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Speculative trading and its effect on the forward premium puzzle: new evidence from Japanese yen market

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Abstract

The aim of the paper is to investigate a forward premium anomaly in reference to the speculation strategy carry trade. The article focuses on the Japanese yen. The paper shows that the existence of the puzzle is highly dependent on the frequency of crisis episodes, the sign and size of the interest rate differential, and the attractiveness of the currency as a target or funding one in carry trade. The study shows that the uncovered interest parity holds during a high-volatility period and the forward premium anomaly arises in a low-volatility regime. However, the anomaly does not appear for all tested exchange rates. For currency pairs with a high interest-rate differential, it seems to apply to the exchange rates where a high-yielding currency is perceived as an attractive target currency. In turn, for currency pairs with slightly different interest rates, it depends highly on the sign of interest rate differential and the currency's attractiveness as a funding currency.

Keywords: forward premium anomaly, speculation, carry trade, Japanese yen, Markov switching regression

JEL: C58, E44, F31, G12, G14, G15

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1 Introduction

Interest rate parity is one of the cornerstones of international finance theory. The uncovered interest parity (UIP) states that the expected exchange rate return equals the interest rate differential, or equivalently the forward premium. One of the most compelling anomalies that emerges in international finance is a rejection of the UIP condition. This phenomenon is generally called the forward premium puzzle (forward discount bias). There is overwhelming evidence supporting the rejection of the UIP hypothesis (Fama 1984; Froot, Frankel 1989; McCallum 1994; Zhou, Kutan 2005; Clarida, Davis, Pedersen 2009; among others).

Although a wide range of explanations has been proposed in various streams of literature, there appears to be no consensus on the reasons for the UIP failure. This situation raises a number of problems, as most models of international finance assume the validity of the UIP. A better understanding of the forward premium anomaly is necessary to build more realistic and fitted models. The paper aims to explain the phenomenon of a forward premium anomaly in reference to the activity of speculators in the foreign exchange market. The article focuses on the carry trade strategy. The paper assumes that the existence of a forward premium puzzle is highly dependent on three main factors: the frequency of crisis episodes, the sign and size of the interest rate differential between the two currencies and the attractiveness of the currency as a target or funding one in the carry trade. It is worth emphasizing that most published studies about UIP analyse only exchange rates related to the US dollar. However, the US dollar is neither a good example of carry trade target nor funding currency. In the paper we apply Japanese yen exchange rates, stressing the fact that the Japanese currency is the most popular funding currency in the carry trade and its value and volatility is profoundly affected by carry trader's activity in the market.

The paper is organized as follows. Section 2 contains a literature review about the empirical failure of uncovered interest parity. Section 3 thoroughly explains currency carry trade strategies and their influence on the UIP tests' results. Section 4 describes the empirical methodology and data. Section 5 reports the results of the UIP test in the Japanese yen foreign exchange market based on a Markov switching regression model. Section 6 provides conclusions and draws some implications for future research.

2 The empirical failure of uncovered interest parity

There are a few major streams in the literature on international economics that explain the empirical failure of UIP. The first one assumes that market participants are not risk-neutral and the forward premium bias is likely to be driven by the presence of a non-zero and time-varying risk premium. A UIP model with risk premium is built by Domowitz and Hakkio (1985), Engel (1996), Jiang and Chiang (2000), Berk and Knot (2001), Li, Ghoshray and Morley (2012), Shimizu (2017), among others. Research results are inconsistent. The obtained results depend on the type of risk premium model, time-horizon, analyzed foreign exchange rates etc. McCallum (1994) claims that the non-zero risk premium is the main reason leading to deviations from UIP but only over a short-term horizon. These research findings are in line with explanations provided by other researchers. Lothian and Wu (2011) test the UIP hypothesis for ultra-long time series on two currency pairs, the French franc to the pound sterling and the US dollar to the pound sterling. Their sample period covers the 19th and 20th centuries. They find that uncovered interest parity holds for the whole sample period and forward premium anomaly occurs only when the 1980s make up a significant portion of the sample period. In their opinion forward premium anomaly is a distinctive feature of the late 1970s and the 1980s.

Another potential explanation of the forward premium puzzle are deviations from neoclassical rational expectations theory. Mark and Wu (1998) build a model in which both rational and irrational market participants influence price volatility in the foreign exchange market. They claim that irrational traders may contribute to UIP failure. Chakraborty and Evans (2008) build a UIP model under the assumption of adaptive learning, especially constant-gain learning. They explore market participants' decision-making process within a bounded rationality framework. It is assumed that market participants have limited common knowledge since they estimate their own perceived laws of motion. Chakraborty and Evans (2008) show that adaptive learning may lead to deviations from UIP, but only over a short--term horizon. However, over a long-term horizon, expectations formed under adaptive learning will be similar to rational.

The literature provides a wide range of other explanations of the forward premium puzzle. Bansal and Dahlquist (2000) find that UIP performs better in developing countries than in developed countries. They claim that country-specific macroeconomic attributes such as per capita income, inflation rates, interest rates, and country risk ratings are essential in explaining forward premium puzzle. Bansal and Dahlquist (2000) perform tests on US exchange rate data for 28 economies. They find that forward premium anomaly is present only when US interest rates exceed foreign interest rates. When foreign interest rates exceed US interest rates, UIP holds systematically better. Then, the problem of the forward premium puzzle seems to occur only for developed economies which are marked by high income, relatively low inflation and low-interest rates. Nevertheless, their results come across as being inaccurate and incredible, especially taking into account the current situation in the foreign exchange market. It is worth emphasizing that Bansal and Dahlquist (2000) analyse the sample that covers the period from January 1976 to May 1998 and they demonstrate that, over the sample period, the US dollar has appreciated against most of the studied currencies. Little wonder that for the negative interest rates differential they find a positive relationship between changes in spot US dollar exchange rates and the interest rates differential.[1] Appreciation of lower-yielding currency is consistent with uncovered interest parity. It doesn't mean, however, that the forward premium anomaly is identified only with developed economies. Nevertheless, their findings provoke greater thinking and inspire further investigations.

