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Extracting Market Expectations from Currency Options' Risk Reversals

Zastosowanie zmienności implikowanej strategii *risk reversal* dla opcji na kurs walutowy do oceny oczekiwań uczestników rynku

Keywords: foreign exchange market; 25-delta risk reversal; currency options; carry trade speculation strategies; Brexit

Słowa kluczowe: rynek walutowy; strategia 25-*delta risk reversal*; opcje walutowe; strategie spekulacyjne *carry trade*; Brexit

JEL Code: F31; G13; G14; G15

Introduction

Currency option market has developed strongly since breakdown of the Bretton Wood agreement in the early 1970s. Options have begun to be an alternative risk management tool to cope with the high exchange rate volatility. After the stock market crash in 1987 market participants could have observed some new phenomena in option prices. The so-called volatility smile appeared to violate the famous Black–Scholes model [Black, Scholes, 1973]. It is believed that the volatility smile (skew) might have reflected market participants' fear of another stock market crash [Wang, 2008]. Since that time, many researchers have focused their effort to extract information embedded in option market prices. There are numerous implications of their studies. Options market prices contain valuable information about the nature of investors that are useful both to assess changes in their risk perception and to build more complex derivatives which are applied for risk management or policy making purposes [Omer, 2009].

The changes in market expectations can be observed based on the measures of volatility implied in option prices. They can provide important insight into market participants' perception about the future price movement of the underlying asset. Moreover, currency options cover all moments of the probability distribution which gives the unique piece of information for researchers. An important part of research in finance refers to information content in options that can be obtained by estimating implied risk-neutral density function. The function provides information regarding the market participants' expectations concerning the future movement of the underlying assets. It may, for instance, inform us whether market participants place greater probability on a downward than on an upward price changes. The parametric method, applied to calculate option implied risk-neutral density, was first developed by Breeden and Litzenberger [1978]. According to Bliss and Panigirtzoglou [2002], the parametric methods are very sensitive to computational errors and so are likely to lose some information embedded in options' prices. Malz [1997], among others, applied the polynomial function to fit the implied volatility curve based on the delta of options. Malz [1997, 2014] suggests estimating implied risk-neutral density function of foreign exchange rates by using the information embedded in straddle, strangle and risk reversal options' combinations. The paper is focused only on option's risk reversal implied volatility and its application in deriving market expectations.

The aim of the paper is to show the application of currency options' risk reversal to evaluate market expectations about future changes in currency value. The paper contributes to the literature by analysing changes in FX market participants' risk perception, not only during the time of financial crisis but also after such events like the 2015 Pacific typhoon or the 2016 Brexit referendum. The paper is focused on three foreign exchange rates, such as Japanese yen to Australian dollar (JPY/AUD), American dollar to British pound (USD/GBP) and Polish zloty to euro (PLN/EUR).

The paper is organized as follows. Section 2 describes over-the-counter currency option market and implied volatility smile phenomenon. Much attention is put to depict the risk reversal options' combination and its application for assessing market participants' expectation about future price movements of underlying asset. Section 3 provides the empirical evidence and results for Japanese yen, British pound and Polish zloty foreign exchange market. Section 4 summarizes and concludes.

1. Foreign exchange options risk reversals

The most widely used formula for pricing an option was developed by Black and Scholes [1973]. A Black–Scholes (BS) formula for put and call option are given by (1):

$$C(S_t,t)=S_tN(d_1)-K^{-r(T-t)}N(d_2)$$
$$P(S_t,t)=K^{-r(T-t)}N(-d_2)-S_tN(-d_1)$$

where:

$$d_1=\frac{\ln\frac{S_t}{K}+(r+\frac{1}{2}\sigma^2)(T-t)}{\sigma\sqrt{T-t}} \qquad (1)$$
$$d_2=d_1-\sigma\sqrt{T-t}$$

where:
$C(S_t,t)$ – theoretical call option price at time $t\in[0,T]$
$P(S_t,t)$ – theoretical put option price at time $t\in[0,T]$
S_t – the price of underlying asset at time *t*
K – strike price
r – risk-free interest rate
$T-t$ – time to maturity
$N(x)$ – cumulative distribution function of the standard normal distribution
σ – expected volatility of underlying instrument

