

## TESTING UNCOVERED INTEREST PARITY IN THE PLN/JPY FOREIGN EXCHANGE MARKET: A MARKOV-SWITCHING APPROACH

**Katarzyna A. Czech (ORCID: 0000-0002-0660-7124)**  
Faculty of Economic Sciences  
Warsaw University of Life Sciences – SGGW, Poland  
e-mail: katarzyna\_czech@sggw.pl

**Abstract:** Uncovered Interest Parity argues that a high-interest-rate currency tends to depreciate and a low-interest-rate currency to appreciate. Many researchers find opposite tendency in foreign exchange market. This puzzling feature of foreign exchange market is known as forward premium puzzle. The aim of the paper is to examine how exchange rate volatility influences the relationship between returns and interest rate differentials. Markov switching model is applied. It is shown that in regime of low volatility, in the PLN/JPY market, forward premium anomaly appears. However, during the time of high volatility the UIP holds.

**Keywords:** foreign exchange market, uncovered interest rate parity, forward premium anomaly, Markov-switching model

### INTRODUCTION

Uncovered Interest Parity (UIP) argues that a high-interest-rate currency tends to depreciate and low-interest-rate currency to appreciate. However, many researchers have usually rejected the theory, pointing the fact that low interest-yielding currencies has a tendency to depreciate rather than appreciate. This puzzling feature of foreign exchange market is one of the robust anomaly in financial economy and it is generally known as *forward premium puzzle* [Fama 1984]. There appears to be many empirical evidence against uncovered interest parity theory. Fama (1984), Froot and Frankel (1989), McCallum (1994), among others, observe UIP deviations in relation between interest rates of two countries and exchange rates between these countries. Many researchers try to understand and tackle the problem of UIP puzzle but there is still no consensus on how to explain it.

There are two main streams in the literature on international economics which explain forward premium puzzle. The first one is focused on theory of rational expectations. The theory assumes that economic outcomes do not differ systematically from what the market participants expected them to be. People do not make systematic errors when building forecasts and the deviations from their predictions are only random. Therefore, formed expectations are essentially the same as predictions which are based on available informations and economic models [Muth 1961]. Testing uncovered interest parity involves combining it with the assumption of rational expectations. However, some researchers like Mark and Wu [1998] or Chakraborty and Evans [2008] claim that failure of UIP may result from the irrational expectations. Mark and Wu build the model in which both rational and irrational market participants have an impact on the price volatility in foreign exchange market. They believe that irrational traders (noise-traders) contribute to the deviations from UIP conditions for exchange rates. Chakraborty and Evans [2008] build model under assumption of adaptive learning, especially constant-gain learning. This approach explores market participants decision making process within a bounded rationality framework. In adaptive learning approach, market participants are assumed to have limited common knowledge since they estimate their own perceived laws of motion. Moreover, they are assumed to discount past information when build their forecasts. Chakraborty and Evans [2008] find that the adaptive learning may lead to deviations from UIP in short time. They claim, however, that even under adaptive learning, in long time, formed expectations will be similar to rational expectations.

The second main stream in literature on uncovered interest rate parity explains forward premium anomaly in respect of the assumption of risk neutrality. It is believed that market participants are not risk-neutral but risk-averse and they require a risk premium when investing in foreign exchange market. Therefore, the failure of UIP may result from existence of non-zero risk premium. The problem of risk premium in foreign exchange market is analyzed by many researchers. UIP model with risk premium is built by Domowitz and Hakkio [1985], Jiang and Chiang [2000], Berk and Knot [2001], Serwa [2009], Li et al. [2012], among others. The research results are inconsistent. A non-zero risk premium in foreign exchange market is detected only by some of researchers (Poghosyan et al. [2008], Serwa [2009] and Li et al. [2012]). Estimation results depend on the type of risk premium model, time-horizon, analyzed foreign exchange market etc. McCallum [1994] claims that non-zero risk premium is the main reason leading to deviations from UIP but only over short-term horizon.

The literature provides also other explanation of forward premium puzzle. Alexius [2001] claim that UIP doesn't hold for short-term interest. However, when you conduct an analysis on the basis of long-term interest rates, UIP holds much better. Bansal and Dahlquist [2000] find that uncovered interest parity performs better in developing compared to developed countries. They claim that country-specific attributes such as per capita income, interest rates, inflation and

country risk rating are essential in explaining deviations from uncovered interest parity. Lothian and Wu [2011] study UIP by constructing ultra-long time series. Their results show that UIP may be violated during a particular short period, but it holds much better over the long period.