Flood and Rose (2002) publish another inspiring research paper. They find that UIP works systematically better in the time of crisis when high price volatility is observed in the financial market. Similar results are obtained by Clarida, Davis and Pedersen (2009). They show that forward premium anomaly relates to a stable time period when both exchange and interest rates display consistently lower volatility. Another explanation of the forward premium puzzle, presented by Evans and Lewis (1995), is the "peso problem" effects. They analyse how the potential for discrete shifts in the distribution of future shocks to the foreign exchange market may affect the rational expectations held by market participants.

Moreover, Sarno, Valente and Leon (2006) claim that major US dollar exchange rates are linked nonlinearly to forward premium in the UIP model. There is a variety of reasons that explain

[1] Interest rate differentials are computed as US interest rates minus foreign interest rates. The spot exchange rate is the price of foreign currency in units of US dollar.

nonlinearity in the relationship between exchange rates and interest rates differential, like transaction costs (Baldwin 1990; Hollifield, Uppal 1995; among others) or the limits to speculation hypothesis (Lyons 2001; Sarno, Valente, Leon 2006). The basic idea of limits to speculation hypothesis is that UIP failure persists over a long period because financial institutions are not willing to trade on these deviations since other investment opportunities yield higher Sharpe ratios. According to Lyons (2001), there is a band of inaction where the forward bias does not attract speculative capital and UIP failure will persist until it generates Sharpe ratios that are large enough to attract speculative capital. Hochradl and Wagner (2010) show, however, that strategies based on forward premium bias can be employed as attractive investment strategies with high Sharpe ratio and useful diversification devices. In their opinion, the limits to speculation hypothesis are unlikely to provide the explanation of the forward premium puzzle.

An alternative explanation of UIP failure is a high activity of carry traders in the foreign exchange market (Baillie, Chang 2011). Baillie and Chang assume that forward premium anomaly may result from the growth in carry trade activity. Higher demand for high-yielding currencies and higher supply for low-yielding currencies leads to an appreciation of high-yielding currency against low--yielding currency. Depreciation of low interest-yielding currencies is contrary to the UIP theory and favourable to carry trade speculators. However, during times of crises, price trend directions in the foreign exchange market are opposite. Carry trade unwinding leads to the appreciation of low-yielding currencies and depreciation of high-yielding currencies, which is consistent with the UIP. Similar results are obtained by Cho, Han and Lee (2019). It implies that carry trade activity may explain, at least to some extent, a forward premium anomaly. When speculators' involvement in carry trade is high, UIP failure is observed. This observation is the starting point for this paper. It is assumed that forward premium anomaly is related to foreign exchange markets that are attractive for speculators.

3 Carry trade and forward premium anomaly

Uncovered interest-rate parity represents a fundamental parity condition for testing foreign exchange market efficiency. The simple risk-neutral efficient market hypothesis assumes that market participants are risk-neutral and their expectations are rational. Assuming that covered interest-rate parity holds and investors are risk-neutral, the UIP states that the interest rate differential is equal to the expected change in the exchange rate (Isard 2006):

$$E_t\left(s_{t+1}|\Omega_t\right) - s_t = i_t - i_t^* \tag{1}$$

where:

s_t – the logarithm of price of the base currency in units of quote currency at time t,

$E_t\left(s_{t+1}|\Omega_t\right)$ – the logarithm of expected spot exchange rate at time $t+1$, based on information known at time t,

i_t and i_t^* – interest rates in quote and base currency countries, respectively.

Since obtaining accurate and reliable data on exchange rates expectations is extremely difficult, equation (1) is hardly testable. Therefore, the UIP hypothesis is very often tested jointly with the assumption of rational expectations. Under the assumption of rational expectations, the future value of the spot exchange rate is equal to the expected spot exchange rate at time $t+1$ plus a white-noise error term which is uncorrelated with information available at time t (η_{t+1}) (Isard 2006).

$$s_{t+1} = E_t\left(s_{t+1}|\Omega_t\right) + \eta_{t+1} \tag{2}$$

where:

s_{t+1} – the logarithm of the spot exchange rate at time $t+1$,

$E_t\left(s_{t+1}|\Omega_t\right)$ – the logarithm of the expected spot exchange rate at time $t+1$, based on information known at time t,

η_{t+1} – a white-noise error term.

Assuming that market participants are endowed with rational expectations and risk-neutral, the UIP holds when expected profits from holding one currency rather than another are offset by the interest rate differential. The baseline econometric model applied to test uncovered interest parity is as follows (Isard 2006):

$$s_{t+1} - s_t = \alpha + \beta\left(i_t - i_t^*\right) + \varepsilon_{t+1} \tag{3}$$

where:

s_{t+1} – the logarithm of the spot exchange rate at time $t+1$,

s_t – the logarithm of the spot exchange rate at time t,

i_t and i_t^* – interest rates in quote and base currency countries, respectively,

ε_{t+1} – a disturbance term uncorrelated with information available at time t.

Under the UIP parity condition, the slope coefficient β in equation (3) should be equal to unity (β = 1) and the coefficient α should be equal to zero (α = 0). Empirical studies based on a regression model (3) generally reject the UIP hypothesis (Fama 1984; Froot, Frankel 1989; McCallum 1994; Zhou, Kutan 2005; Clarida, Davis, Pedersen 2009; among others). A well-known empirical regularity is that β is significantly less than one, and in fact very often closer to minus unity than plus unity (Froot, Thaler 1990).

Assuming that investors are risk-neutral and form expectations rationally, exchange rate changes should eliminate any gains arising from the interest rates differential across countries. However, an overwhelming number of empirical studies show that high-interest yielding currencies tend to appreciate, while low-interest yielding currencies tend to depreciate. A currency speculation strategy that exploits that foreign exchange market anomaly is called carry trade.

Market evidence suggests that the carry trade is the most widely used currency speculative strategy (Galati, Melvin 2004). The motivation behind the strategy is to exploit profit by applying the combination of the low cost of funds in one market and high returns in another. Currency carry trade comprises borrowing money in a low-yielding currency and investing those funds in high-yielding currencies (Fong 2010). The profitability of carry trade is highly affected by both exchange rates and interest rate volatility. The vast majority of published research findings provide evidence that carry trade usually generates high excess returns with Sharpe ratios at least as high as those on equity market (Gyntelberg, Remonola 2007; Darvas 2009; Fong 2010; Menkhoff et al. 2012; Egbers, Swinkels 2015; Accominotti, Chambers 2016). Furthermore, higher involvement of investors in the carry trade conduces higher carry trade returns because the simultaneous short positions taken in low-yielding currency prominently depreciate its value.

