interest rate transactions, we provide a schematic overview in Figure A-1 in Appendix AI. There, we also include an example on how positions are rolled in the FX market using data on the EURUSD exchange rate to illustrate the actual steps and explain the precise calculations.

C. High-Frequency UIP Regressions

We start with the forward premium puzzle that arises in standard Fama (1984) regressions testing the expectations hypothesis of forward FX rates (or studying violations of UIP using a regression approach). Replacing the forward rate in equation (1) with the expected spot rate we get:

$$\frac{E_t\left[S_{t+\tau}\right]}{S_t} = \left(\frac{1 + i_t^{\tau}}{1 + i_t^{\tau,*}} \right).$$

Delivery on a 1-month forward contract occurs on the calendar day in the next month that corresponds to the calendar day in the current month when the spot trade settles, i.e., at $t + 2$

days.[10]

UIP regressions are regularly run taking a log linear approximation (lower case letters indicate logs) of $(1+i_t^{\tau})$ and $(1+i_t^{\tau,*})$ ignoring Jensen's inequality arising from the expectations operator,i.e.,

$$
\begin{aligned}
E_t[s_{t+\tau} - s_t] &= i_t^{\tau} - i_t^{\tau,*}, \\
s_{t+\tau} - s_t &= \alpha + \beta\big(i_t^{\tau} - i_t^{\tau,*}\big) + \varepsilon_{t+\tau}, \qquad (3) \\
&= \alpha + \beta\big(f_t^{\tau} - s_t\big) + \varepsilon_{t+\tau}, \qquad (4)
\end{aligned}
$$

where equation (3) follows by imposing rational expectations and equation (4) follows by imposing covered interest parity (CIP). Bekaert and Hodrick (1993) show that unless the forward rate is matched with the appropriate future spot rate by accounting for all the delivery rules, the calculation of the return on the forward contract is generally not correct and, hence, the regression is potentially biased. However, they also show that for regressions using monthly forward rates (as is usually done in the literature), the bias introduced by this measurement error is not driving the widely documented failure of UIP.

We deviate from the large existing literature by considering higher frequencies to run the regression and a focus on a daily horizon for the FX instruments. With such a short-dated view, it is imperative to carefully measure FX returns, and to correctly line up forward and spot rates. To set up the regression and extract the one-day forward premium, we use the SN FX swap contracts:

$$
\begin{aligned}
s_{t+1} - s_t &= \alpha + \beta\big(i_t^{\text{SN}} - i_t^{\text{SN},*}\big) + \varepsilon_{t+\tau}, \\
&= \alpha + \beta\big(f_t^{\text{SN}} - s_t\big) + \varepsilon_{t+\tau}, \qquad (5)
\end{aligned}
$$

where $s_{t+1} - s_t$ is the change in the spot rate from value date $t+2$ to value date $t+3$ and $i_t^{\text{SN}} - i_t^{\text{SN},*} = FP_t^{\text{SN}}$ are the spot-next forward points that capture the one-day interest rate differential for the same time period.[11] That is, regression (5) appropriately aligns the daily changes in the spot rate from t to $t+1$ with the corresponding interest rate differential for daily rates.

[10] This only holds if this day next month is a business day. If that is not the case, delivery occurs on the following business day as long as it remains in the same month. Otherwise, delivery occurs on the first previous business day. One final exception is the so-called "end-to-end"-rule which applies when the value date falls on the last business day of the month. In this case, the corresponding forward value day will automatically be the last business day in the subsequent month (see, e.g., Bekaert and Hodrick (1993)).

[11] An exception to this rule is the CAD, for which the settlement period is $t+1$. Correspondingly, we use tomorrow-next contracts for this currency.

D. High-Frequency Portfolio Sorts

Fama (1984) regressions are not the only way to test for violations of UIP. A related failure is the well-known carry trade anomaly. While the forward premium puzzle is a fact about a regression coefficient, the carry trade is about a profitable trading strategy based on portfolio sorts. Hassan and Mano (2018) propose a comprehensive framework that allows to analytically relate regression-based and portfolio-based facts by recasting both the forward premium puzzle as well as the carry strategy in the context of trading strategies.

The traditional carry trade is implemented by lending in currencies that have high interest rates while borrowing in currencies that have low interest rates. Related, the dollar carry trade is implemented by going long all foreign currencies when the world average interest rate is high relative to the U.S. interest rate, and by going short all foreign currencies when it is low (see Lustig et al. (2014)). Finally, the forward premium puzzle corresponds to a forward premium trading strategy that involves going long a currency when its interest rate exceeds its own long-run mean and going short otherwise.

The trading strategies related to UIP violations are formed using a decomposition of the unconditional covariance of expected currency returns (or risk premia) with forward premia into a cross-currency ("static trade"), a between-time-and-currency ("dynamic trade"), and a cross-time ("dollar trade") component:

$$\begin{aligned}\sum_{i,t}\left[\left(rx_{i,t+1}-\overline{rx}\right)\left(fp_{i,t}-\overline{fp}\right)\right] = & \underbrace{\sum_{i,t}\left[rx_{i,t+1}\left(\overline{fp_i^e}-\overline{fp^e}\right)\right]}_{\text{Static Trade}} + \\ & \underbrace{\sum_{i,t}\left[rx_{i,t+1}\left(fp_{i,t}-\overline{fp_t}-\left(\overline{fp_i^e}-\overline{fp^e}\right)\right)\right]}_{\text{Dynamic Trade}} + \\ & \underbrace{\sum_{i,t}\left[rx_{i,t+1}\left(\overline{fp_t}-\overline{fp^e}\right)\right]}_{\text{Dollar Trade}} + \underbrace{\sum_{i,t}\left[\overline{rx}\left(\overline{fp^e}-\overline{fp}\right)\right]}_{\text{Constant}}, \qquad (6)\end{aligned}$$

where $rx_{i,t+1} = f_{it} - s_{i,t+1}$ is the log excess return on currency i between time t and $t+1$, $fp_{it} \equiv f_{it} - s_{it}$ is the forward premium (or the negative of the forward discount), $\overline{rx}$ is the mean currency return across currencies and time periods, $\overline{fp_t}$ is the average forward premium of all currencies at time t, $\overline{fp_i}$ is the currency-specific mean forward premium, and $\overline{fp}$ is the unconditional mean forward premium. The superscript e denotes investor's ex ante (i.e., at time 0) expectations.

The static trade represents a static version of the carry trade (SC) where the portfolio is long currencies that are expected to have high interest rates on average and short those that are expected to have low interest rates. The traditional carry trade (TC) is the sum of the static and the dynamic trade, while the return to the forward premium trade (FP) is the sum of the dynamic and the dollar trade, i.e., relation of the traditional carry and the forward premium trade is determined by the relative contribution of the dynamic trade (DT) as they share the between-time-and-currency part. The dollar trade is the dollar carry (DC) strategy proposed in Lustig et al. (2014) and it is also a component of the forward premium trade. By construction the the dollar and the carry trades are independent. In addition to the various strategies, we also consider returns to the dollar portfolio (DOL) that always goes long a basket of foreign currencies. In sum, we have:

$$\text{Traditional Carry: } \sum_{i,t} \left[rx_{i,t+1} \left(fp_{i,t} - \overline{fp}_t \right) \right] \tag{7}$$

$$\text{Static Carry: } \sum_{i,t} \left[rx_{i,t+1} \left(\overline{fp_i^e} - \overline{fp^e} \right) \right] \tag{8}$$

$$\text{Dollar Carry: } \sum_{i,t} \left[rx_{i,t+1} \left(\overline{fp}_t - \overline{fp}^e \right) \right] \tag{9}$$

$$\text{Forward Premium: } \sum_{i,t} \left[rx_{i,t+1} \left(fp_{i,t} - \overline{fp}_i^e \right) \right] \tag{10}$$

Note that the portfolio weights in equations (7) to (10) are linear and depend on deviations from means. The extant literature studies returns to the various trading strategies (in particular the carry and dollar trades) predominantly based on monthly, quarterly, or lower frequency holding periods. We focus on much higher frequencies and consider daily close-to-close returns measured at 17:0 ET as well as returns split into overnight and intraday components. In order to account for the interest portion of these portfolio returns, we attribute the interest rate differential fully to the overnight component of trading returns for positions that are open at 17:00 ET on the previous day.

II. Data

We compile our data from multiple sources. Data on intraday foreign exchange rates are obtained from Refinitiv covering 25 years of high-frequency data from January 1999 to December 2023. We focus on the G9 currencies, i.e., the Australian dollar (AUD), the Canadian dollar (CAD), the euro (EUR), the Japanese yen (JPY), the New Zealand dollar (NZD), the Norwegian krone (NOK), the Swedish krona (SEK), the Swiss franc (CHF), and the British pound (GBP), all vis-à-vis the U.S. dollar.

We transform the tick-by-tick data from Refinitiv in the following way. We obtain the best bid and ask quote recorded to the nearest even second. After applying a number of filters to correct the data for outliers, the price at each five-minute tick is obtained by linearly interpolating from the average of the bid and ask quotes for the two closest ticks. If no quote was submitted during a specific interval, we fill the gap with the most recent available price.

Following previous studies (see, e.g., Andersen, Bollerslev, Diebold, and Vega (2003)) we exclude quotes that are submitted on days that are associated with low trading activity. For example. we remove all quotes on weekends between Friday 17:00 and Sunday 17:05 (Eastern Time, ET). Similarly, we drop quotes around fixed holidays, i.e., Christmas (24 to 26 December), New Year (31 December to 2 January), and 4 July, and around flexible holidays, such as Good Friday, Easter Monday, Memorial Day, Labor Day, and Thanksgiving (including the day after). In addition, we collect dates of country-specific holidays from Bloomberg in order to correctly align the days of interest accrual with the corresponding daily spot transactions. As a result, daily observations vary across currency pairs, ranging between 5,470 days for the yen to 5,877 days for the euro.

We supplement the high-frequency FX spot data with daily data from Bloomberg on short-term forward points with tomorrow-next (TN) and spot-next (SN) maturities. These short-term forward contracts exactly match the settlement period of a one-day spot trade, allowing us to align daily spot rate changes with daily forward discounts. Moreover, and in line with existing literature, we use forward rates from Datastream with one-month maturity for monthly UIP regressions. For additional robustness tests, we source deposit interest rates with maturities ranging between one day (tomorrow-next and spot-next, respectively) and one month (1M) from Datastream as well.[12]

Lastly, we collect information on announcements dates and times from Bloomberg's Economic Calendar. Following Savor and Wilson (2014), we primarily focus on central bank announcements as well as the main macroeconomic announcements related to labor market dynamics (e.g., U.S. non-farm payroll), inflation (e.g., CPI Ex. Food and Energy), and output (e.g., GDP QoQ or Industrial Production MoM).

[12] We use historical monthly data on 1-month forwards during the period January 1994 to December 1998 to proxy the ex-ante expectations $\overline{fp}^e$ introduced in section D of the previous section.

III. Daily Regression-Based Tests

We begin by running conventional monthly UIP regressions, with the twist that we split returns into intraday (ID) and overnight (ON) components aggregated over the month. In line with how interest accrual is measured, we use 17:00 ET as the close of day to define daily log spot returns:

$$\Delta s_{t+1}^{\text{CTC}} = s_{t+1}^{17:00} - s_t^{17:00},$$

where $s_t^{17:00}$ is the log mid-price at the end of day t. We express returns in U.S. dollar (domestic) per foreign currency, i.e., a negative return observation implies an appreciation of the U.S. dollar appreciates against the foreign currency. Note that our choice of closing time differs from the "London fix" time at 16:00 GMT that is often used in studies using FX data.

To decompose the daily currency returns into an intraday and an overnight component, we take the perspective of a U.S. investor based in New York and define the beginning and ending of the intraday period as 7:00 ET and 17:00 ET on day t, respectively. In line with previous studies (e.g., Cespa, Gargano, Riddiough, and Sarno (2022)), we assume that these hours capture the most active trading period in the spot market for New York based market participants. The overnight window for day t covers the period between 17:00 ET on day $t-1$ until 7:00 ET on day t. This window thus comprises all opening times and some of the closing times of the major FX trading venues located outside of the U.S.[13] In addition, interest on FX positions is paid at 17:00 and is thus attributed to the overnight period.

More formally, we define the components as follows, ensuring that our intraday (ID) and overnight (ON) return measures exactly add up to the close-to-close returns (CTC):

$$\Delta s_t^{\text{ID}} = s_t^{17:00} - s_t^{7:00}. \qquad \Delta s_t^{\text{ON}} = s_t^{7:00} - s_{t-1}^{17:00}.$$

We also create monthly time series by aggregating all daily log returns within a month (i.e., $t \in m$) for a total of 300 monthly observations for the CTC, ID and ON returns, respectively:

$$\Delta s_t^{\text{CTC,m}} = \sum_{t \in m} \Delta s_t^{\text{CTC}} \qquad \Delta s_t^{\text{ID,m}} = \sum_{t \in m} \Delta s_t^{\text{ID}} \qquad \Delta s_t^{\text{ON,m}} = \sum_{t \in m} \Delta s_t^{\text{ON}}$$

Lastly, we construct daily log excess return (rx) for a U.S. investor, who takes long positions in foreign currencies as

$$rx_{t+1}^k = \Delta s_t^k + s_t - f_t$$

[13] As FX markets trade around the clock, defining intraday vs. overnight periods is not straightforward. We use 7:00 ET as Krohn, Mueller, and Whelan (2024) for example show that volume starts to pick up around that time for many currencies with a local spike at 7:00 ET. However, our results are robust to moving the start of the intraday period back to 8:00 ET.

where s_t and f_t refer to daily spot and short-term forward rates, and Δs_t^k are the returns during intraday period k, where $k \in \{CTC, ON, ID\}$.