Flood and Rose [2002] find that UIP works systematically better in the time of crisis, when high price volatility is observed in the financial market. The same results are obtained by Clarida et al. [2009]. They show that forward premium anomaly relates to stable time period, when both exchange and interest rates display consistently lower volatility. This is a starting point for this paper. It is assumed that for high-volatility periods UIP holds. However, in low-volatility and stable periods we can observe forward premium anomaly in foreign exchange market.

Baillie and Chang [2011] claim that UIP deviations may be explained by the existence of carry trade speculation strategies<sup>1</sup>. They assume that exchange rate movement in the direction opposite to that predicted by UIP may result from the growth in carry trade activity. An increase in carry trade activity tends to weaken low interest-yielding currencies and strengthen high interest-yielding currencies, which is contrary to UIP predictions. The most popular funding currency for carry traders is the Japanese yen. Therefore the paper studies the uncovered interest parity in the Polish zloty (PLN) to Japanese yen (JPY) foreign exchange market (PLN/JPY market, where PLN is a quote currency and JPY is a base currency). The aim of the paper is to examine how exchange rate volatility influences direction of relationship between returns and interest rate differentials in Poland and Japan.

## METHODOLOGY AND DATA

Uncovered interest parity (UIP) represents the basis parity condition for testing foreign exchange market efficiency. It states that interest rate in quote currency country must be higher (lower) than interest rate in base currency country by an amount equal to the expected depreciation (appreciation) of quote currency. One can assume that quote currency is a domestic currency and base currency is a foreign currency.

Uncovered interest parity describes relationship between interest rates and expected exchange rate changes:

$$\frac{1 + r_t}{1 + r_t^*} = \frac{E(S_{t+k} | \Omega_t)}{S_t} \quad (1)$$

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<sup>1</sup> The motivation behind the carry trade strategy is to exploit profit by applying the combination of low cost of funds in one market and high returns in another. The strategy comprises borrowing funds in a low-interest-rate currency and investing them in high-interest-rate currencies [Fong 2010].

where  $S_t$  is the price of base currency in units of quote currency in time  $t$   $E(S_{t+k}|\Omega_t)$  is expected spot exchange rate at time  $t+k$ , based on information known at time  $t$ ,  $r_t$  and  $r_t^*$  are interest rates in quote and base currency countries respectively.

Market participants expectations of future spot exchange rates are hardly observable, therefore the UIP is tested jointly with assumption of rational expectations. Under assumption of rational expectations, future value of spot exchange rate is equal to expected spot exchange rate at time  $t+k$  plus a white-noise error term which is uncorrelated with information available at time  $t$ .

$$S_{t+k} = E_t(S_{t+k}|\Omega_t) + \varepsilon_{t+k} \quad (2)$$

where  $\varepsilon_{t+k}$  is white-noise error term which is uncorrelated with information available at time  $t$ .

Thus assuming that market participants are endowed with rational expectations and risk-neutral, UIP states that realized foreign exchange gain from holding one currency rather than another must be offset by interest rate differential. The baseline econometric model applied to test uncovered interest rate parity is as follows:

$$s_{t+k} - s_t = \alpha + \beta(r_t - r_t^*) + \varepsilon_{t+k} \quad (3)$$

where  $s_t$  denotes the logarithm of spot exchange rate at time  $t$ ,  $s_{t+k}$  is the logarithm of spot exchange rate at time  $t+k$ . Under the UIP parity condition, the slope parameter  $\beta$  in equation (3) should be equal to unity ( $\beta = 1$ ) and the coefficient  $\alpha$  should be equal to zero ( $\alpha = 0$ ). Empirical studies based on regression model (3) generally rejects the UIP hypothesis. A well-known empirical regularity is that  $\beta$  is significantly less than one, and in fact very often closer to minus unity than plus unity (Froot and Thaler 1990).

Sarno et al. [2006] claim that deviations from uncovered interest parity condition display significant nonlinearities. In recent years researchers apply nonlinear models in explaining relationship between interest rate differentials and change in exchange rates. It is believed that behavior 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 the certain time period. In the article the Markov Switching (MS) model is applied to test uncovered interest rate parity in the PLN/JPY foreign exchange market.