Since S_t, r are observable in interest rate and underlying instrument market, K, T, t are specified in contract, the only unknown variable is volatility σ. It can be either estimated from time series return of underlying instrument (e.g. standard deviation) or calculated from the market prices of traded options by reversing the Black–Scholes formula. The volatility obtained from BS model is called implied volatility [Dumas, Fleming, Whaley, 1998]. The Black–Scholes model assumes that prices of underlying instrument follow a Geometric Brownian motion with constant volatility. It means that implied volatility should be the same for all options on the same underlying instrument but with different strikes and expiries. It is one of assumptions that usually turns out to be inappropriate [Coleman, Li, Verma, 2001]. It is observed that implied volatilities change with both maturity and strike prices. Firstly, options with the same exercise prices but with different maturities mark substantial differences in implied volatility [Heynen, Kemna, Vorst, 1994]. Due to the fact that implied volatility of long-term options differs from the volatility of short-term options, the term structure of options' implied volatility is curved. Secondly, observed implied volatility is very often a convex function of strike prices. This phenomenon is called "volatility skew" or "volatility smile" [Mayhew, 1995]. It means that usually out-of-the-money and in-the-money options display higher volatilities than at-the-money options. The Black–Scholes model assumes constant volatility and lognormal distribution of underlying asset. However, the major avenue of research shows that the prices of underlying asset are usually skewed (negatively or positively) with higher kurtosis (fat tails) compared to the Black–Scholes log-normal distribution. Moreover, both kurtosis and skew of distribution may be changing over time. The analysis of kurtosis and skewness may provide important information about market participants' expectation concerning future price movements of underlying asset.

The paper is focused on currency options market. The most common currency options pricing model was developed by Garman and Kohlhagen [1983]. They extended the Black–Scholes formula (1) to deal with the presence of two interest rates (one for each currency). The trading conventions are very specific for currency market and significantly different from the trading procedures in bond or equity options market. Currency options are traded mostly in terms of volatilities, not in terms of option's premiums. Over-the-counter currency option quotes are made on Garman–Kohlhagen implied volatilities. Moreover, implied volatilities are not quoted at a fixed strike price, but at a Garman–Kohlhagen delta. The implied volatility quotes are mainly available in three types of options strategies: the delta-neutral straddle, the risk reversal, and the butterfly spread [Beber, Breedon, Buraschi, 2010]. The foreign exchange option's implied volatilities can be written as follows:

$$\begin{aligned} \sigma_{ATM} &= \sigma_{50\Delta call} \\ \sigma_{RR} &= \sigma_{25\Delta call} - \sigma_{25\Delta put} \\ \sigma_{BF} &= \frac{\sigma_{25\Delta call} + \sigma_{25\Delta put}}{2} - \sigma_{ATM} \end{aligned} \tag{2}$$

where:
σ_{ATM} – at-the-money (ATM) implied volatility with an approximate delta of 0.5
σ_{RR} – risk reversal implied volatility
σ_{BF} – butterfly spread's implied volatility
Δ – the rate of change of option price with respect to changes in the underlying instrument

A straddle is a combination of a call and put option with the same strike price and the same maturity, assuming delta for both options equals 0.5. When a strike price is close to a forward price, the straddle is used as a measure of at-the-money (ATM) implied volatility with an approximate delta of 0.5. The second strategy, risk reversal, measures the difference between implied volatility of an out-of-the-money (OTM) call option and out-of-the-money (OTM) put option. In regard to Black–Scholes option's delta, the moneyness level is usually set at 25-delta. The 25-delta risk reversal consists of a long position in a 25-delta call option and a short position in a 25-delta put option. As far as a 25-delta put and a 25-delta call options are concerned, the strike prices are such that about 25% of the distribution lies to the right of the call's strike and 25% to the left of the put's strike [Campa, Chang, Reider, 1998]. The risk reversal is applied to measure the slope of implied volatility smile. The butterfly spread strategy is a combination of four option contracts with the same expiration dates but three different strike prices. It is quoted as the average of two OTM options' volatilities minus the ATM volatility (2). The butterfly spread is perceived as a measure of curvature of the implied volatility smile [Deuskar, Gupta, Subrahmanyam, 2008].

The paper is focused on option's risk reversal strategy. In respect of the foreign exchange option market, risk reversals reflect the cost of buying insurance against foreign currency appreciation, financed by providing insurance against foreign currency depreciation [Brunnermeier, Nagel, Pedersen, 2008]. Moreover, risk reversal can be applied to assess market perception of risk associated with high appreciation or high depreciation of the currency. When risk reversal is large and positive, it suggests that higher probabilities are attached to large appreciation of base currency against quoted currency. On the other hand, when risk reversal is large and negative, it implies that higher probabilities are attached to large depreciation of base currency against quoted currency [Campa, Chang, Reid, 1998].