A. *Forward Premium Regressions*

We start by re-examining the forward premium puzzle using the following fixed effects panel regression:

$$\Delta s_{t+1}^j = \alpha + \beta(f_t^\tau - s_t^j) + \varepsilon_{t+1}^j, \tag{11}$$

where $\Delta s_{t+1}^j = s_{t+1}^j - s_t^j$ refers to the monthly log exchange rate change for currency j, f_t^τ denotes the 1-month log forward rate (i.e., $\tau = 1\text{M}$) and s_t^j is the log spot rate in period t.

A positive coefficient under the null $H_0 : \beta = 1$ implies that the forward rate is an unbiased estimate of the future spot exchange rate. As rational agents drive the value of the forward rate to the price of the expected future exchange rate, speculation in the forward market becomes unprofitable. In contrast, if the forward rate is higher (lower) than the expected spot rate, market participants earn a premium from buying (selling) a currency in the forward market.

Unlike the original Fama (1984) specification, we estimate three separate versions of regression (11) using our monthly CTC, ID or ON return time series as the dependent variable on the left-hand side, respectively. The top panel in Figure 1 illustrates our first major finding. The bar plot shows the estimated β-coefficients from the panel regression for the three return series along with the corresponding error bands. In line with previous papers, the coefficient based on CTC returns is negative (-0.5, grey bar) and far from unity. According to Fama (1984), such a result is consistent with perfect risk-sharing and the existence of a time-varying risk premium; however, alternative channels can also explain this finding such as deviations from full information rational expectations (see, e.g., Froot and Ramadorai (2005) and Stavrakeva and Tang (2024)) or imperfect risk-sharing, market segmentation and the role of financial intermediation (see, for example, Gabaix and Maggiori (2015) and Chernov et al. (2024)).

Panel A in Figure 1 also shows a strong divergence in the relationship between the forward discount and returns for different periods of the day. The estimated β-coefficient is positive (0.89, blue bar) and statistically not different from unity for the overnight hours (the p-value is 0.86), while during local trading hours in New York, the same β-coefficient is significantly negative with a point estimate of -1.31 (orange bar). Thus, the results suggest that the failure of the UIP relationship detected in conventional regressions is primarily due to exchange rate movements during the intraday period; whereas forward discounts and currency returns seem to be more aligned during the overnight hours.

[INSERT FIGURE 1 HERE]

In the bottom panel of Figure 1, we present the corresponding results for daily panel regressions, carefully matching up daily spot rate changes with short-term forward discounts (using tomorrow-next or spot-next contracts) as outlined in Section I. The divergence between overnight and intraday returns is now even more striking, with estimated β-coefficients equal to 1.32 and -1.28 for the respective windows. Both coefficients are significantly different from zero, and the discrepancy between overnight and intraday periods further suggests differing patterns in the time-varying risk premium over the course of the day.

In Table I we report the daily regression results at the individual currency level, as well as for the unconditional dollar portfolio (DOL) that goes long all foreign currencies in equal weights. For CTC returns (Panel A), β-coefficients are negative for seven currencies, but the null hypothesis cannot be rejected due to the massive standard errors. The point estimate for the slope coefficient is only positive for CAD, and JPY. Splitting the time series into an overnight and intraday component, the various regression results almost uniformly confirm those highlighted in Figure 1 as all point estimates for the slope coefficient are positive overnight and negative during the day (with the exception of JPY ID). Moreover, the null hypothesis $H_0 : \beta = 1$ can only be rejected for JPY for the overnight period but is strongly rejected for 7 out of 9 individual currency pairs during the day (the exceptions are CAD and again JPY).

[INSERT TABLE I HERE]

In addition to the strong pattern for the slope coefficient, Table I also highlights systematic differences of the intercepts between intraday and overnight hours. Overnight (Panel B), the intercept is negative for all currencies except NOK, ranging between -2.65 bps (GBP) and 0.24 bps (NOK), while during the day (Panel C), the intercept term is largely positive (exceptions are JPY and NOK), ranging between -1.03 bps (JPY), and 3.18 bps (CHF). For the dollar portfolio for example, the intercept switches from -1.19 bps (with a t-statistic of 2.95) to 1.59 bps (with a t-statistic of 3.28). The significant negative intercepts reflect the average appreciation of the U.S. dollar during the overnight period in the U.S. markets, whereas the positive intecepts in Panel C are reflecting the average depreciation of the U.S. dollar during the main trading hours in New York (see also Krohn et al., 2024).

The corresponding regression results for the monthly data are qualitatively the same and are presented in the Online Appendix. Thus, the daily as well as the monthly regression results suggest that deviations from the expectation hypothesis are largely driven by return dynamics in play during U.S. trading hours. Moreover, the results point towards the existence of a risk premium that is only statistically different from zero during certain hours of the trading day. The results are also consistent with the view that rational agents' expectations about the future path of the spot exchange rate are in line with the forward rate during overnight hours, but then deviate when trading in New York commences. The differences in expected and realized future spot rates generate room for a risk premium to be earned mainly during the day (in the U.S.).

B. Bootstrap Evidence

To further assess the statistical robustness of our findings, we conduct a block-bootstrapping exercise, where we randomly sample 5,000 combinations of days from the sample of ID (orange), and ON (blue) returns. The optimal block length is chosen following Patton et al. (2009), although we show in the Appendix that results are robust to alternative block lengths. For each sample, we estimate daily UIP panel regressions and plot the distribution of the slope coefficient, $\hat{\beta}$ in Figure 2.

[INSERT FIGURE 2 HERE]

We find that the empirical distributions of the coefficients from both intraday periods barely overlap. Coefficients for ON returns are centered around 1.32, and more than 95% of coefficient estimates are positive. In contrast, the distribution of slope coefficients for ID returns is notably shifted towards the left. It is centered around -1.28 whereby the vast majority of estimated slope coefficients has a negative sign. Moreover, as indicated by the blue and orange vertical dashed lines, the 95% confidence interval of both distributions do not overlap, building further confidence in the statistical differences between the estimates.[14] Overall, the bootstrapping exercise highlights the validity of the differences in UIP regression outcomes for different return windows measured over a 24-hour period.

[14] We report in the appendix empirical distributions from the same bootstrap exercise for CTC returns, as well as the empirical distributions of p-values, assessing the null hypothesis $\beta = 1$.

C. UIP Regressions Over Time

Bussiére et al. (2022) show that the conventional UIP relationship tends to hold during the period after the global financial crisis, while the negative slope coefficient in the UIP regressions is largely driven by pre-crisis dynamics. They label the change in the sign of the β-coefficient the "new Fama puzzle".

[INSERT FIGURE 3 HERE]

Thus, in Figure 3 we apply a similar split to our baseline short-term UIP regressions with the first sub-period ranging from January 1999 to December 2008 (CTC^{99-08}) and the second from January 2009 to December 2023 (CTC^{09-23}). The CTC results (grey bars) in Figure 3 support the findings in Bussiére et al. (2022) at the daily frequency, as the estimated β-coefficient turns positive for the most recent period after the financial crisi. However, error bands are large again and we cannot reject the null hypothesis for the pre-crisis period. Separating the overnight from the intraday returns, however, paints again a clearer picture as the expectations hypothesis can be strongly rejected for the intraday period (orange bars) whereas coefficient estimates are not significantly different during overnight period (blue bars).

The divergence between these two periods is stronger for the second sub-sample period, during which the estimated β-coefficient exceeds the value of 2 overnight but it is close to -1.5 during the day. The decomposition of CTC-returns into different components suggests that the new Fama puzle might be particularly driven by the strong response of the exchange rate to the forward discount during the overnight hours.

D. Covered Interest Parity

The interest rate differentials used in setting up the UIP regression are generally measured without using actual interest rates but via the forward discount, i.e., the difference between forward and spot rates (see equation (4)). In frictionless markets, the two measures must coincide as covered interest rate parity must hold. In reality, however, interest rate differentials measured using deposit rates may differ from forward discounts at any point in time. In Figure 4, we thus present the results of short-term UIP panel regressions when short-term deposit rates are used as regressors on the right-hand side (i.e., as suggested in equation (3)).

[INSERT FIGURE 4 HERE]

While the point estimates for the slope coefficient are slightly different, the results remain qualitatively the same. For CTC returns, the estimated β is close to zero with large error bands, for the overnight period the coefficient is closer to one and the null hypothesis cannot be rejected while during the intraday period the coefficient turns negative and we can reject the expectations hypothesis. That is, the main result with respect to the split between overnight and intraday returns is not driven by potential concerns about deviations from CIP.

IV. Daily Portfolio-Based Tests

We implement the trading strategies described in equations (7) to (10) at the daily frequency. In addition, we split the portfolio returns into overnight and intraday components. Panel A in Table II considers a close-to-close (CTC) return decomposition of that trading strategies and the components described in equation (6). The carry trade exhibits a statistically marginally significant average annual excess return of around 3.6% per year. This is in line with existing evidence for our sample period as returns for the carry trade are significantly lower than during the 1980s and 1990s. The decomposition in Panel A also highlights that virtually 100% of the carry return is due to the actual carry (i.e., the forward premium) and is not driven by an appreciation of high interest rate currencies.

[INSERT TABLE II AND FIGURE 5 HERE]

Moving across columns provides additional insights regarding the profitability of the other strategies. First, the biggest share of the carry returns comes from the static component (5.34%), while the re-balancing of currencies captured by the dynamics component in fact generates negative returns (-1.72%). For the FP trade and Dollar trade, we find that both trading strategies generate positive excess returns of 4.54% and 2.83%, respectively; however, in contrast to the carry trade excess returns earned by both of these approaches are not statistically different from zero. Lastly, across all five columns excess returns are driven by the positive forward discount ($f_t - s_t$), while the spot component (Δs)is small and not distinguishable from zero.

Panel B then provides an intraday decomposition of returns to all of these five strategies, reporting excess returns that are earned for holding foreign currency positions during the first hour after the cut-off point at 17:00 ($xret^{1H}$) and the spot returns during that hours (Δs^{1H}). The last two rows refer to the return components that are earned throughout the rest of the day, distinguishing between the overnight period that excludes the first hour (Δs^{ON-1H}) and intraday period (Δs^{ID}). First, excess returns held for just the first hour of the trading remain significant and positive at 0.78%. These excess returns are smaller compared to the CTC returns in Panel A, as spot returns asssociated with carry portfolios are strongly negative during the first hours of the trading day. Importantly, it is only due to subsequent return dynamics that occur during the rest of the day which make the carry trade an economically significant trading approach. In fact, during the overnight period the spot carry component is -3.45% ($\Delta s^{1H} + \Delta s^{ON-1H}$), while it reverses to 3.44 (Δs^{ID}) during the intraday period. Second, similar trends can be observed for the other trading strategies. For example, over the entire overnight period the Dollar and FP trade generate negative return of -2.45% and 6.08%, respectively, while intraday spot returns increase to more than 4.57% and 5.25 %.

Figure 5 illustrate the return dynamics for CTC excess returns and the intraday components for all strategies showing the time series dynamics of a total return index over the sample period 1999 to 2023. The black line tracks the total return to a $1 investment at the beginning of the sample. Over the whole sample period, the portfolio value of the carry trade increases by around 140% with marked drawdowns during the global financial crisis and the COVID episode for example. Positively contributing to these patterns are intraday spot returns (orange line) and the excess returns overnight that contain the forward discount component (solid blue line). The overnight spot returns, in contrast, are negative as indicated by the dashed blue line that largely evolves below one, reaching a final investment of 0.44 at the end of the sample. In similar way for the other trading strategies, the intraday component is largely positive and arguably the main driver of the total return series (black line).

Overall, Table II and Figure 5 add new nuances to our understanding of the profit-generating process of well-known currency trading strategies. While they confirm findings of previous work that excess returns of these strategies are largely driven by the forward discount, they highlight that an additional crucial component are systematic spot movements during the intraday hours. In fact, it appears that only during these hours spot returns diverge from the forward discount and sizeable risk-premia emerge during the second half of the trading day.

To visualize this point, Figure 6 plots the evolution of spot returns over the course of the trading (solid line). The red-dashed line refers to the inverted forward discount, i.e., an overlap between the two lines implies zero excess returns and in the cross-section the forward discount is offset by spot return dynamics. For brevity, we focus on the Carry trade (Panel A), it's static component (Panel B), and the Dollar Trade (Panel C). The shaded areas indicate the 95% range of intraday returns based on 10,000 bootstrapped samples with replacement. We include these to exemplify the variation in cumulative returns. Building upon the results II, Panel A suggests that risk premia earned by the carry trade are offset by about 20:00 and remain close to the forward discount until about 7:00 in the morning. Subsequently in the run-up to market opening in the U.S., spot returns start moving in favor of the carry trade profits and rever the negative overnight trend. Spot returns revert until zero by then end of the trading day. This pattern is largely mirrored for the static trade, with the important exception that spot returns actually turn positive in the last few hour before market closing. Lastly, for the Dollar trade, the spot component overshoots the level of the forward discount and the dollar appreciates by almost 6% within the first four hours of trading. Subsequently, we note a strong reversal and foreign currencies appreciate strongly up to 2% by the end of trading day. Again, the divergence from the forward discount appears in the intraday period. Overall, these graphs confirm the importance of intraday pattens in spot markets for currency strategies.