MS model is popularized in economics by Hamilton [1989]. His pioneering work examine a persistency of recessions and booms by applying 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. Markov switching model includes description of probability law governing the change in regimes. Hamilton uses a two-regime model to explain returns in foreign exchange market. The model is specified as:

$$s_{t+k} - s_t = \alpha_{v_t} + \sigma_{v_t} \varepsilon_{t+k}$$

(4)

*where*

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

where

$\alpha_{v_t}, \sigma_{v_t}$  are the estimated coefficients,

$v_t$  is a random variable that can assume only an integer value  $\{1, 2, \dots, M\}$  and evolves according to a first-order Markov process with a transition probability matrix  $\mathbf{P}$ . 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  $(2 \times 2)$  matrix  $\mathbf{P}$  is presented below:

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

(5)

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

In the paper Markov Switching model (6) is applied for analysis of the relationship between change in exchange rates and interest rate differentials:

$$s_{t+k} - s_t = \alpha + \beta_{v_t} (r_t - r_t^*) + \sigma_{v_t} \varepsilon_{t+k}$$

(6)

*where*

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

The MS model (6) assumes that there are simultaneous switches in slope coefficient  $\beta$  and volatility parameter  $\sigma$ . Intercept  $\alpha$  is assumed to not switch. It results from the belief that regime switches in exchange rate returns should be interpreted as switches in relationship between exchange rate returns and interest rate differentials rather than just switches in intercept [Ichiue and Koyama 2011].

The study is carried out using end-of-month data over the period from January 2000 to December 2015 with the total of 192 observations. Data covers the Polish zloty to Japanese yen spot exchange rates and monthly interbank interest rates (1M Wibor, 1M Libor JPY) expressed at annual rates. The Polish zloty is assumed to be a domestic (quote) currency, and the Japanese yen is used as a foreign (base) currency. Non-overlapping monthly data with one-month interest rates are analysed in order to avoid possible estimation biases in standard errors arising from overlapping data. All data are from Reuters Datastream.

## EMPIRICAL RESULTS

To study uncovered interest parity in the PLN/JPY exchange rate market the Markov Switching model (6) is applied. Table 1 reports the estimation results.

Table 1. Parameters estimates of the regime-switching model (6) in the PLN/JPY market

	PLN/JPY	
	1	2
$\alpha$	-0.01	
$\beta$	1.3*	-0.01
$\sigma$	0.08**	0.03**
$N$	192	
$P_{11}, P_{12}$	0.82	0.18
$P_{21}, P_{22}$	0.02	0.98
$d_1, d_2$	5.42	42.32

Notes: the values with \*\* and \* are different from 0 at the one and five-percent-significance level, respectively

Source: own calculations based on Eviews 8 econometric software

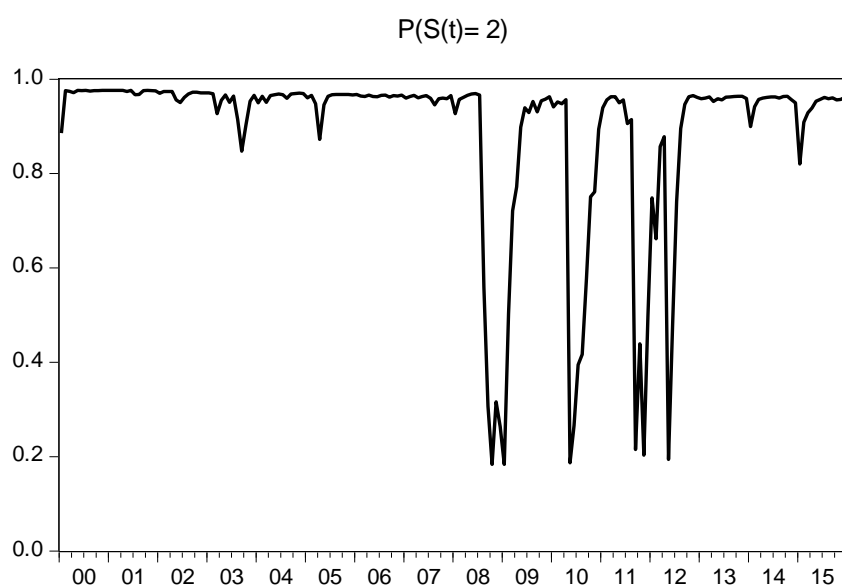
Table 1 shows that two regimes are distinguished. The first regime is the regime of higher volatility ( $\sigma = 0.08$ ) in which estimated slope coefficient is significant, positive and close to one as uncovered interest rate parity holds. The second regime, however, is the regime of lower volatility ( $\sigma = 0.03$ ) and negative insignificant coefficient  $\beta$ . High-volatility period is associated with the time of high financial turbulences and recession. Low-volatility period is related with economic expansion and good mood among financial market participants. Therefore, the research results are consistent with previous research conducted by Flood and Rose [2002] and Clarida et al. [2009]. It is shown that in regime of low volatility in the PLN/JPY exchange market, forward premium anomaly is observed. However, during the time of high volatility in the foreign exchange market, uncovered interest rate parity holds. It needs to be emphasized that for exchange rates where interest rate differential is higher than for PLN/JPY, coefficient  $\beta$  in low-volatility regime is even closer to -1 than to 0.