It needs to be emphasized that when the foreign exchange market is effective and uncovered interest rate parity holds, carry trade strategy should on average yield zero return. Thus, high excess returns of carry trade violate the UIP condition. Moreover, an increase in carry trade activity tends to weaken low-yielding currency (funding currency) and strengthen high-yielding currencies (target currencies), which is also contrary to the UIP. According to Baillie and Chang (2011), uncovered interest parity deviations might be explained by high investors' involvement in the carry trade.

There are several studies that test UIP in reference to the carry trade. Spronk, Verschoor and Zwinkels (2013) show that carry trade is part of the explanation of a forward premium anomaly. They build a heterogeneous agent model with three types of agents: fundamentalists, chartists and carry traders. In their opinion, carry traders have a directional role in the estimation of the slope coefficient in the UIP regression model. Moreover, the value of β decreases when the importance of the carry traders' forecast increases. However, given that interest rate differentials are persistent, carry traders introduce momentum effects in a currency that is later picked up and extrapolated by chartists. Carry trade might have no such impact on the foreign exchange market but for chartists. Dos Santos, Klotzle and Pinto (2016) demonstrate that UIP does not hold for Brazilian, Polish, Indonesian, Turkish, Mexican, and South African currencies and that base lower-yielding currency (US dollar) depreciation rather than appreciation was observed. They stress that the presence of the forward premium puzzle opens space for carry trade operations in the foreign exchange market. Moreover, they detect negative and time-varying risk premium for the majority of the studied investing currencies. Dos Santos, Klotzle and Pinto (2016) claim that the existence of negative and time-varying risk premium, along with a negative β coefficient, increases the forward premium bias.

4 Model and data

In recent years many researchers have applied nonlinear models in explaining the relationship between interest rate differentials and change in exchange rates (Chen 2006; Sekioua 2006; Lothian, Wu 2011; Ichiue, Koyama 2011; Cho, Han, Lee 2019). It is commonly believed that the behaviour of economic variables depends on different states of the world. Thus, properties of foreign exchange time series are dependent on the regime which prevails at a certain period. The paper applies the Markov switching (MS) model to test uncovered interest-rate parity in the Japanese yen foreign exchange market. The coefficients in the MS models are different in each regime to account for the possibility that the relationship between exchange rate returns and interest rate differential may undergo a finite number of changes over the sample period. Although the regimes are not observed, probabilistic statements can be made about the relative likelihood of their occurrence.

The MS model is popularized in economics and finance by Hamilton (1989). His pioneering work studies a persistency of recessions and booms by applying the regime-switching model. The model involves multiple structures that characterize time series in different regimes. Moreover, switching between these structures is permitted. However, a change in regime is not regarded as an outcome of a foreseeable, deterministic event, but rather a change in regime is itself a random variable. The MS model includes a description of probability law governing the change in regimes. Engel and Hamilton (1990) use a two-regime model to explain returns in the foreign exchange market. One can specify the model as:

$$s_{t+1} - s_t = \alpha_{v_t} + \sigma_{v_t} \varepsilon_{t+1} \tag{4}$$

where:

$v_t \in \{1, 2\}$

where:

α_{v_t}, σ_{v_t} – the estimated coefficients,

v_t – an unobservable state variable assuming the discrete values one or zero.

One of the simplest and well-known time series models for a discrete-valued random variable is a Markov chain. The model (4) assumes that v_t evolves according to a first-order Markov process with a transition probability matrix **P**. The process is in regime 1 when v_t equals 1, while the process is in regime 2 when v_t equals 2. Transition probabilities in an (2×2) matrix **P** are presented below:

$$P = \begin{bmatrix} p_{11} & p_{12} \\ p_{21} & p_{22} \end{bmatrix}, \ p_{ij} \geq 0 \tag{5}$$

The row j, column i element of **P** is the transition probability p_{ij}. Transition probability p_{ij} gives the probability that state i will be followed by state j.

The paper employs a Markov switching model (6) for analysis of the relationship between interest rate differentials and exchange rate returns:

$$s_{t+1} - s_t = \alpha + \beta_{v_t} \left(i_t - i_t^* \right) + \sigma_{v_t} \varepsilon_{t+1} \tag{6}$$

where:

$v_t \in \{1, 2\}$

The MS model (6) assumes that there are simultaneous switches in slope coefficient β and volatility parameter σ. Intercept α is assumed not to switch. It results from the belief that regime switches in exchange rate returns should be interpreted as switches in the relationship between exchange rate returns and interest rate differentials rather than just switches in intercept (Ichiue, Koyama 2011). Bekaert and Hodrick (1993) apply a similar model to the two-regime model (6), but they assume simultaneous switches in all coefficients (α, β, σ). The current study is most closely related to the research of Ichiue and Koyama (2011). However, our approach differs from the Ichiue and Koyama (2011) study as our model distinguishes only two not four regimes. We believe that for the currency pairs mostly applied in the carry trade, the trend and the volatility depend perfectly on each other. The approach is similar to Engel (1994) and Engel and Hamilton (1990). Moreover, Ichiu and Koyama (2011) analyse currency pairs with the US dollar base currency related to the Japanese yen, pound sterling, Swiss franc and euro. Even though they assume that forward premium anomaly may be related to the carry trade strategy, their research does not take into account high-yielding currencies that represent the popular basket of the carry trade target currencies. Moreover, during the period in which they analyse it, the US dollar has been changing from low- to high-yielding currency, from the funding to target one. We believe that a study of the forward premium anomaly in relation to the carry trade might be more accurate when a base currency plays a fixed funding or target role. Additionaly, we assume that the trend and the volatility coefficients switch simultaneously especially for currency pairs with the high interest rate differential that does not change significantly over time.