Risk reversals are believed also to reflect the changing risk appetite or risk perception of market participants. Gagnon and Chaboud [2007] analysed US dollar to Japanese yen 25-delta risk reversals and they found that risk reversals may be very useful to show changes in carry traders' risk perception. The higher is the value of risk reversal, the higher probabilities are attached to large Japanese yen appreciation, which is identified with possible carry trade losses. Campa, Chang and Reider [1998] found that the stronger is the currency, the more expectations are skewed towards a large appreciation of that currency. Risk reversals were applied by them as a measure of skewness. According to Campa, Chang and Reider [1998], when e.g. US dollar is strong, market participants may attach greater probabilities to states of the world in which US currency becomes much stronger. They claim that the relatively high valuation of these states may result from market participants' risk aversion.

Kohler [2010] applied risk reversals to analyse situation on currency market during turbulent times in financial market. She demonstrated that during financial market crises in 1997–1998 and 2008–2009, market participants disproportionately tried to hedge against an appreciation of funding carry trades' currencies (e.g. Japanese yen and Swiss franc) or to hedge against a large depreciation of less actively traded currencies (e.g. South African rand).

2. Extracting market expectations from currency options' 25-delta risk reversal

Foreign exchange market has been surveyed every three years since 1986 by the Bank for International Settlements. Last survey, that took place in April 2016, shows that daily average turnover in FX market amounted to 5.1 trillion USD [Bank for International Settlements, 2016]. Vast majority (88%) of all foreign exchange transactions were in US currency. The second place belongs to euro (EUR). The market share of euro accounted for 31% in 2016. The third most commonly traded currency was Japanese yen (JPY). 22% of all transactions in April 2016 were conducted in

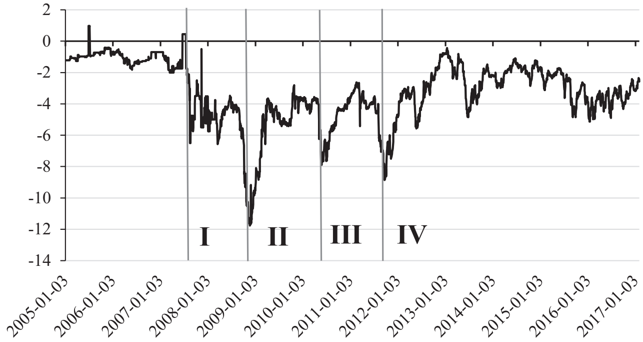
JPY. Another very important currency is British sterling (GBP) that accounted for about 13% of market share. The paper is focused on Japanese yen to Australian dollar (JPY/AUD), American dollar to British pound (USD/GBP) and Polish zloty to euro (PLN/EUR) exchange rates. In the exchange rates, the first mentioned currency is a quoted currency, and the second currency is a base currency. Exchange rates are depicted in proper mathematical expression where base currency is a denominator and quoted currency is a numerator. An increase of exchange rate is associated with the appreciation of base currency and depreciation of quoted currency. The empirical analysis is based on data sets that cover 25-delta risk reversals daily quotes for currency pairs JPY/AUD, USD/GBP, and PLN/EUR during the period from January 2005 till January 2017. Prices are expressed in volatility points. Options on each currency pair have 3 months fixed time to maturity.

The paper is focused on Japanese yen, as a popular carry trades' funding currency that is believed to reflect changes in market participant's risk perception, especially during turbulent times in financial market. The 2016 Brexit referendum impact on market participants' currency risk perception is presented on the basis of USD/GBP exchange rate. The paper studies also PLN/EUR exchange rate market in order to show the influence of 21st-century financial crisis on market expectations concerning Polish currency.

One of the most popular investment strategies in currency market is so-called carry trade. In the most basic form of the strategy, investors and traders borrow low-yielding currencies in order to finance a purchase of currency with a relatively high interest rate [Liu, Margaritis, Tourani-Rad, 2012]. The prolonged low interest policy of the Bank of Japan brought about Japanese yen to be the one of the most popular funding currencies [Czech, 2016]. During the period from January 2005 to June 2007, carry traders activities contributed to the significant increase in supply of Japanese yen which had a profound impact on the yen depreciation. The situation has changed when the sub-prime mortgage crisis began (Fig.1, I).

In the aftermath of events I and II (Fig. 1) market participants expectations changed dramatically. 25-delta risk reversals reached as low level as -12. When the risk reversal quote is large and negative it implies that higher probabilities are attached to large depreciation of base currency (Australian dollar). Thus, market participants expected Japanese yen to appreciate against Australian dollar. The same results have been obtained by Brunnermeier, Nagel and Pedersen [2008], among others. It is worth stressing the fact that, between July 2007 and February 2009, exchange rate USD/JPY went down from 123.86 to 87.32.