Table 1 shows also that value of slope coefficient in regime 1 is higher than the absolute value of coefficient  $\beta$  in regime 2. This suggest that exchange rates move faster when the Japanese yen (low-interest-rate currency) appreciates than when it depreciates against Polish zloty (high-interest-rate currency). With the risk of fast appreciation of low-yielding currency (currency crash risk), market participants may require risk premium for taking short position in that currency. According to Ichiue

and Koyama [2011] a time-varying risk premiums may be the reason for forward premium puzzle.

On the basis of estimated transition probabilities we can assume that distinguished regimes are persistent (table 1). The probability of remaining in present state is high, 82% for regime 1 and as much as 98 % for regime 2. Regime 2 is, however, more stable than regime 1. That is, the shift from regime 1 to regime 2 is more likely than that from regime 2. The smoothed probabilities of staying in regime 2 are given in Figure 1 in graphical form.

Figure 1. The smoothed probabilities of staying in regime 2



Source: own preparation

Figure 1 shows that in the time of analysis several regime switches are detected. In the time period from January 2000 to December 2015 the first switch to regime 1 is observed in 2008 when the financial crisis begun and many financial institutions reported huge losses. The financial crisis led to the change in the relationship between the interest rate differentials and the PLN/JPY exchange rate returns. It is worth to emphasize that regime 1 is the regime with higher volatility in which uncovered interest rate parity holds.

Table 1 provides also information about expected duration of each regime ( $d$ ). The expected duration of regime 1 equals about 5 months and regime 2 about 42 months. The expected duration of regime 1 for which uncovered interest rate parity holds is much lower. It means that the Japanese yen appreciates less frequently against Polish zloty, but once it occurs, the exchange rates move faster than when it depreciates. It may result from huge activity of carry traders. When there is

a turmoil in financial market, the risk-aversion increases among investors, then speculators are forced to unwind their carry trade position. They sell higher-yielding currencies and buy Japanese yen to repay a loan. The huge increase in demand for Japanese yen leads to its appreciation. Moreover, Brunnermeier et al. [2009] claim that a reduction in speculators positions increases the exchange rate volatility. It may explain, at least to some degree, the nature of regime 1 with value of slope coefficient close to 1 and high volatility.

## SUMMARY

Uncovered interest parity (UIP) assumption is an important building block in many models of open economies. Researchers have usually rejected the theory, indicating a tendency of low interest-yielding currencies to depreciate rather than appreciate as UIP suggests. This puzzling feature of foreign exchange market is generally known as forward premium puzzle. Literature provides several explanations of this phenomenon. In the paper it is assumed that there is a change in the relationship between interest rate differential and exchange rate return. Moreover, the direction of the relationship depends on the volatility in foreign exchange market. It is believed that there are regimes in which uncovered interest parity holds and regimes in which forward premium anomaly is detected.

A Markov regime-switching model is applied. The model allows slope coefficient to vary over time. It is shown that in the time of high volatility in the PLN/JPY exchange rate market, uncovered interest parity holds. However, in the time of low volatility, forward premium puzzle appears. The results are consistent with previous studies conducted by Flood and Rose [2002] and Clarida et al. [2009]. Moreover, it is shown that Japanese yen currency appreciates less often than depreciates, but once it occurs, its appreciation is bigger and faster than depreciation.

According to Ichiue and Koyama [2011] fast appreciation of low-yielding currency may lead to existence of non-zero time-varying risk premium in foreign exchange market. The time-varying risk premium, on the other hand, may be a reason for forward premium puzzle.

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