It should be emphasized that the vast majority of published UIP tests are performed on exchange rates related to the US dollar (Bekaert, Hodrick 1993; Baillie, Kilic 2006; Lee 2013; Cho, Han, Lee 2019; among others). The paper is focused on the Japanese yen exchange rates, which can be considered as a novel aspect of the study. The Japanese yen constitutes an example of a prolonged low-yielding currency. Additionaly, the currency is the most popular funding currency in the carry trade and its value and volatility are highly affected by carry traders' activity in the market (Ranaldo, Söderlind 2010; Liu, Margaritis, Tourani-Rad 2012). The Japanese yen has been the third most heavily traded currency in the world over the past decade. In 2016, it accounted for 21.6% of global reported FX market turnover (BIS 2016). The paper aims to explain the forward premium puzzle in relation to the carry trade currency speculation strategy. Thus, the sample data covers a specific period from January 2005 to December 2016 that is strictly connected with the time of both high activities of carry traders and carry trades' unwinding.

The activity of carry traders in the foreign exchange market can be measured based on the report of open futures and options positions held by non-commercial traders (McGuire, Upper 2007). The report is published by the US Commodity Futures Trading Commission. US non-commercial traders are classified by CFTC as those who use futures and options not for hedging but for speculative purposes. Figure 1 presents the Japanese yen carry trade activity during the period from January 2000 to December 2016. The net Japanese yen position is measured as a ratio of non-commercial short minus long positions in futures and options on Japanese yen. The higher the ratio, the higher the Japanese yen carry trade activity. Figure 1 reports weekly data that reflects positions at the close of every business Tuesday.

Figure 1 presents two sample periods of very high Japanese yen carry trade's activity. During the periods January 2005 – August 2008 and January 2013 – December 2015 net positions of non-commercial traders in futures and options on Japanese yen were positive. It may indicate that the Japanese yen was then highly employed as a funding currency in the carry trade. Negative values of carry trade ratio (Figure 1) reflects the unwinding of carry trade positions.

The paper tests the UIP hypothesis for seven appropriately chosen spot monthly exchange rates related to the Japanese yen. The Japanese yen is assumed to be the home currency (base currency) and the Swiss franc (CHF), euro (EUR), pound sterling (GBP), Australian dollar (AUD), New Zealand dollar (NZD), Indonesian rupee (IDR), and South African rand (ZAR) are applied as foreign currencies (quote currencies). These currencies exhibit countries with both high and low-interest rates in the analysed period (Table 2):

– low-interest rate differential (CHF/JPY),

– switching from high- to low-interest rate differential (EUR/JPY, GBP/JPY),

– high-interest rate differential (AUD/JPY, NZD/JPY, IDR/JPY, ZAR/JPY).

The choice of lower-yielding and higher-yielding currencies enable to show that a forward premium anomaly is highly related not only to the sign and size of interest rate differential, but also to unique features of the currency like its application and attractiveness to speculators. The currencies are selected based on the Bloomberg Carry Trade indices. The Japanese yen, Swiss franc, euro, pound sterling, Australian dollar, and New Zealand dollar are six out of ten currencies included in the G10 Bloomberg FX Carry Trade Index. The Japanese yen and Swiss franc are well-known funding currencies. The euro and pound sterling are examples of currencies that switch from target to funding currency during the analysed period. The Australian dollar and New Zealand dollar are the most popular high-yielding target currencies among G10 currencies. The Indonesian rupee and South African rand are two out of eight currencies included in the Bloomberg Cumulative Carry Trade Index for eight emerging-market currencies.

Alexius (2001), Chinn and Meredith (2004), among others, find that UIP doesn't hold for short--term interest rates. However, when you conduct an analysis based on long-term interest rates, UIP holds much better. Thus, with the object of enhancing the UIP test reliability and validity, we apply both short- and long-term interest rates. As short-term interest rates, we apply monthly data of 1-month interbank interest rates (if not available, 1-month deposit rates) and as long-term interest rates we use monthly data of 10-year government bond yields in each country. For euro currency, German 10-year government bond yields are applied. Beginning-of-month data of spot exchange rates, 1-month interbank interest rates and 10-year government bond yields are obtained from Refinitiv Datastream.

5 Empirical results

The paper studies uncovered interest parity for exchange rates of the Swiss franc, euro, pound sterling, Australian dollar, New Zealand dollar, Indonesian rupee, and South African rand against the Japanese yen during the period from January 2005 to December 2016. The Japanese yen and Swiss franc are identified as funding currencies in the whole sample period. After the 2008 financial crisis, the pound sterling and euro switched from being target to funding currencies. It needs to be stressed that before financial crisis the pound sterling was perceived as a popular target currency in carry trade (Liu, Margaritis, Tourani-Rad 2012). The Australian dollar, New Zealand dollar, Indonesian rupee, and South African rand are identified as target currencies in the whole sample period. The Australian dollar and New Zealand dollar are examples of high-yielding currencies of developed countries. The Indonesian rupee and South African rand are examples of high-yielding currencies of emerging countries.

Table 1 reports the estimation results of the Markov switching model (6). The parameters of the model are computed based on the quasi-Newton algorithm (Broyden, Fletcher, Goldfarb and Shanno – BFGS). Results obtained for short-term and long-term interest rates do not vary significantly. Based on the Markov switching model two regimes are distinguished. For all currency pairs, the first regime (I) is a higher volatility regime and the second regime (II) is a lower-volatility regime. All estimated volatility coefficients (σ) are significantly different than zero at the 0.01 significance level.

Based on the estimated transition probabilities, we can assume that distinguished regimes are persistent, except for the IDR/JPY market, where regime I is not persistent. In all cases, the estimated β coefficient in regime I is positive and we cannot reject, at the 0.01 significance level, the null hypothesis indicating the slope coefficient equals to unity. It indicates that for the higher-volatility regime, UIP holds. It concerns both low- and high-yielding, both developed and emerging countries' currencies. These results are consistent with previous studies conducted by Clarida, Davis and Pedersen (2009), Baillie and Chang (2011) and Cho, Han and Lee (2019). On the other hand, the outcomes do not confirm the Bansal and Dahlquist (2000) conclusions that UIP performs better in developing compared to developed countries.