[INSERT TABLE 6 HERE]

V. FOMC and Macroeconomic Announcements

A. Regression-Based Tests

Having established a way to run daily regressions to test the expectations hypothesis, we can now further investigate how UIP deviations arise. In this section, we focus on the role of central bank and macroeconomic announcements, and on how large movements in time-varying risk premia on these days may impact the relationship between exchange rates and interest rates.

We focus on days of major U.S. announcements, i.e., we follow the literature and assess the marginal impact on the slope coefficient on days of FOMC announcements, non-farm payroll, CPI, and GDP announcements. To this end, we estimate the following augmented regressions

$$\Delta s^j_{t+1} = \alpha + \alpha^A \times \mathbb{1}^A + \beta(f^\tau_t - s^j_t) + \beta^A(f^\tau_t - s^j_t) \times \mathbb{1}^A + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, $(f^\tau_t - s^j_t)$ refers to the short-term forward discount with maturity $\tau = 1D$, and $\mathbb{1}^A$ is an indicator variable equal to one on the day before major U.S. announcement days, and zero otherwise. Results are reported in Table III. For each of the three sub-period, the first column shows the estimation results when all four announcement types are considered (1,017 days), while the subsequent columns refer to subsets of the announcements.

[INSERT TABLE III HERE]

Isolating FOMC announcement and days of major macroeconomic releases in a regression framework, which uses short-term forwards, we can precisely pin down the importance of news releases for UIP. In fact, for close-to-close returns, we find that the slope coefficient is positive on non-announcement days (0.19), while the marginal effect on announcement days, i.e., β^A, is -0.93. Even though we cannot reject the null hypotheses $H_0 : \beta = 1$ or $H_0 : \beta + \beta^A = 1$, the change in sign of the point estimates suggests there are substantial differences in the UIP relationship across different types of days.

Moving onto the overnight and intraday periods, results from Table I carry over: UIP holds during the overnight period and it fails during the intraday hours. For instance, for the overnight period the p-value of testing the aggregate impact of the forward discount on spot returns, i.e., $\beta + \beta^A$, is 0.49 while it is only 0.01 during the intraday period, strongly rejecting the parity condition during these hours. While the slope coefficient is negative across all days, the rejection is particularly pronounced on announcement days, as indicated by the substantially lower value of β^A, which ranges between -0.40 and -3.48 across the three columns.

Overall, these results suggests that risk premia on announcement days are different than on non-announcement days. In a next step, we explore the implications of different risk premia dynamics across different types of days for the cross-section of currencies.

B. Portfolio-Based Tests

To further understand the impact of news releases and announcements on risk premia in the cross-section of currencies, Table IV reports results of the high-frequency Hassan and Mano (2018) decomposition by isolating the importance of announcement days during our sample. Panel A (Panel B) reports results for currency excess returns (spot returns) for all days ("All"), FOMC and major U.S. macroeconomic releases ("Ann", 998 days), and all other days ("Other", 4991 days). All returns are expressed in annualized percentage and scaled by the number of days in each subsample, i.e., the rows "Ann", and "Other" equal the return values displayed in the row "All".

Starting with the traditional carry (TC), Table IV suggests a significant proposition of the strategy's excess returns of 3.63% are earned on a limited number of days. In fact, 2.25%, or 62%, are generated on FOMC and major U.S. announcement days, which only represent 17% of days in the entire sample. On the majority of other days (83% of the sample), the strategy only earns statistically insignificant 1.37%. Focusing on the sub-components - i.e., SC and DY - the table shows that the returns are primarily driven by the static portfolio components of the carry trade. On FOMC and macro announcement days, the consistently low- and high-yielding currencies in total generate over 4% annualized excess returns, while the significantly negative returns of the dynamic strategy (-1.38-1.38=-2.52), overall dampen the profitability of the carry. Similar dynamics can be observed for the dollar portfolio, where foreign currencies collectively appreciate by 2.35% on announcement days, while returns are negative on other days of the sample (-2.08%).

For the DC and FP trade, in contrast, we observe a different pattern. Excess returns on FOMC days are negative for both strategies, generating negative returns of -1.12% and -3.64$. On no-announcement days, the excess returns turn positive earning over 5% and 6%, respectively. Taken together, we note that even though all strategies earn positive returns during the intraday period, the profitability of different strategies varies across different types of days.

Panel B provides an overview of the decomposition but focuses on the spot return component. Overall, the pattern largely resembles the previously discussed dynamics, suggesting that spot prices display substantial movements on announcement days. For example, for TC, Panel B suggests that only on the two different types of announcement days the strategy earns positive spot returns (1.65%), while returns on all other days are in fact negative (-1.66%).

[INSERT TABLE IV HERE]

The significance of announcement days for some currency trading strategies is also illustrated by figure 7. On the left we depict total return indices for the traditional carry, static carry and the dollar portfolio, while the right panel refers to the dollar carry, the forward premium trade and the dollar carry trade by Lustig et al. (2014). All panels show total return indices for an initial investment of $1, when one enters short- and long positions on all days (black line), when one does not enter positions a day before FOMC announcement (blue), or on FOMC annoucement and days of macroeconomic releases (orange). First, Taking TC as example, return diminish from 2.37 for every dollar invested to just abut 2.07 if FOMC days are excluded and only 1.39 if also trades around macroeconomic releases are avoided. Similar observations conclusions can be drawn for and DOL. Second, for DC, FP and DC-LRV the opposite pattern is noticeable, i.e., the decision not to take long positions in all currencies on announcement days increases returns. Third, while returns mostly accumulated in incremental steps during most over our sample, the global financial crisis, the COVID pandemic and the following period of increased interest rates had a big impact on these strategies. In particular the profitability of DC, FP, and DC-LRV are driven by the subsample following the COVID-pandemic and the start of global hiking cycle.

[INSERT FIGURE 7 HERE]

Lastly, Figure 8 provides insights into the intraday dynamics of the strategies' spot component. Panel A presents the intraday components for all days, while Panels B and C focus solely on FOMC and macroeconomic announcement days, respectively. Panel D covers all other days, during which neither of the two types of announcements occur.

Panel A highlights the differences between overnight and intraday returns, with all strategies generating negative returns during the early part of the day. Specifically, FP and DC spot returns drop to -6% and -8% in the first few hours of the trading day, only beginning to recover slowly thereafter. In contrast, all currencies generate positive returns during the intraday hours, with SC and DC closing the day with the highest returns, followed by DC-LRV, DOL, TC, and FP.

Regarding announcement days, Panels B and C suggest that intraday returns are generally flatter during the overnight period. For example, on FOMC days, overnight returns never fall below -1% and are even positive for DOL and SC. The flatter return pattern could be indicative of the generally lower average trading volume in the run-up to major announcements, as market participants await the outcome of monetary policy decisions or news releases. Additionally, both panels emphasize the importance of announcements, particularly for the carry trade and its component. SC returns ("light green") clearly depict a jump at 14:00 in Panel B and at 8:30 in Panel C, followed by further increases for the rest of the trading day. Similar dynamics, though sometimes with a delay, can be observed for the other strategies. Overall, the panels highlight the importance of intraday trading hours for the profitability of some currency trading strategies, as returns tend to be close to zero or negative during the overnight hours of the average day but turn positive during the day, in particular when major news are released.

[INSERT FIGURE 8 HERE]

VI. Conclusion

In this paper, we document that high-frequency deviations from uncovered interest parity (UIP) are primarily driven by intraday spot return dynamics. On average, the U.S. dollar appreciates sufficiently during the overnight period, offsetting the forward discount as predicted by theory. However, it diverges during intraday hours, undergoing a sharp depreciation, which leads to the failure of UIP.

Using short-term forward points and accounting for settlement conventions in the foreign exchange market, we show how the slope coefficient of conventional UIP regressions switches from a positive value of 1.32 during the overnight hours, to -1.28 during the intraday period for the panel of G9 currencies vis-à vis the U.S. dollar. This pattern is a robust feature of the data, with our sample spanning over 25 years of high-frequency data and currencies that collectively represent more than 75% of the daily average trading volume.

Furthermore, we exploit the large cross-section of high-frequency returns and assess the implications of intraday UIP deviations for trading strategies. Decomposing high-frequency portfolio returns, we document that for compensation to the carry strategy is almost exclusively coming from intraday returns, as the profits earned from entering forward positions in U.S. dollar (i.e., the forward discount) are largely offset by overnight spot return movements. For example, annualized average excess returns to the traditional carry trade during our sample period are 3.63%, with 3.44% coming from intraday spot returns.

Lastly, we divide the sample into different subsets to emphasize the significance of FOMC announcements and major U.S. macroeconomic releases in driving time-varying currency risk premia. Although these days account for only 15% of our sample, nearly two-thirds of the excess returns from the traditional carry trade are earned during this small subset of days. The same is not true, however, for the dollar carry as well as the forward premium trade that exhibit negative excess returns on FOMC and macro announcement days. In contrast to the carry portfolio, returns to these portfolios are exclusively earned on non-announcement days.

Overall, our findings based on high-frequency data provide compelling evidence that the significantly positive excess returns earned by well-known currency trading strategies are indeed compensation for risk, which investors are primarily exposed to during intraday hours. Moreover, the results suggest that while exposures over the course of the day are similar, they diverge significantly on days when central bank or macroeconomic news is released.

VII. Tables

Table I

Daily UIP Regressions and Intraday Returns

This table reports results of the following regression

$$\Delta s^j_{t+1} = \alpha + \beta(f^{\tau,j}_t - s^j_t) + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(f^{\tau,j}_t - s^j_t)$ refer to the short-term forward discount with maturity τ =1D. Panel A, B, and C refer to close-to-close, overnight, and intraday returns, respectively. For the definitions of overnight and intraday returns see Note 1. Numbers in round parentheses refer to t-statistics based on Newey and West (1987) or Driscoll and Kraay (1998) adjusted standard errors. Numbers in squared parentheses show the p-value based on a Wald-test with the null hypothesis $H_0 : \beta = 1$. The sample period is January 1999 to December 2023.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK	DOL	PANEL
					Panel A: Close-to-Close						
α	0.41	0.38	0.68	0.31	-0.15	-2.29	-0.42	-0.32	-0.23	0.37	0.16
	(0.36)	(0.57)	(0.58)	(0.34)	(-0.20)	(-2.26)	(-0.43)	(-0.26)	(-0.24)	(0.56)	(0.25)
β	-0.14	1.62	-0.02	-0.26	-2.29	2.48	-0.92	-1.22	-0.49	0.12	0.04
	(-0.10)	(0.78)	(-0.02)	(-0.22)	(-1.41)	(3.12)	(-0.92)	(-0.95)	(-0.42)	(0.11)	(0.06)
p-val	[0.40]	[0.76]	[0.37]	[0.28]	[0.04]	[0.06]	[0.06]	[0.08]	[0.20]	[0.41]	[0.16]
$\bar{R}^2$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	5676	5804	5774	5876	5796	5469	5756	5632	5737	6000	51520
					Panel B: Overnight						
α	-0.63	-0.65	-2.14	-2.31	-2.54	-0.90	-0.64	-1.90	-2.02	-1.27	-1.39
	(-0.80)	(-1.66)	(-3.09)	(-4.37)	(-4.92)	(-1.19)	(-1.01)	(-1.97)	(-3.10)	(-3.21)	(-3.45)
β	1.20	1.80	0.77	1.83	1.25	2.27	1.27	0.24	1.06	2.04	1.32
	(1.33)	(1.75)	(1.28)	(2.57)	(1.26)	(3.61)	(2.03)	(0.25)	(1.30)	(3.08)	(3.03)
p-val	[0.82]	[0.44]	[0.71]	[0.24]	[0.80]	[0.04]	[0.67]	[0.43]	[0.94]	[0.12]	[0.46]
$\bar{R}^2$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	5676	5804	5774	5876	5796	5469	5756	5632	5737	6000	51520
					Panel C: Intraday						
α	1.04	1.03	2.81	2.62	2.39	-1.39	0.23	1.59	1.79	1.65	1.56
	(1.34)	(1.81)	(3.07)	(3.68)	(4.02)	(-1.97)	(0.29)	(1.97)	(2.17)	(3.24)	(3.04)
β	-1.34	-0.18	-0.79	-2.09	-3.55	0.21	-2.18	-1.46	-1.55	-1.92	-1.28
	(-1.52)	(-0.09)	(-0.87)	(-2.04)	(-2.75)	(0.39)	(-2.92)	(-1.73)	(-1.79)	(-2.38)	(-2.35)
p-val	[0.01]	[0.54]	[0.05]	[0.00]	[0.00]	[0.14]	[0.00]	[0.00]	[0.00]	[0.00]	[0.00]
$\bar{R}^2$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	5676	5804	5774	5876	5796	5469	5756	5632	5737	6000	51520

Table II

Intraday Returns and Cross-Sectional Currency Strategies

This table reports annualized average returns to the different currency strategies obtained from the Hassan and Mano (2018) decomposition. Results in Panel A are based on close-to-close returns, distinguishing between excess returns (rx), forward discount ($f_t - s_t$) and spot returns (Δs). Panel B shows results for a decomposition reporting excess returns when short- and long-positions are closed after the entire overnight periods (rx^{1H}), after the first hour of trading (rx^{1H}), and the spot returns during the first hour, the rest of the ON period and during the ID hours (Δs^{1H}, Δs^{ON-1H} and Δs^{ID}). The columns refer to different trading strategies, i.e., traditional carry ("TC"), static carry ("SC"), dollar carry ("DC"), forward premium ("FP"), or the dynamic trade ("DT"), the dollar portfolio ("DOL"), and the dollar carry trade by Lustig et al. (2014). Numbers in parentheses show t-statistics. The sample period is January 1999 to December 2023.