Additionally, the obtained results can be linked to the carry trade unwinding during a higher-volatility regime. Lower activity of carry traders lead to the appreciation of low-interest-yielding currencies (e.g. the Japanese yen) and depreciation of high-interest-yielding currencies, which is consistent with the UIP. It is closely related to the research of De Bock and de Carvalho Filho (2015), who claim that depreciation of high-yielding currencies after risk-off episodes may be related to the sudden withdrawal of carry trade positions by global investors. Furthermore, similar to our study, Menkhoff et al. (2012) find a significantly negative co-movement between the value of high interest-rate currencies and exchange rates' volatility. Our study shows that the estimated β coefficients in high-volatility regime I are positive (Table 1). It implies that during a high-volatility period the high-interest yielding currencies tend to depreciate relative to low-yielding currencies. Moreover, Menkhoff et al. (2012) claim that low-interest-rate currencies, applied as the carry trade funding currencies, provide a hedge against unexpected volatility changes. This is mainly due to the fact that during the higher volatility regime I the funding currencies of low-interest countries appreciate.

It needs to be stressed, however, that there is a substantial difference in the duration of regime I (d_1). High-volatility regime I, when UIP usually holds, spans longer for lower-yielding currencies (like the Swiss franc and euro) and its duration decreases for higher-yielding currencies. The only exception is GBP/JPY, where the duration of regime I amounts to almost 28 months, in comparison to 10 and 8 months for CHF/JPY and EUR/JPY, respectively. One can assume that there is a negative link between the interest rate differential and regime I duration. Generally, the higher the average interest-rate differential, the shorter the period when UIP holds.

The smoothed probabilities of staying in regime 1 are given in Appendix (Figure 1 and Figure 2) in graphical form. For all currency pairs, several regime switches are detected. The first significant switch to regime I is observed in late 2007 and 2008 when the financial crisis began and many financial institutions reported huge losses. The financial crisis triggered a change in the relationship between interest rate differentials and Japanese yen exchange rate returns. It has been shown that, for all currency pairs, during the 2008 financial crisis the UIP holds.

In all cases, the absolute value of the estimated β coefficients in regime II are lower than the estimated slope coefficients in regime I (Table 1). It implies that the exchange rate moves faster when the low-interest-rate currencies strongly appreciate. Moreover, the expected duration of regime II spans longer than the duration of regime I. All these results indicate that the strong appreciation of low-interest-rate currencies, that is in line with UIP, occurs less frequently. This is consistent with the study of Ichiue and Koyama (2011), who claim that low-interest-rate currencies appreciate less often, but once it occurs, their appreciation moves faster than their depreciation. Strong appreciation of low-interest-rate currencies may result from rapid carry trade unwinding during the high-volatility time.

The results presented in Table 1 show that for exchange rates apart from GBP/JPY, NZD/JPY (long-term rates), estimated β coefficients in regime II are significantly different than the one at 0.1 significance level. Regime II is the low-volatility regime where forward premium anomaly arises. Additional evidence of the anomaly's existence is the negative value of the estimated slope coefficient. For exchange rates such as CHF/JPY, EUR/JPY, AUD/JPY and ZAR/JPY (long-term rates) estimated β coefficients in regime II are negative. However, for GBP/JPY, NZD/JPY and ZAR/JPY (short-term rates) the estimated slope coefficients are positive. A positive relationship between interest rate differentials and exchange rate returns is in line with UIP. All these results indicate that for the low-volatility regime II, a forward premium anomaly exists only for some currency pairs. Nevertheless, the estimated slope coefficients in regime II are very often closer to zero than one which contradicts UIP.

Moreover, the results of the Markov switching model for high-yielding currencies (AUD, NZD, IDR, ZAR) show that the estimated β coefficients are negative mainly for AUD and IDR currency pairs (Table 1). It may suggest that both the Australian dollar and the Indonesian rupee are popular carry trade target currencies and their value tends to strongly appreciate during the periods of high carry trade activity. Cho, Han and Lee (2019) results also indicate that the Australian dollar is considered to be significant target currency among carry traders. The South African rand, in turn, is an example of a high-yielding currency that used to depreciate highly during the sample period. It should be stressed that carry traders invest in a currency that they believe will increase in value. When the country's economic situation is not good enough, they are not attracted by the country's high interest rates.

It seems to be fair to conclude that carry trade activity may have an impact on the forward premium puzzle in the Japanese yen market. During 2008 and the early part of 2009 the Japanese yen carry trades were unwound. The Japanese yen appreciated against other currencies, especially against high-yielding currencies like AUD, NZD, IDR and ZAR. The appreciation of low-yielding Japanese yen against high-yielding currencies is in line with UIP. However, during the low-volatility time, when carry trade activity brings Japanese yen depreciation against higher-yielding currency, forward premium anomaly arises. Nevertheless, the forward premium anomaly does not apply to all currency pairs.

There are two additional points that are relevant to our current discussion. First, smoothed probabilities of staying in regime 1 (Figure 2 and Figure 3) display higher amount of switches between regime I and II for CHF/JPY and EUR/JPY exchange rates. Moreover, after the 2008 crisis, these currencies exhibit a higher tendency to remain in regime I, where UIP holds. It needs to be stressed, however, that after 2008 interest rates in both the Eurozone and Switzerland were, on average, lower than interest rates in Japan. Additionally, the euro and Swiss franc may be perceived as safe haven currencies that tend to appreciate during unstable periods. In the post-crisis period, the carry trade high activity leads again to depreciation of the Japanese yen and the new period of forward premium anomaly starts. However, it concerns only exchange rates with a positive interest rate differential. The depreciation of the Japanese yen against the lower-yielding Swiss franc and euro was in line with UIP (the higher-yielding currency was depreciating against the lower-yielding currency). On the other hand, when the Swiss franc or the euro turns out to be more popular as a funding currency than the Japanese yen, it will lead to their depreciation and even to forward premium anomaly in the CHF/JPY and EUR/JPY market (e.g. when CHF would be more popular than JPY as a funding currency it would depreciate harder than JPY and in the results JPY would appreciate against CHF. Finally the appreciation of the higher-yielding currency violates the UIP). Thus, UIP test results for currency pairs with slightly different interest rates depend highly on the currency's attractiveness as a funding currency. This conclusion constitutes a new finding to the literature about forward premium anomaly. It does not mean, however, that there are no other factors that have an impact on UIP test results. It should be stressed that forward premium anomaly is usually linked to monetary policy in the country. In April 2013, the Bank of Japan adopted Quantitative and Qualitative Monetary Easing to achieve a 2% price stability target. It brought about Japanese yen depreciation and also affected the results of the UIP test during the sample period.

Second, smoothed probabilities of staying in regime I for the GBP/JPY exchange rate substantially differs from others. In comparison to other currency pairs, the GBP/JPY duration of staying in regime I is the longest. In contrast to CHF and EUR, average interest rates in the UK are perpetually higher than average interest rates in Japan. Therefore, UIP holds only when the higher-yielding pound sterling is depreciating against the lower-yielding Japanese yen. In the pre-crisis period (2005–2008) and post--crisis period (2013–2015), pound sterling appreciated against the lower-yielding Japanese yen. Those periods represent forward premium anomaly regimes in the GBP/JPY market (regime II, Figure 1 and Figure 2). In turn, regime I for GBP/JPY covers the period of the financial crisis and additionally, the period after the UK "Brexit" referendum in June 2016. During the period of the financial crisis, the carry trade low activity led to an appreciation of the funding currency (JPY) and depreciation of the target currency (GBP). The appreciation of the lower-yielding Japanese yen against the higher--yielding currencies was typical for a crisis period and was observed for the majority of exchange rates related to the Japanese currency with a high interest rate differential. However, the period after the UK "Brexit" referendum represents a distinct view on the issue. In that time, the pound sterling turned out to be an attractive funding currency of carry trade. A depreciation of the slightly higher-yielding pound sterling against the Japanese yen was in line with UIP and contributed to switching to regime I. It again shows that UIP test results for currency pairs with slightly different interest rates are highly dependent on the currency's attractiveness as a funding currency.

6 Conclusions

Many researchers try to understand and tackle the problem of the forward premium anomaly, but there is still no consensus on how to explain it. In the paper, we attempt to the explain empirical rejection of uncovered interest parity for exchange rates related to the Japanese yen. We estimate a model that incorporates two regimes. The estimated slope coefficients are widely dispersed and obtain values from negative to positive. It remains true that forward premium anomaly is regime-dependent and related to price volatility in the foreign exchange market.

Our findings are as follows. The obtained results show that for all Japanese yen currency pairs UIP holds during high volatility period. These outcomes are consistent with previous studies conducted by Clarida, Davis and Pedersen (2009), Baillie and Chang (2011), Ichiue and Koyama (2011) and Cho, Han and Lee (2019). Additionally, the research results can be linked to the carry trade unwinding during a higher-volatility regime. Lower activity of carry traders leads to appreciation of low interest--yielding currencies and depreciation of high interest-yielding currencies, which is consistent with UIP. Additionally, there is a negative link between interest rate differentials and the eduration of a high--volatility regime. Generally, the higher the average interest-rate differential, the shorter the period when UIP holds.

The research results suggest that the forward premium anomaly arises in low-volatility regimes. During low-volatility periods investors tend to engage in carry trades leading to appreciation of the target currency and depreciation of the funding currency, which contradicts the UIP theory. However, it concerns mainly the Japanese yen exchange rates, where high-yielding currency is perceived by carry traders as an attractive target currency. The results of the Markov switching model for high-yielding currencies show that the estimated β coefficients in a low-volatility regime are negative mainly for the Australian dollar and the Indonesian rupee currency pairs. It may suggest that both currencies constitute an example of popular carry trade target currencies and their value tends to appreciate during periods of high carry trade activity. Cho, Han and Lee (2019) results also indicate that the Australian dollar is considered to be a significant target currency among carry traders. Furthemore, the research results suggest that the existence of the forward premium anomaly for currency pairs with slightly different interest rates depends highly on the currency's attractiveness as a funding currency. It applies to the currency pairs of two countries with low-interest rates. The conclusion constitutes a new finding to the literature about forward premium anomaly.

We have shown that the existence of a forward premium puzzle is highly dependent on three main factors: the frequency of crisis episodes, the sign and size of the interest rate differential between the two currencies and the attractiveness of the currency as a target or funding currency in the carry trade. For Japanese yen exchange rates with a high-interest rate differential, the UIP test results are determined by the high-volatility episodes and the quote currency's atractiveness as a target currency. It has been shown that during high volatility periods UIP holds. However, in the low-volatility regime, a forward premium anomaly arises especially for such currency pairs where the quote high-yielding currency is attractive to carry traders. For Japanese yen exchange rates with a low-interest rate differential, the UIP test results are determined mainly by the frequency of crisis episodes, the sign of interest rate differential between two currencies and the quote currency's atractiveness as a funding currency. It is shown that during the 2008 crisis the UIP holds. In the post-crisis period, high carry trade activity leads again to Japanese yen depreciation and a new period of forward premium anomaly starts. However, it concerns only exchange rates with a positive interest rate differential. After 2008, interest rates in both the Eurozone and Switzerland where, on average, lower than interest rates in Japan. Depreciation of the Japanese yen against the lower-yielding Swiss franc and euro was in line with UIP. As far as the pound sterling is concerned, the average interest rates in the UK has decreased after the 2008 crisis but, in contrast to CHF and EUR, they have been perpetually higher than average interest rates in Japan. Therefore, in a situation of the positive interest rate differential, UIP holds only when the higher-yielding pound sterling is depreciating against the lower-yielding Japanese yen. In the post-crisis period the pound sterling appreciated against the slightly lower-yielding Japanese yen, which indicates the existence of forward premium anomaly. However, after the UK "Brexit" referendum, the pound sterling has strongly depreciated and turned out to be an attractive funding currency in carry trade. A depreciation of the slightly higher-yielding pound sterling against the Japanese yen was in line with UIP and contributed to switching to regime I. It again shows that UIP tests results for the currency pairs with slightly different interest rates are highly dependent on the currency's attractiveness as a funding currency. We therefore argue that the forward premium anomaly is driven, at least to some extent, by the magnitude and direction of speculative capital movements in the foreign exchange market.

The study does not take into account the currency pairs of two countries with high-interest rates. Further UIP tests for such exchange rates may lead to exciting and relevant conclusions about forward premium anomaly. We believe that the UIP test result for the exchange rates of two high--yielding currencies is largely linked to the currency's attractiveness as a target currency. We leave this for future work.