Panel A: Close-to-Close

	TC	SC	DC	FP	DT	DOL	DC-LRV
xret	3.63	5.34	4.54	2.83	-1.72	0.27	4.04
	(1.96)	(1.60)	(1.33)	(0.64)	(-0.66)	(0.17)	(1.19)
$f_t - s_t$	3.63	2.40	2.42	3.66	1.23	-0.11	2.46
	(103.32)	(366.77)	(67.14)	(61.33)	(34.55)	(-6.33)	(66.55)
Δs	-0.00	2.94	2.12	-0.83	-2.95	0.38	1.58
	(-0.00)	(0.88)	(0.62)	(-0.19)	(-1.13)	(0.24)	(0.46)

Panel B: Intraday Decomposition

	TC	SC	DC	FP	DT	DOL	DC-LRV
rx^{ON}	0.18	2.58	-0.02	-2.42	-2.40	-3.33	0.59
	(0.13)	(1.09)	(-0.01)	(-0.84)	(-1.33)	(-3.26)	(0.27)
rx^{1H}	0.78	-0.25	0.42	1.46	1.04	-1.37	0.84
	(2.24)	(-0.55)	(1.09)	(2.76)	(3.19)	(-7.62)	(2.21)
Δs^{1H}	-2.85	-2.65	-2.01	-2.20	-0.20	-1.27	-1.61
	(-8.18)	(-5.74)	(-5.20)	(-4.18)	(-0.60)	(-7.00)	(-4.23)
Δs^{ON-1H}	-0.60	2.84	-0.44	-3.88	-3.44	-1.96	-0.26
	(-0.44)	(1.20)	(-0.21)	(-1.35)	(-1.90)	(-1.93)	(-0.12)
Δs^{ON}	-3.45	0.18	-2.45	-6.08	-3.63	-3.22	-1.87
	(-2.52)	(0.08)	(-1.14)	(-2.10)	(-2.02)	(-3.15)	(-0.87)
Δs^{ID}	3.44	2.76	4.57	5.25	0.68	3.60	3.45
	(2.83)	(1.15)	(1.71)	(1.54)	(0.35)	(2.95)	(1.29)

Table III

UIP Regressions and Major U.S. Announcements

This table reports results of the following regression

$$\Delta s^j_{t+1} = \alpha + \alpha^A \times \mathbb{1}^A + \beta(f^j_t - s^j_t) + \beta^A(f^j_t - s^j_t) \times \mathbb{1}^A + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, $(f^\tau_t - s^j_t)$ refers to the short-term forward discount with maturity τ =1D, and $\mathbb{1}^A$ is an indicator variable equal to one on the day before major U.S. announcement days, and zero otherwise. Major U.S. macroeconomic announcements include FOMC rate decisions (FOMC), change in nonfarm payrolls (NFP), consumer price index excluding food and energy (CPI), and annualised gross domestic product (GDP). Numbers in round parentheses refer to Driscoll and Kraay (1998) adjusted standard errors. Numbers in squared parentheses show p-values from Wald-tests with either the null hypothesis $H_0 : \beta = 1$ or $H_0 : \beta + \beta^A = 1$. The sample period is January 1999 to December 2023.

	Close-to-Close			Overnight			Intraday		
	All Ann.	FOMC	Macro	All Ann.	FOMC	Macro	All Ann.	FOMC	Macro
α	-0.99	-0.31	-0.69	-1.82	-1.58	-1.62	0.83	1.27	0.93
	(-1.41)	(-0.47)	(-1.00)	(-3.98)	(-3.81)	(-3.63)	(1.59)	(2.48)	(1.78)
α^A	(6.93)	(14.44)	(6.15)	(2.58)	(5.70)	(1.63)	(4.34)	(8.74)	(4.52)
	(3.54)	(3.17)	(2.90)	(2.37)	(2.63)	(1.39)	(2.62)	(2.05)	(2.44)
β	0.19	0.12	0.14	1.35	1.31	1.36	-1.16	-1.19	-1.22
	(0.26)	(0.18)	(0.19)	(2.82)	(2.97)	(2.91)	(-2.05)	(-2.16)	(-2.19)
β^A	-0.93	-3.07	-0.71	-0.20	0.41	-0.31	-0.74	-3.48	-0.40
	(-0.62)	(-0.82)	(-0.45)	(-0.20)	(0.19)	(-0.30)	(-0.64)	(-0.99)	(-0.32)
p-val$^\beta$	[0.28]	[0.21]	[0.24]	[0.47]	[0.48]	[0.44]	[0.00]	[0.00]	[0.00]
p-val$^{\beta+\beta^A}$	[0.22]	[0.29]	[0.30]	[0.86]	[0.73]	[0.96]	[0.01]	[0.10]	[0.04]

Table IV

UIP HM Decomposition and U.S. Announcement Days

This table reports annualized average excess returns (Panel A) and spot returns (Panel B) to the different strategies of the decomposition, introduced by Hassan and Mano (2018). Returns are reported when the strategies are implemented every day (i.e., "All". 5989 days), only on announcement days ("Ann", 998) and only on all the other days ("Other", 4991 days). The columns refer to different trading strategies, i.e., traditional carry ("TC"), static carry ("SC"), dollar carry ("DC"), forward premium ("FP"), or the dynamic trade ("DT"), the dollar portfolio ("DOL"), and the dollar carry trade by Lustig et al. (2014). Returns are annualized, expressed in percentage, and scaled by the number of days for each row. Numbers in parentheses show *t*-statistics. The sample period is January 1999 to December 2023.

Panel A: Excess Returns

	TC	SC	DC	FP	DT	DOL	DC-LRV
All	3.63	5.34	4.54	2.83	-1.72	0.27	4.04
	(1.96)	(1.60)	(1.33)	(0.64)	(-0.66)	(0.17)	(1.19)
Ann	2.25	4.77	-1.12	-3.64	-2.52	2.35	-1.93
	(3.15)	(4.30)	(-0.68)	(-1.93)	(-3.20)	(3.17)	(-1.18)
Other	1.37	0.57	5.66	6.46	0.80	-2.08	5.97
	(0.81)	(0.18)	(1.90)	(1.62)	(0.32)	(-1.49)	(2.00)

Panel B: Spot Returns

	TC	SC	DC	FP	DT	DOL	DC-LRV
All	-0.00	2.94	2.12	-0.83	-2.95	0.38	1.58
	(-0.00)	(0.88)	(0.62)	(-0.19)	(-1.13)	(0.24)	(0.46)
Ann	1.65	4.37	-1.55	-4.27	-2.72	2.37	-2.37
	(2.31)	(3.94)	(-0.94)	(-2.27)	(-3.47)	(3.20)	(-1.44)
Other	-1.66	-1.43	3.67	3.44	-0.22	-1.99	3.95
	(-0.97)	(-0.45)	(1.23)	(0.86)	(-0.09)	(-1.43)	(1.32)

VIII. Figures

Figure 1. UIP Regressions and Intraday Returns.
The figure shows the estimated β-coefficient from the panel regressions

$$\Delta s_{t+1}^{j} = \alpha + \beta(f_t^{\tau} - s_t^{j}) + \varepsilon_{t+1}^{j}$$

where $\Delta s_{t+1}^{j} = s_{t+1}^{j} - s_t^{j}$ refers to the log spot return of currency j, and $(f_t^{\tau} - s_t^{j})$ refer to the forward discount with maturity τ, respectively. In the top panel, τ refers to one-month (1M), while in the bottom panel τ refers to one-day (1D). For the definitions of overnight and intraday returns see Note 1. Error bars refer to 90% confidence intervals, based on Driscoll and Kraay (1998) adjusted standard errors. The sample period is January 1999 to December 2023.

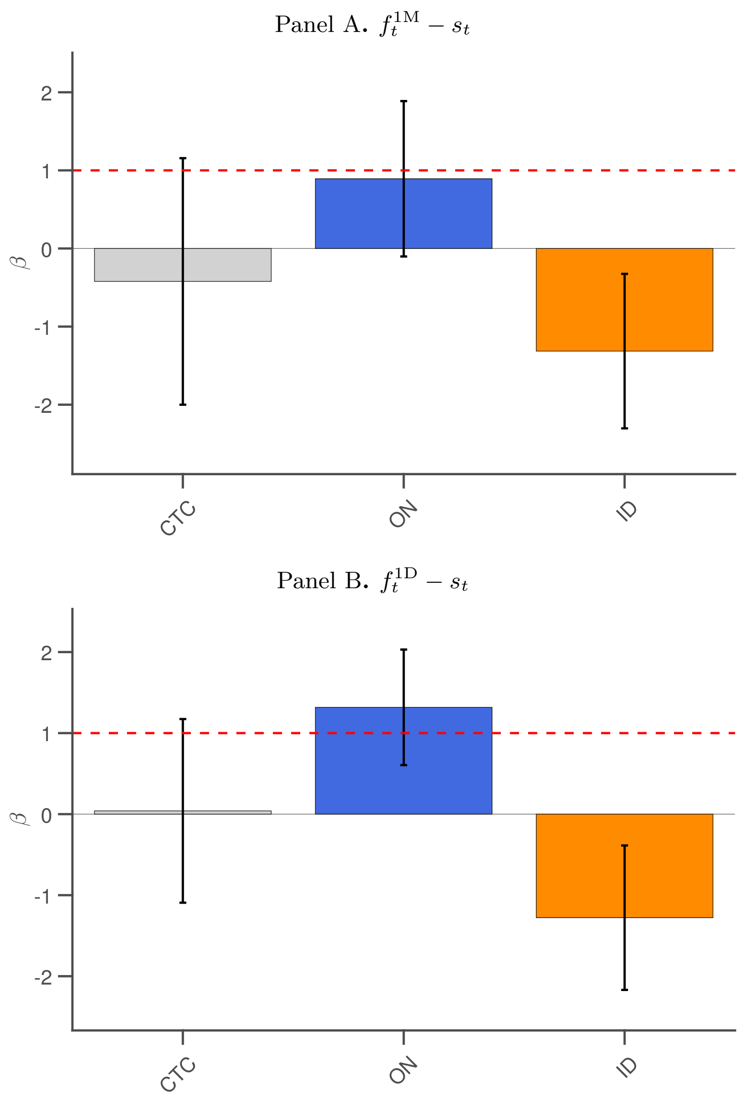


Figure 2.

UIP and Intraday Returns: Bootstrapped ON and ID Slope Coefficients.

The figure shows the distribution of the estimated slope coefficient from a UIP panel regression based on returns during overnight (ON, blue) or intraday (ID, orange) periods, using a block bootstrap sampling of 5,000. Each histogram is normalized such that the area sums up to 1. Vertical blue and oranged dashed lines indicate 95% confidence intervals. The vertical black lines with β^{ON} and β^{ID} indicate the magnitude of coefficients from panel regression from the entire sample. The sample period is January 1999 to December 2023.

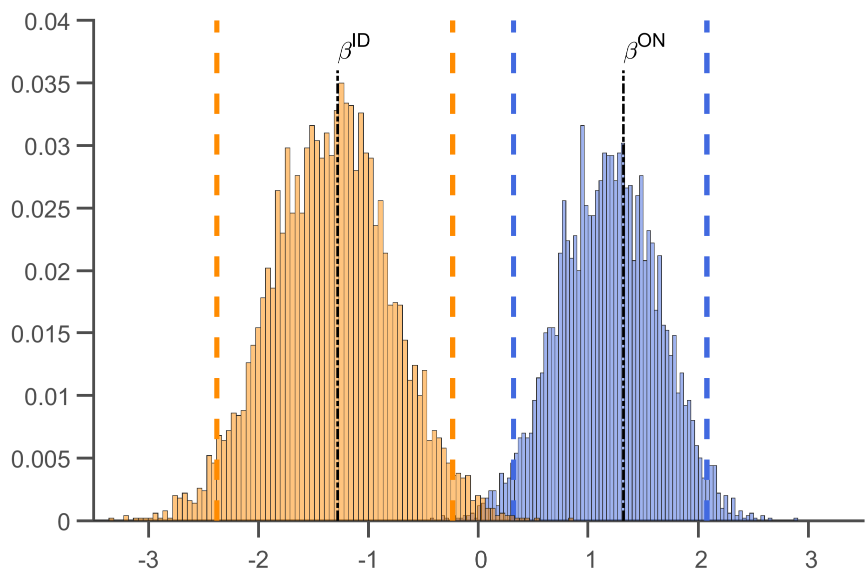


Figure 3. New Fama Puzzle: Intraday Returns and UIP.

The figure shows the estimated β-coefficient from the panel regressions

$$\Delta s^j_{t+1} = \alpha + \beta(f^\tau_t - s^j_t) + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(f^\tau_t - s^j_t)$ refer to the forward discount with maturity τ =1D, respectively. For the definitions of overnight and intraday returns see Note 1. Error bars refer to 90% confidence intervals, based on Driscoll and Kraay (1998) adjusted standard errors. For each intraday period, the sample is divided into two sub-samples, January 1999 to December 2008 (e.g., CTC^{99-08}) and January 2009 to December 2023 (e.g., CTC^{09-23}).

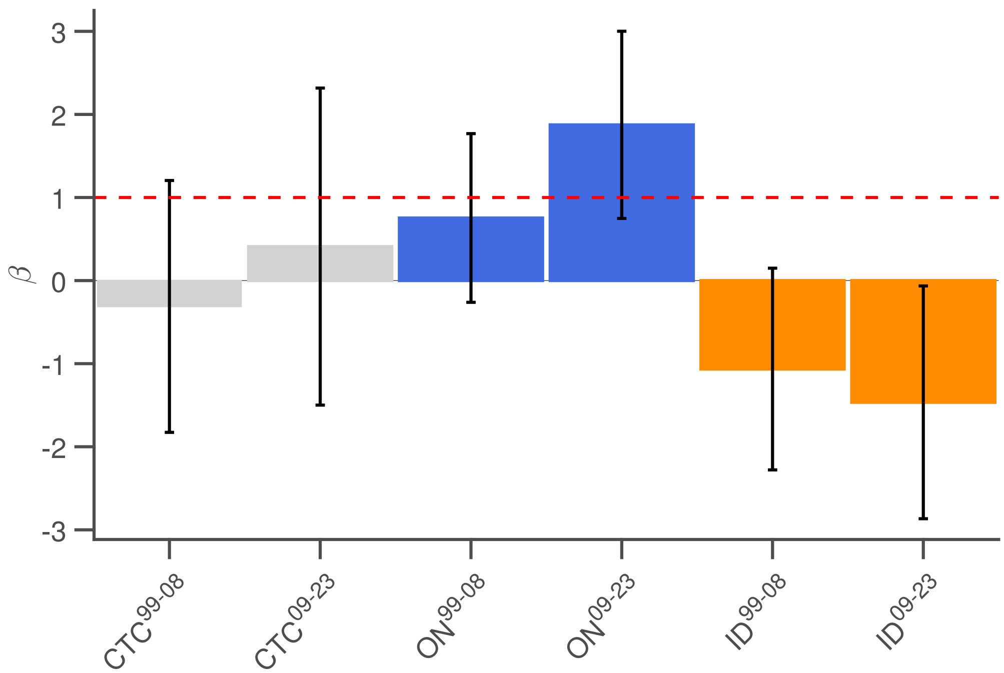


Figure 4. Intraday Returns, UIP, and CIP Deviations.
The figure shows the estimated β-coefficient from the panel regressions

$$\Delta s^j_{t+1} = \alpha + \beta(i^\tau_t - i^{j,*}_t) + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(i^\tau_t - i^{j,*}_t)$ refer to the differential of deposit rates with maturity τ =1D, respectively. For the definitions of overnight and intraday returns see Note 1. Error bars refer to 90% confidence intervals, based on Driscoll and Kraay (1998) adjusted standard errors. The sample period is January 1999 to December 2023.

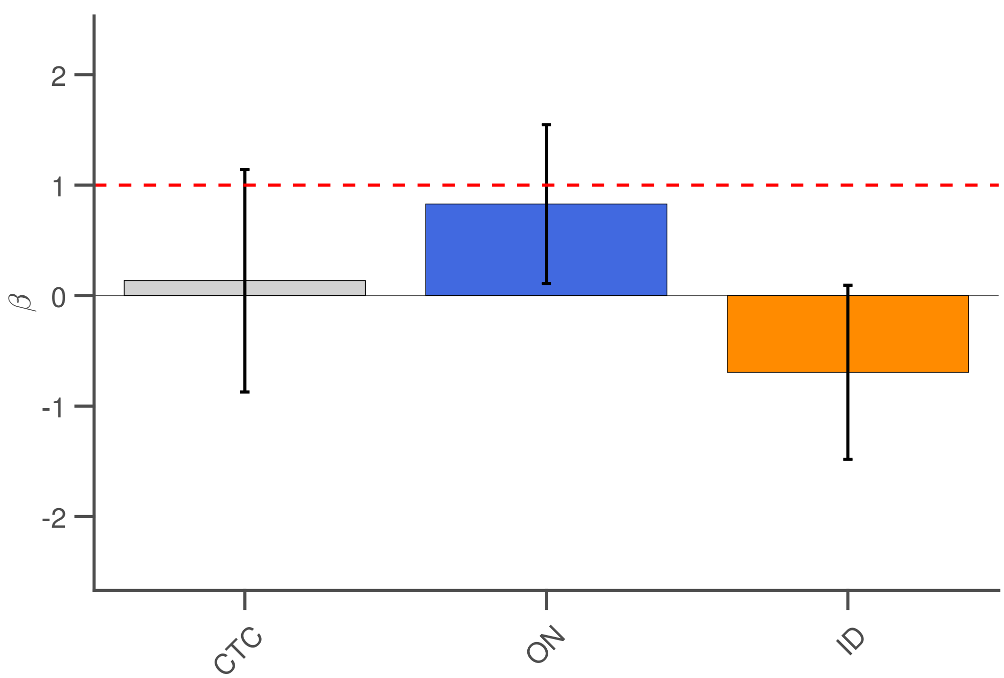


Figure 5. Intraday Returns and Total Return Indices

This figure shows daily total return indices for the five currency strategies following the return decomposition in Hassan and Mano (2018). The black line refers to daily CTC excess returns (rx^{CTC}) while the blue line refers to daily excess returns where short- and long-positions are closed after the overnight period (rx^{ON}). The dashed blue (Δs^{ON}) and dashed orange (Δs^{ID}) lines refer to spot returns during each of the intraday periods. The columns refer to different trading strategies, i.e., traditional carry ("TC"), static carry ("SC"), dollar carry ("DC"), forward premium ("FP"), or the dynamic trade ("DT") and the dollar portfolio ("DOL"). The sample period is January 1999 to December 2023.

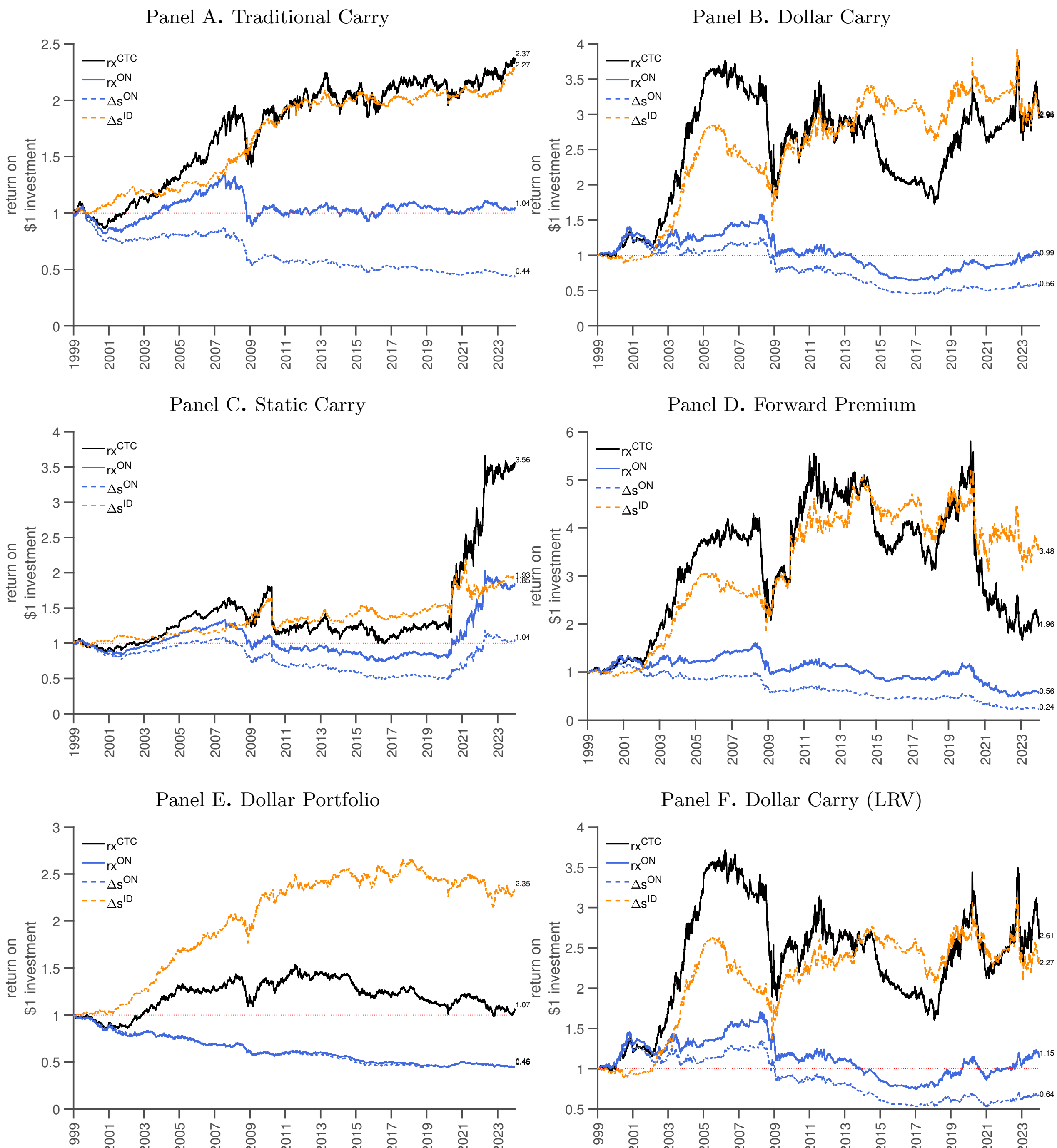


Figure 6. Intraday Returns

This figure shows intraday returns for different currency trading strategies, following the return decomposition in Hassan and Mano (2018). The panels show intraday spot return dynamics for traditional carry ("TC"), static carry ("SC"), dollar carry ("DC"), forward premium ("FP"), or the dynamic trade ("DT") and the dollar portfolio ("DOL"). The red-dashed line refers to the inverted average daily forward discount. The gray-dashed line indicates the start of the intraday period at 8:00 ET. The shaded areas indicate the dispersion of intraday returns based on 10,000 bootstrap samples (with replacement), whereby the bottom (upper) limits refers 5% lowest (highest) average returns. The sample period is January 1999 to December 2023.

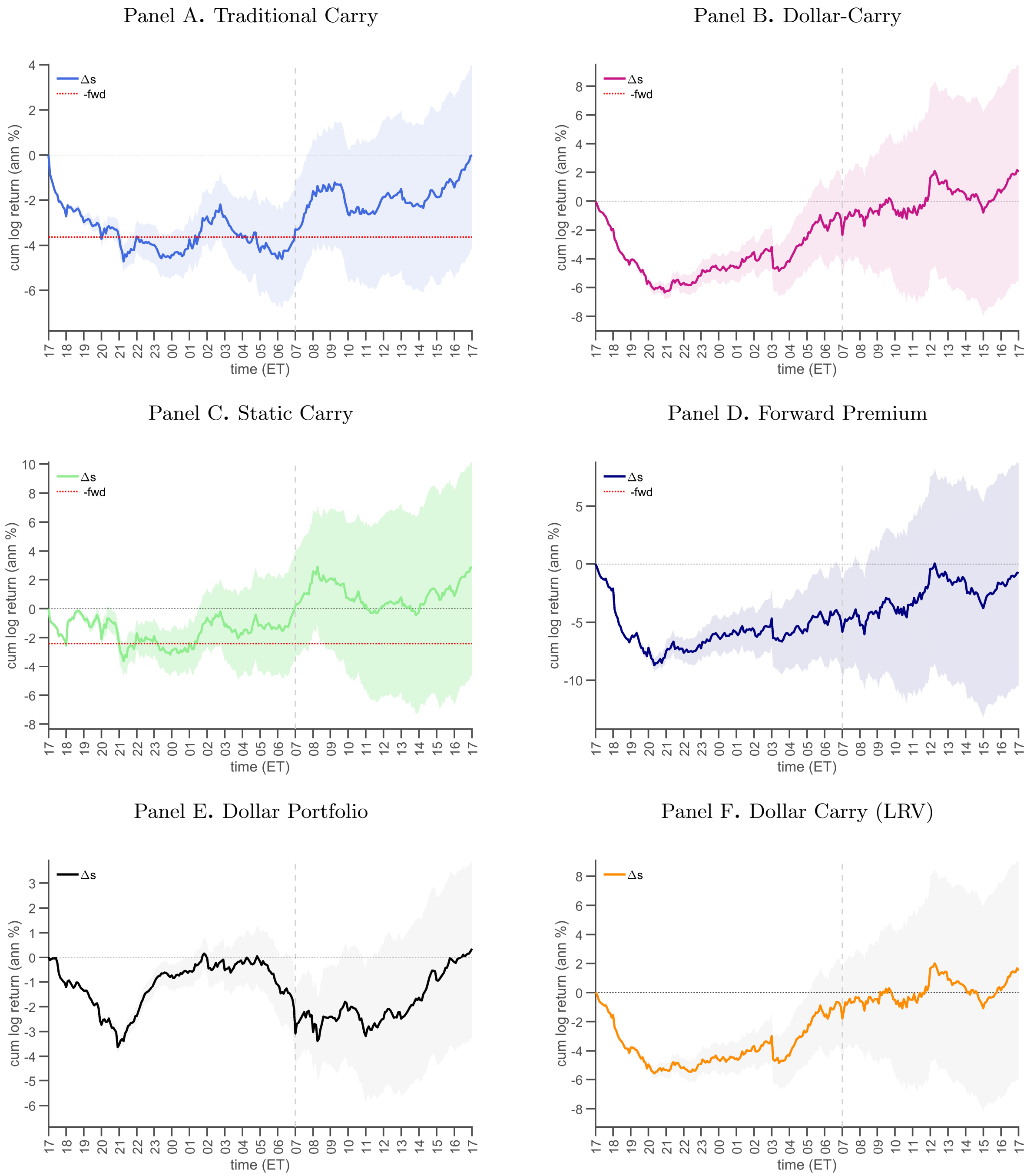


Figure 7. Total Return Indices and Announcement Days

This figure shows daily total returns indices for different currency trading strategies, following the return decomposition in Hassan and Mano (2018). Total return indices are plotted for tje traditional carry ("TC"), static carry ("SC"), dollar carry ("DC"), forward premium ("FP"), or the dynamic trade ("DT") and the dollar portfolio ("DOL"). The black line considers all days, the blue line excludes returns generaed on FOMC days, and the ograne line excludes returns generated on both, FOMC and macroeconomic announcement days. The red-dotted line indicates the initial investment of $1 dollar. The sample period is January 1999 to December 2023.