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Appendix

Table 1

Parameters estimates of the regime-switching model (6)

	CHF/JPY		EUR/JPY		GBP/JPY		NZD/JPY		AUD/JPY		IDR/JPY		ZAR/JPY	
	I	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**	**I**	**II**
Short-term rates														
α	0.000		-0.003		-0.008		-0.009		-0.002		0.013		-0.002	
p-value$_1$	0.962		0.479		0.543		0.246		0.772		0.169		0.932	
β	1.046	-0.48	1.153	-0.09	2.283	0.137	1.162	0.153	0.788	-0.03	1.689	-0.19	0.252	0.074
p-value$_2$	0.186	0.381	0.137	0.625	0.001	0.596	0.032	0.356	0.863	0.402	0.000	0.118	0.474	0.823
p-value$_3$	0.954	0.007	0.844	0.000	0.058	0.001	0.765	0.000	0.822	0.000	0.011	0.000	0.025	0.000
σ	0.077	0.005	0.098	0.010	0.089	0.024	0.584	0.064	0.415	0.039	0.052	0.039	0.523	0.083
p-value$_4$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$p_{11}; p_{12}$	0.88	0.12	0.90	0.10	0.96	0.04	0.85	0.15	0.87	0.13	0.48	0.52	0.84	0.16
$p_{21}; p_{22}$	0.15	0.85	0.08	0.92	0.03	0.97	0.01	0.99	0.02	0.98	0.01	0.99	0.02	0.98
$d_1; d_2$	8.3	6.7	10.1	12.0	27.9	35.2	6.5	82.8	7.9	64.5	1.9	124.2	6.2	52.8
Long-term rates														
α	-0.002		-0.005		-0.013		-0.022		0.001		0.025		0.018	
p-value$_1$	0.667		0.179		0.259		0.238		0.845		0.034		0.737	
β	1.547	-0.33	1.166	0.014	1.499	0.416	1.307	0.516	0.669	-0.26	1.018	-0.33	0.055	-0.23
p-value$_2$	0.272	0.575	0.116	0.942	0.044	0.303	0.234	0.284	0.562	0.519	0.000	0.025	0.964	0.757
p-value$_3$	0.699	0.025	0.823	0.000	0.503	0.150	0.780	0.317	0.775	0.002	0.885	0.000	0.439	0.094
σ	0.093	0.009	0.107	0.011	0.144	0.028	0.736	0.064	0.467	0.039	0.182	0.039	0.539	0.083
p-value$_4$	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
$p_{11}; p_{12}$	0.86	0.14	0.88	0.12	0.94	0.06	0.85	0.15	0.88	0.12	0.49	0.51	0.83	0.17
$p_{21}; p_{22}$	0.10	0.90	0.09	0.91	0.03	0.97	0.01	0.99	0.02	0.98	0.01	0.99	0.02	0.98
$d_1; d_2$	7.3	10.2	8.5	11.7	17.8	38.3	6.5	88.6	8.1	66.1	1.9	95.5	5.9	49.9

Tested hypotheses: H_0: $\alpha = 0$ (p-value$_1$), H_0: $\beta = 0$ (p-value$_2$), H_0: $\beta = 1$ (p-value$_3$), H_0: $\sigma = 0$ (p-value$_4$).

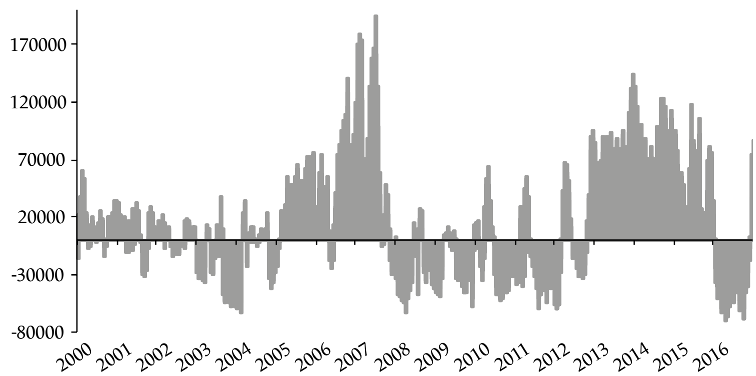
Source: own elaboration based on data from Refinitiv Datastream.

Table 2
Summary descriptive statistics for short-term (STR) and long-term (LTR) interest rates (in %)

		Mean		Median		Maximum		Minimum		Std. dev.		Skewness		Kurtosis	
		STR	**LTR**	**STR**	**LTR**	**STR**	**LTR**	**STR**	**LTR**	**STR**	**LTR**	**STR**	**LTR**	**STR**	**LTR**
r*	JPY	0.3	1.0	0.2	1.2	0.9	2.0	0.0	-0.2	0.2	0.5	1.3	-0.4	3.5	2.3
r	CHF	0.4	1.4	0.1	1.7	2.9	3.3	-1.8	-0.6	1.0	1.1	0.7	-0.2	2.8	1.9
	EUR	1.3	2.4	0.6	2.9	5.1	4.6	-0.4	-0.2	1.6	1.4	0.8	-0.3	2.3	1.8
	GBP	2.1	3.2	0.6	3.3	6.7	5.5	0.3	0.7	2.2	1.2	0.8	-0.1	1.7	1.7
	NZD	4.5	4.9	3.2	5.2	9.8	6.7	2s.3	2.2	2.3	1.2	0.8	-0.4	1.8	1.9
	AUD	4.3	2.8	4.4	3.2	8.3	4.7	1.9	0.1	1.6	1.3	0.3	-0.5	2.0	2.0
	IDR	7.5	9.1	6.9	8.7	15.5	16.7	3.8	5.1	2.3	2.4	1.0	0.6	4.0	3.0
	ZAR	7.4	8.2	7.0	8.2	13.2	10.5	5.0	5.9	2.1	0.7	1.1	-0.3	3.5	3.8
r – r*	CHF/JPY	0.2	0.4	-0.1	0.5	2.2	1.6	-1.9	-0.6	0.9	0.6	0.5	0.1	2.5	2.1
	EUR/JPY	1.1	1.4	0.4	1.6	4.3	2.9	-0.5	-0.2	1.4	0.8	0.7	-0.1	2.0	1.7
	GBP/JPY	1.9	2.2	0.4	2.2	5.9	3.6	0.2	0.6	2.1	0.8	0.7	-0.1	1.6	1.9
	NZD/JPY	4.3	3.8	3.0	4.0	9.0	5.2	2.1	2.3	2.2	0.7	0.7	-0.3	1.7	1.9
	AUD/JPY	4.0	1.7	3.9	1.9	7.5	3.0	1.8	0.0	1.5	0.8	0.2	-0.4	1.7	2.1
	IDR/JPY	7.3	8.1	6.7	7.9	15.4	15.2	3.6	4.3	2.3	2.1	1.2	0.6	4.4	3.5
	ZAR/JPY	7.1	7.1	6.9	7.1	12.5	9.5	4.9	5.3	1.9	0.9	1.1	0.5	3.4	3.1

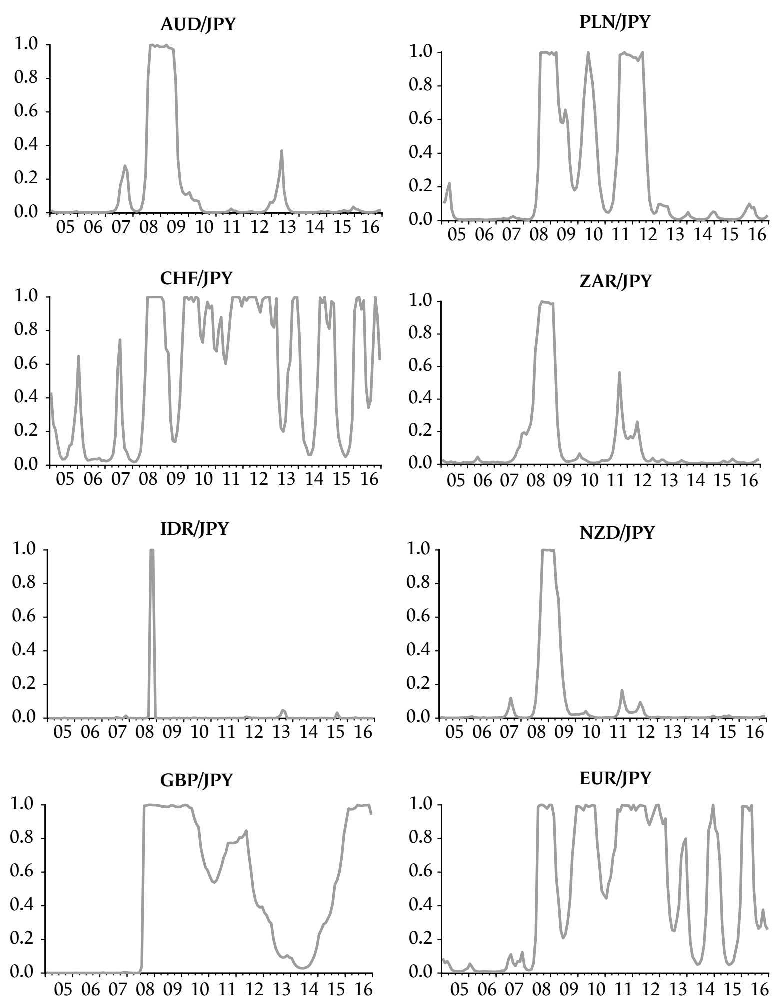
Source: own elaboration based on data from Refinitiv Datastream.

Figure 1
Japanese yen carry trade activity (sample period: January 2000 – December 2016)



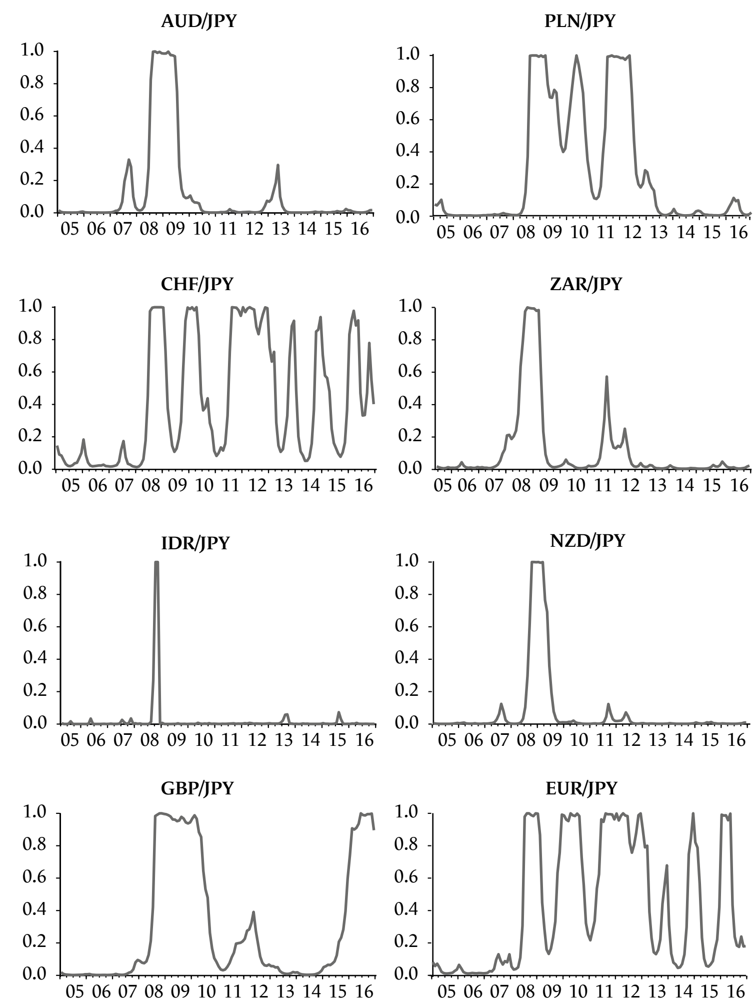
Source: own elaboration based on Commitments of Traders Report released by the US Commodity Futures Trading Commission.

Figure 2
The smoothed probabilities of staying in regime 1 (switching regression for short-term interest rates)



Source: own elaboration based on data from Refinitiv Datastream.

Figure 3
The smoothed probabilities of staying in regime 1 (switching regression for long-term interest rates)



Source: own elaboration based on data from Refinitiv Datastream.