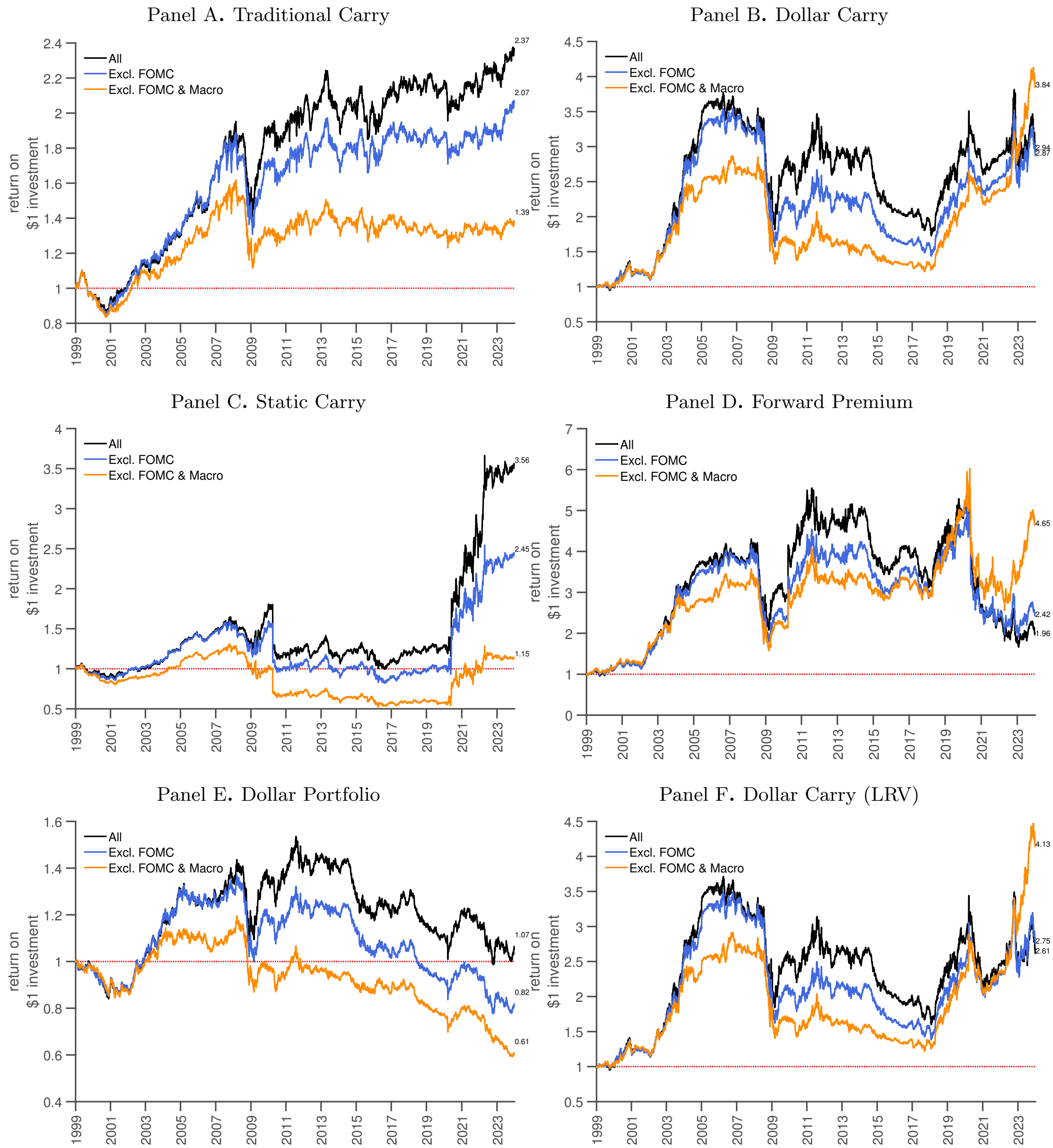
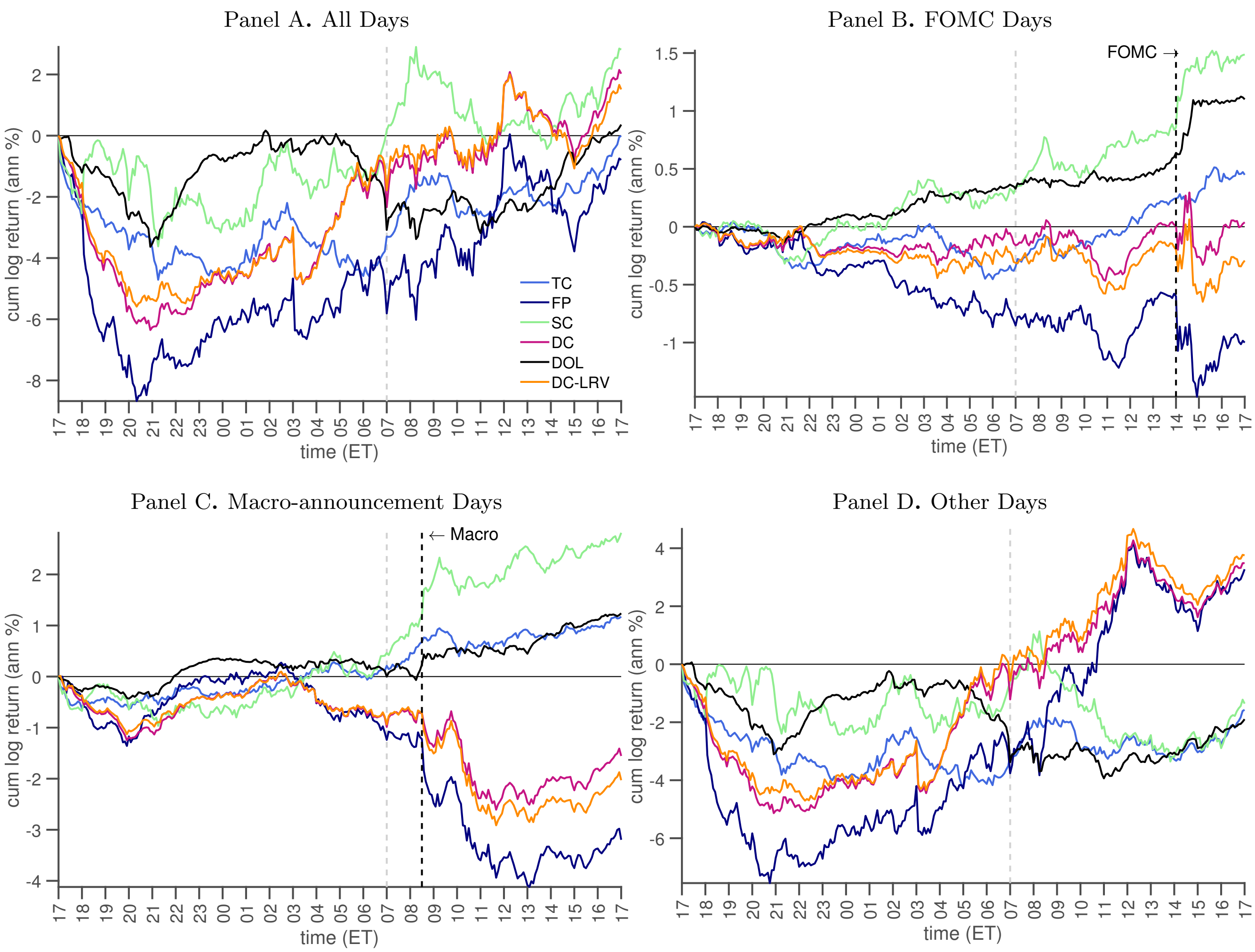


Figure 8. Intraday Currency Portfolio Returns and Major U.S. Announcements This figure shows intraday returns for different currency trading strategies, following the return decomposition in Hassan and Mano (2018), for all days (Panel A), FOMC days (Panel B), macroeconomic announcement days (Panel C), and all other days. The panels show intraday spot return dynamics for traditional carry ("TC"), static carry ("SC"), dollar carry ("DC"), forward premium ("FP") and the dollar portfolio ("DOL"). To save space, returns of the dynamic trade ("DT") are omitted. The grey-dashed line indicates the start of the intraday period. The black-dashed lines in Panel C and D indicate the time of FOMC (14:00 ET) and macroeconomic (8:30 ET) announcements. The sample period is January 1999 to December 2023.



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AI. Examples

The timing for the various short-dated FX and interest rate transactions is discussed in detail in Section B. In this section, we provide a visual overview in Figure A-1.

[INSERT FIGURE A-1 AND TABLE A-I HERE]

Furthermore, Table A-I contains actual data on the EURUSD FX pair collected from Bloomberg between 15 and 19 May 2023. This allows to illustrate the specific calculations required to calculate the cost of rolling over an FX position. Imagine that on Tuesday, 16 May, the EURUSD spot rate is trading at 1.086/0865. To buy 100 EUR spot, a trader then pays 108.65 USD with settlement on Thursday, 18 May, i.e., two days later. However, instead of accepting delivery at this date, the trader could sell 100 EUR in a TN transaction F_t^{TN} the following day, Wednesday, 17 May. In the front leg of the swap (effective on 18 May), the trader will sell 100 EUR (offsetting the open spot position to be settled) at the TN rate and in the back leg of the swap (effective on Friday, 19 May), the trader will buy back 100 EUR at the spot rate. On 17 May, the TN rate is quoted in swap points as 0.577/0.622, which translates into a EURUSD forward rate equal to 1.08386/08426, while the new prevailing spot rate is 1.0838/0842. The cost of rolling over the position is thus 108.42-108.386 = 3.4 cents or 3.4 basis points.[15]

[15]Note that the example is chosen such that there is no "weekend seasonality" effect. Whenever instruments span a weekend or a holiday, the implied interest covers not one but two or more days. Given the quoting conventions, this results in a "seasonality" effect in the quotes as they spike on a weekly basis. This does not, however, mean that interest rates jump around.

AJ. Appendix: Figures

Figure A-1. Short Maturity Trading in FX and Deposit Rates

This figure illustrates the timing of transaction and settlement dates for short term deposit rates (i_t^{ON}, i_t^{TN}, i_t^{SN}), spot transactions (S_t) and forwards (F_t^{ON}, F_t^{TN}, F_t^{SN}). For example, in the case of FX forwards (swaps) we have Overnight (ON): swap today (t) against tomorrow ($t+1$) denoted F_t^{ON}. Tomorrow-Next (TN): forward swap agreed today (t) for tomorrow ($t+1$) against the next day ($t+2$) denoted F_t^{TN}. Spot (S): is effectively a forward contact agreed today (t) for settlement in two days ($t+2$) where the underlying is the cash rate C_t (see discussion in Section B). Spot-Next (SN): forward FX swap agreed today (t) for the spot date ($t+2$) against the following day ($t+3$) denoted F_t^{SN}. An ON trade allows a trader to swap foreign for domestic currencies (or vice-versa) overnight. TN and SN trades allow traders to manage open currency positions.

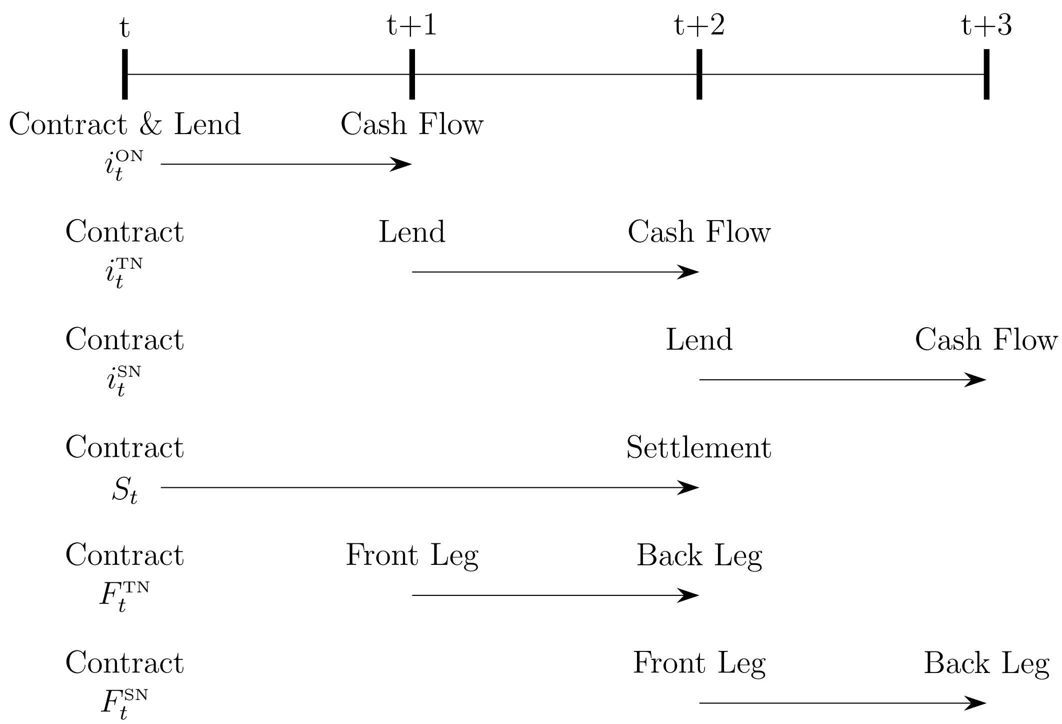
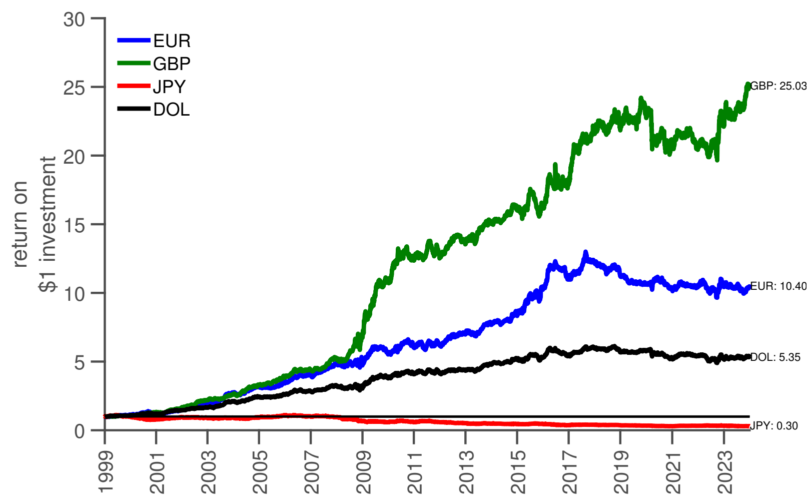


Figure A-2. Intraday Returns: Total return indices and year-over-year performance. The panels show the performance of a trading strategy where an investor takes a long position in the U.S. dollar during the overnight and a short position intraday period. The top panels show the total return indices for the three major currencies (EUR, GBP, JPY) and the dollar portfolio (DOL) with an initial investment of one U.S. dollar. The bottom panels show the total returns by year for the dollar portfolio. The sample period is January 1999 to December 2023.

Panel A. Total Return Index: DOL + G3



Panel B. YbY-Performance: DOL

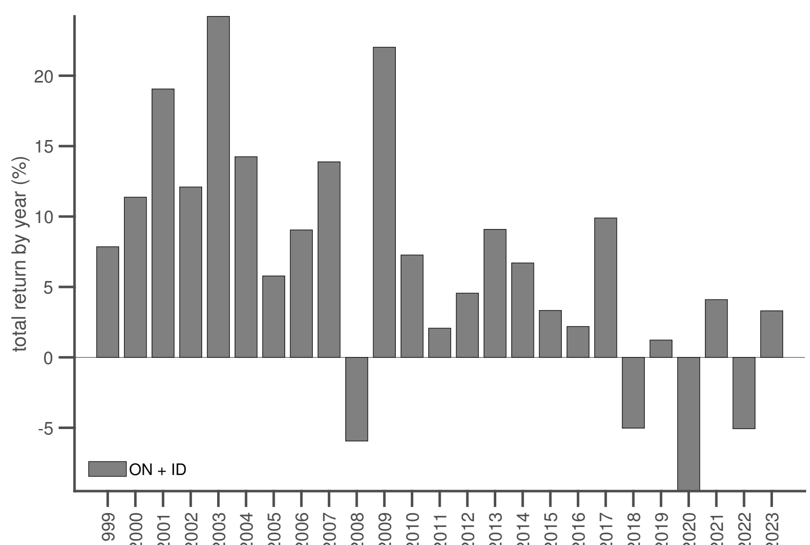


Figure A-3. UIP and Intraday Returns: Bootstrapped Slope Coefficients
The figure shows the distribution of the estimated slope coefficient from a UIP panel regression using a block bootstrap sampling of 5,000. Panel A, C, D show the distribution of β-coefficients based on close-to-close, overnight, and intraday returns. Each histogram is normalized such that the area sums up to 1. Vertical dashed lines indicate 95% confidence intervals. Panel B, D, F show the distribution of the corresponding p-values obtained from a Wald test with the null hypothesis that the slope coefficient is equal to unity. Values are displayed as cumulative distribution function to indicate the proportion of times the p-values is lower than the critical value. The vertical dashed line refers to the p-value of 10%. The sample period is January 1999 to December 2023.

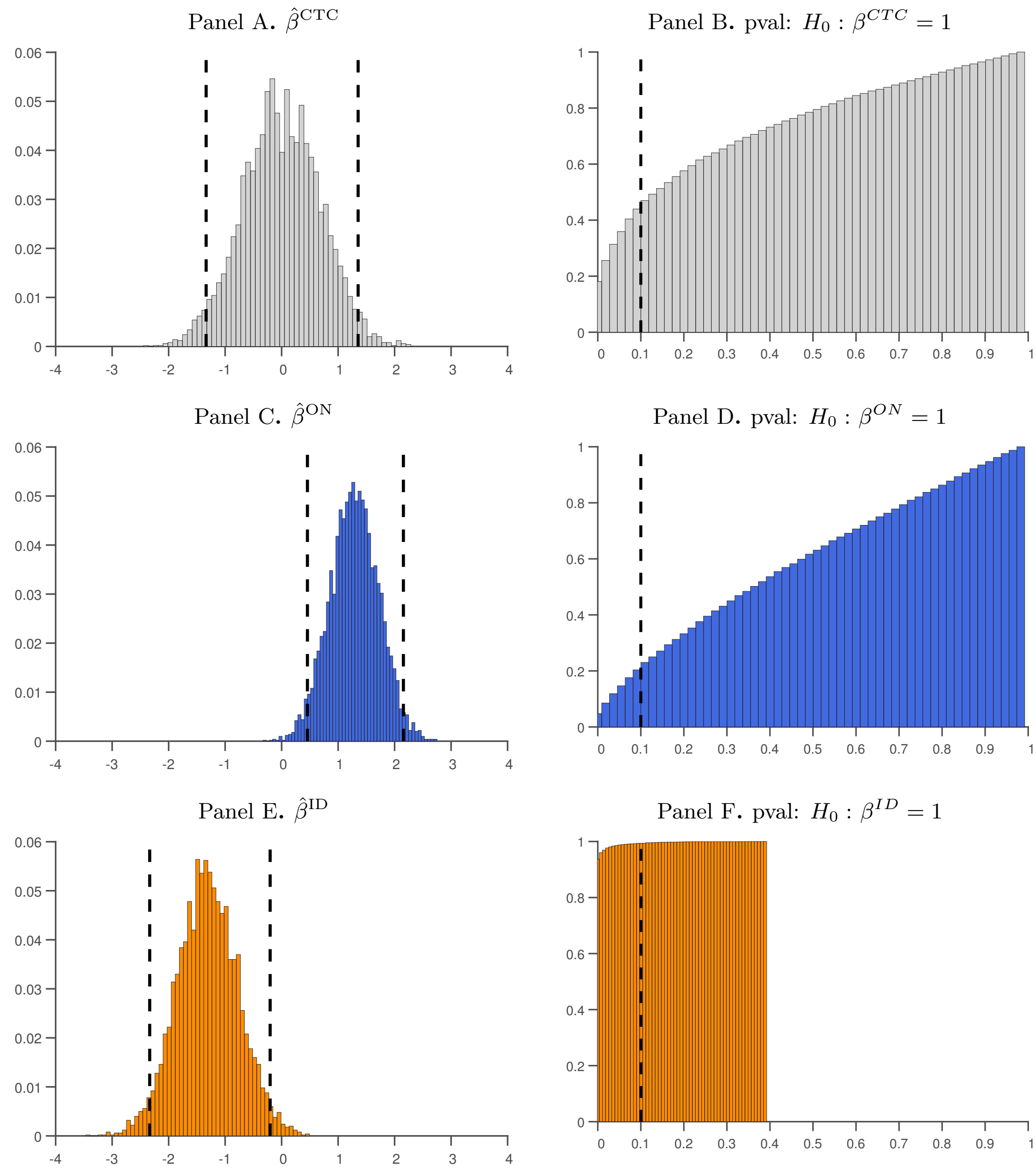
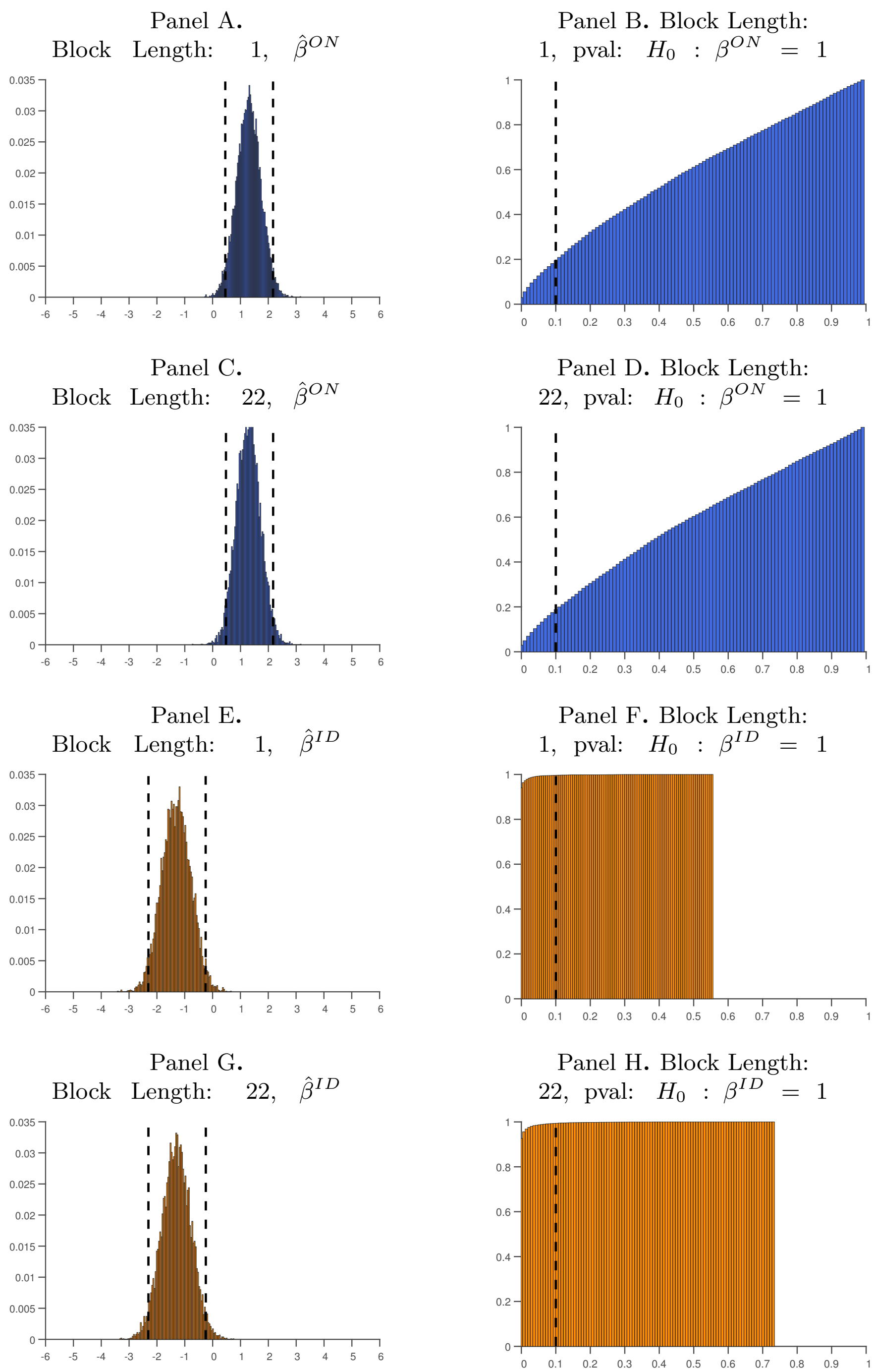


Figure A-4. UIP and Intraday Returns:
Bootstrapped Slope Coefficients and Alternative Block Length

The figure shows the distribution of the estimated slope coefficient from a UIP panel regression using a block bootstrap sampling of 10,000 and for different block size length. Panel A and E (C and G) show the distribution of β-coefficients based on overnight, and intraday returns for a chosen block length o 1 day (22 days). Panel B and D (F and H) show the distribution of the corresponding p-values obtained from a Wald test with the null hypothesis that the slope coefficient is equal to unity. Values are displayed as cumulative distribution function to indicate the proportion of times the p-values is lower than the critical value. The vertical dashed line refers to the p-value of 10%. The sample period is January 1999 to December 2023.



AK. Appendix: Tables

Table A-I

Spot, Swap Points, Short Term Forwards, and Deposit Rates

	Euro spot			Swap points (TN)			Swap points (SN)		
	mid	bid	ask	mid	bid	ask	mid	bid	ask
05/19/2023	1.0805	1.0795	1.0814	0.5893	0.5740	0.6050	0.5900	0.5650	0.6150
05/18/2023	1.0770	1.0769	1.0772	1.7540	1.7290	1.7790	0.5905	0.5680	0.6130
05/17/2023	1.0840	1.0838	1.0842	0.5935	0.5830	0.6040	1.7750	1.7500	1.8000
05/16/2023	1.0862	1.0860	1.0865	0.5997	0.5770	0.6220	0.6000	0.5800	0.6200
05/15/2023	1.0874	1.0873	1.0875	0.5935	0.5850	0.6020	0.6000	0.5750	0.6250

	Forward rates (TN)			Forward rates (SN)		
	mid	bid	ask	mid	bid	ask
05/19/2023	1.0805	1.0796	1.0815	1.0805	1.0796	1.0815
05/18/2023	1.0772	1.0771	1.0774	1.0771	1.0770	1.0773
05/17/2023	1.0840	1.0839	1.0843	1.0841	1.0840	1.0844
05/16/2023	1.0863	1.0861	1.0866	1.0863	1.0861	1.0866
05/15/2023	1.0875	1.0874	1.0876	1.0875	1.0874	1.0876

	$i^{EU,TN}$ ann (%)			$i^{EU,SN}$ ann (%)			$i^{US,TN}$ ann (%)			$i^{US,SN}$ ann (%)		
	mid	bid	ask	mid	bid	ask	mid	bid	ask	mid	bid	ask
05/19/2023	3.2200	3.1200	3.3200	3.2250	3.1500	3.3000	5.0726	5.0226	5.1226	5.1300	5.0800	5.1800
05/18/2023	3.2200	3.1200	3.3200	3.2250	3.1500	3.3000	5.0703	5.0203	5.1203	5.1850	5.0200	5.3500
05/17/2023	3.2200	3.1200	3.3200	3.2250	3.1500	3.3000	5.1100	5.0600	5.1600	5.1300	5.0800	5.1800
05/16/2023	3.2200	3.1200	3.3200	3.2250	3.1500	3.3000	5.0709	5.0209	5.1209	5.1300	5.0800	5.1800
05/15/2023	3.2200	3.1200	3.3200	3.2250	3.1500	3.3000	5.1100	5.0600	5.1600	5.1300	5.0800	5.1800

Table A-II

Statistical Properties: Intraday Returns

This table reports the fraction of return observations that are positive, the p-value from a two-sided test of observing returns in one direction under the null hypothesis of a random walk, as well as mean, median, z-stat, standard deviation, skewness, and kurtosis. The z-stat refers to a non-parametric test assessing if the median is different from zero. Currencies are denominated in U.S. dollar. Returns are expressed in basis points. See The sample period is January 1999 to December 2023.

	Frac > 0	p-val	Mean	t-stat	Std. Dev.	Skew	Kurt
			Panel A: Overnight				
AUD	0.51	0.22	-1.13	-1.62	55.43	-0.98	17.82
CAD	0.50	0.50	-0.74	-1.95	29.92	-0.32	8.72
CHF	0.47	0.00	-1.46	-2.58	44.75	4.78	198.29
EUR	0.48	0.00	-1.71	-3.59	37.66	-0.23	6.17
GBP	0.48	0.00	-2.51	-4.94	40.32	-1.78	35.57
JPY	0.50	0.91	0.71	1.26	44.73	0.28	11.66
NOK	0.49	0.15	-1.08	-1.64	52.16	-0.23	8.66
NZD	0.50	0.50	-1.52	-2.10	57.38	-0.74	10.25
SEK	0.49	0.24	-1.64	-2.59	50.11	-0.83	14.56
DOL	0.48	0.02	-1.18	-2.88	32.39	-0.20	6.44
			Panel B: Intraday				
AUD	0.52	0.01	1.59	2.33	53.88	-0.30	12.05
CAD	0.51	0.05	1.01	1.75	45.78	-0.04	6.17
CHF	0.51	0.02	2.47	4.02	48.57	0.24	6.61
EUR	0.52	0.01	2.03	3.44	46.73	0.15	6.41
GBP	0.53	0.00	2.62	4.83	43.02	0.11	7.11
JPY	0.47	0.00	-1.20	-2.20	43.42	0.16	8.58
NOK	0.51	0.33	0.75	1.01	58.59	-0.43	13.96
NZD	0.52	0.01	2.38	3.44	54.71	-0.06	7.16
SEK	0.51	0.14	1.53	2.16	55.85	0.03	6.48
DOL	0.52	0.00	1.50	3.06	38.79	0.15	6.71

Table A-III

Monthly UIP Regressions and Intraday Returns

This table reports results of the following regression

$$\Delta s^j_{t+1} = \alpha + \beta(f^{\tau,j}_t - s^j_t) + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(f^{\tau,j}_t - s^j_t)$ refer to the short-term forward discount with maturity τ =1M. Panel A, B, and C refer to close-to-close, overnight, and intraday returns, respectively. Numbers in round parentheses refer to t-statistics based on Newey and West (1987) or Driscoll and Kraay (1998) adjusted standard errors. Numbers in squared parentheses show the p-value based on a Wald-test with the null hypothesis $H_0 : \beta = 1$. The sample period is January 1999 to December 2023.

	AUD	CAD	CHF	EUR	GBP	JPY	NOK	NZD	SEK	DOL	PANEL
					Panel A: Close-to-Close						
α	-3.46	5.20	22.92	18.82	-0.40	-26.93	-8.84	17.31	2.53	7.40	4.96
	(-0.18)	(0.37)	(0.85)	(0.95)	(-0.02)	(-1.05)	(-0.51)	(0.59)	(0.11)	(0.49)	(0.33)
β	-0.89	-0.09	-0.08	-1.68	-1.22	0.91	-0.32	0.02	-1.35	-1.15	-0.42
	(-0.73)	(-0.03)	(-0.06)	(-1.35)	(-0.98)	(0.87)	(-0.22)	(0.01)	(-1.01)	(-0.98)	(-0.44)
p-val	[0.12]	[0.68]	[0.40]	[0.03]	[0.08]	[0.93]	[0.36]	[0.61]	[0.08]	[0.07]	[0.14]
$\bar{R}^2$	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
N	299	299	299	299	299	299	299	299	299	299	2691
					Panel B: Overnight						
α	-15.44	-15.49	-46.28	-43.15	-49.38	-5.70	-13.93	-19.10	-34.91	-25.28	-26.67
	(-0.96)	(-1.71)	(-2.47)	(-3.57)	(-3.84)	(-0.32)	(-0.98)	(-0.73)	(-2.67)	(-2.90)	(-3.00)
β	0.66	0.56	1.00	1.12	1.58	1.09	1.45	0.75	-0.10	0.54	0.89
	(0.79)	(0.34)	(1.05)	(1.30)	(1.74)	(1.23)	(1.48)	(0.49)	(-0.12)	(0.72)	(1.47)
p-val	[0.68]	[0.79]	[1.00]	[0.89]	[0.52]	[0.92]	[0.65]	[0.87]	[0.19]	[0.55]	[0.86]
$\bar{R}^2$	0.00	0.00	0.00	0.00	0.01	0.00	0.01	0.00	0.00	0.00	0.00
N	299	299	299	299	299	299	299	299	299	299	2691
					Panel C: Intraday						
α	11.98	20.69	69.20	61.97	48.98	-21.23	5.09	36.41	37.44	32.68	31.63
	(0.98)	(1.60)	(3.03)	(4.15)	(4.21)	(-1.26)	(0.31)	(2.39)	(1.82)	(3.01)	(2.94)
β	-1.54	-0.65	-1.08	-2.79	-2.81	-0.18	-1.77	-0.73	-1.25	-1.69	-1.31
	(-2.06)	(-0.23)	(-1.17)	(-2.84)	(-3.45)	(-0.27)	(-1.88)	(-1.00)	(-1.04)	(-2.00)	(-2.18)
p-val	[0.00]	[0.55]	[0.03]	[0.00]	[0.00]	[0.09]	[0.00]	[0.02]	[0.06]	[0.00]	[0.00]
$\bar{R}^2$	0.01	0.00	0.00	0.02	0.02	0.00	0.01	0.00	0.00	0.01	0.01
N	299	299	299	299	299	299	299	299	299	299	2691

Table A-IV

UIP Regressions and Intraday Returns, by week

The table reports results of the following regressions

$$\Delta s^j_{t+1} = \sum_i \alpha_i \times \mathbb{1}^{wk} + \sum_i \beta_i (f^\tau_t - s^j_t) \times \mathbb{1}^{wk} + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(f^\tau_t - s^j_t)$ refers to the forward discount with maturity $\tau = 1D$, and $\mathbb{1}^{wkd}$ is an indicator variable for each week of the month. Numbers in round parentheses refer to t-statistics based on Driscoll and Kraay (1998) adjusted standard errors. Numbers in squared parentheses show the p-value based on a Wald-test with the null hypothesis $H_0 : \beta = 1$. The sample period is January 1999 to December 2023.

	Week 1	Week 2	Week 3	Week 4
		Panel A: Close-to-Close		
α_i	-0.21	0.46	-0.63	1.82
	(-0.17)	(0.25)	(-0.34)	(0.95)
β_i	-0.87	0.17	1.70	-0.47
	(-0.67)	(0.14)	(1.39)	(-0.42)
p-val	[0.15]	[0.52]	[0.57]	[0.18]
$\bar{R}^2$		0.00		
N		51520		
		Panel B: Overnight		
α_i	-2.46	1.36	0.60	2.73
	(-3.56)	(1.23)	(0.49)	(2.44)
β_i	0.91	1.98	1.65	0.68
	(1.17)	(2.47)	(1.74)	(0.89)
p-val	[0.91]	[0.22]	[0.49]	[0.67]
$\bar{R}^2$		0.00		
N		51520		
		Panel C: Intraday		
α_i	2.25	-0.90	-1.23	-0.91
	(2.29)	(-0.65)	(-0.90)	(-0.64)
β_i	-1.78	-1.81	0.05	-1.14
	(-1.55)	(-1.95)	(0.06)	(-1.50)
p-val	[0.02]	[0.00]	[0.26]	[0.01]
$\bar{R}^2$		0.00		
N		51520		

Table A-V

UIP Regressions and Intraday Returns, by quarter

The table reports results of the following regressions

$$\Delta s^j_{t+1} = \sum_i \alpha_i \times \mathbb{1}^{qtr} + \sum_i \beta_i (f^\tau_t - s^j_t) \times \mathbb{1}^{qtr} + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(f^\tau_t - s^j_t)$ refers to the forward discount with maturity $\tau = 1D$, and $\mathbb{1}^{qtr}$ is an indicator variable for each quarter from Q1 to Q4. Numbers in round parentheses refer to t-statistics based on Driscoll and Kraay (1998) adjusted standard errors. Numbers in squared parentheses show the p-value based on a Wald-test with the null hypothesis $H_0 : \beta = 1$. The sample period is January 1999 to December 2020.

	Q1	Q2	Q3	Q4
	Panel A: Close-to-Close			
α_i	-0.47	1.52	-0.54	1.63
	(-0.36)	(0.80)	(-0.30)	(0.86)
β_i	-0.77	-1.80	1.09	1.27
	(-0.61)	(-1.68)	(0.90)	(1.15)
p-val	[0.16]	[0.01]	[0.94]	[0.81]
$\bar{R}^2$	0.00			
N	51520			
	Panel B: Overnight			
α_i	-2.69	1.66	0.33	3.24
	(-3.51)	(1.47)	(0.30)	(2.79)
β_i	0.86	0.32	2.20	1.74
	(1.16)	(0.45)	(2.87)	(2.26)
p-val	[0.85]	[0.33]	[0.12]	[0.34]
$\bar{R}^2$	0.00			
N	51520			
	Panel C: Intraday			
α_i	2.22	-0.15	-0.87	-1.61
	(2.14)	(-0.10)	(-0.62)	(-1.06)
β_i	-1.63	-2.12	-1.11	-0.48
	(-1.76)	(-2.50)	(-1.30)	(-0.50)
p-val	[0.00]	[0.00]	[0.01]	[0.12]
$\bar{R}^2$	0.00			
N	51520			

Table A-VI

UIP Regressions and Intraday Returns, by Accrual Days

The table reports results of the following regressions

$$\Delta s^j_{t+1} = \sum_i \alpha_i \times \mathbb{1}^{Acc} + \sum_i \beta_i (f^\tau_t - s^j_t) \times \mathbb{1}^{Acc} + \varepsilon^j_{t+1}$$

where $\Delta s^j_{t+1} = s^j_{t+1} - s^j_t$ refers to the log spot return of currency j, and $(f^\tau_t - s^j_t)$ refers to the forward discount with maturity $\tau = 1D$, and $\mathbb{1}^{Acc}$ is an indicator variable distinguishing between interest accrual days of one day versus days with more than one days of interest rate accrual. Numbers in round parentheses refer to t-statistics based on Driscoll and Kraay (1998) adjusted standard errors. Numbers in squared parentheses show the p-value based on a Wald-test with the null hypothesis $H_0 : \beta = 1$. The sample period is January 1999 to December 2020.

	Int. Acc. = 1	Int. Acc. > 1
	Panel A: Close-to-Close	
α_i	0.67	-2.11
	(0.91)	(-1.42)
β_i	-0.17	1.21
	(-0.24)	(0.78)
p-val	[0.10]	[0.89]
$\bar{R}^2$	0.00	
N	51520	
	Panel B: Overnight	
α_i	-0.90	-2.08
	(-1.97)	(-2.31)
β_i	1.08	2.65
	(2.41)	(2.41)
p-val	[0.85]	[0.13]
$\bar{R}^2$	0.00	
N	51520	
	Panel C: Intraday	
α_i	1.56	-0.03
	(2.81)	(-0.03)
β_i	-1.25	-1.44
	(-2.33)	(-1.20)
p-val	[0.00]	[0.04]
$\bar{R}^2$	0.00	
N	51520	