Moreover, Figure 1 presents another two different events that brought about substantial decrease in 25-delta risk reversals. In May 2010 (Fig. 1, III), higher market distress driven by a European sovereign debt crisis led to a large increase of global risk aversion [Botman, Carvalho Filho, Lam, 2013]. Market participants again attached higher probabilities to Japanese yen appreciation rather than depreciation. It means that out-of-the-money put options on JPY/AUD were, on average,



I – subprime mortgage crisis, II – Lehman Brothers bankruptcy, III – European sovereign debt crisis, IV – Pacific typhoon

Fig. 1. A 25-delta risk reversal of JPY/AUD exchange rate during the period 01.2005–01.2017

Source: own elaboration based on Bloomberg data.

more expensive than corresponding OTM call options (in comparison to the value predicted by Black–Scholes model). Market expectations were skewed in favour of a large decrease of JPY/AUD exchange rates.

Another event that highly affected the value of Japanese currency was Pacific typhoon (Fig. 1, IV) that took place in September 2011. Despite the natural disaster in Japan, market participants placed higher probabilities to large appreciation of Japanese yen. As a result, the currency became stronger although there were no sufficient fundamental reasons for it. It is worth emphasizing that, since the mid-1990s, there have been 12 episodes during which the value of Japanese yen has increased by more than 6% (in nominal terms) within one quarter [Botman, Kang, 2015]. Moreover, these periods often coincided with events outside Japan. It shows that the value of Japanese currency is highly affected not only by economic, fundamental factors, but also by global changes in investors' mood, risk perception and global risk aversion.

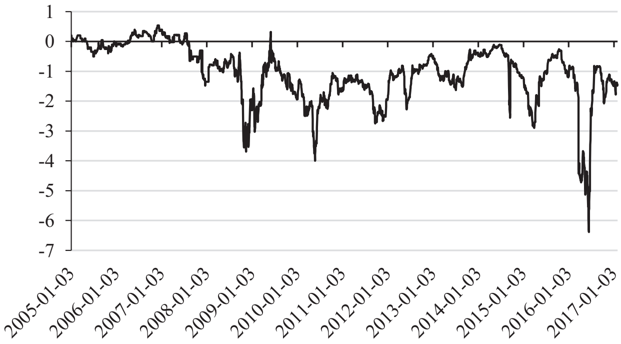


Fig. 2. A 25-delta risk reversal of USD/GBP exchange rate during the period 01.2005–01.2017

Source: own elaboration based on Bloomberg data.

Fig. 2 depicts 25-delta risk reversals of USD/GBP during the period from 01.2005 to 01.2017. During the period from January 2005 to September 2008, the average value of risk reversal was close to zero (Fig. 2). First drop of USD/GBP risk reversals were observed after the bankruptcy of Lehman Brothers in 09.2008. The larger the negative value of 25-delta risk reversal is, the higher probability is attached to depreciation of base currency (British pound). Another decrease of 25-delta risk reversal for USD/GBP resulted from the European sovereign debt crisis in 2010. However, it needs to be emphasized that the biggest drop in risk reversals of USD/GBP occurred in June 2016, when British citizens decided to cut a long-term relationship with the European Union. In effect of Brexit referendum, the risk reversal value plunged the depths it had reached even during the height of financial crisis (Fig. 2). The result of Britain's referendum drew substantial changes in market expectations concerning the value of British pound. Market participants were skew in favour of a large drop in the USD/GBP exchange rate market.

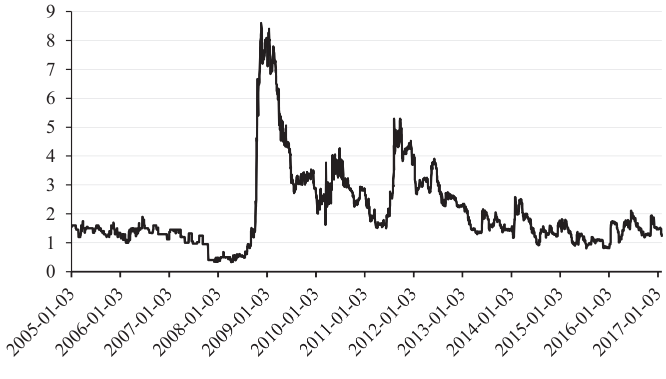


Fig. 3. A 25-delta risk reversal of PLN/EUR exchange rate during the period 01.2005–01.2017

Source: own elaboration based on the data from Bloomberg.

Fig. 3 depicts values of 25-delta risk reversals of PLN/EUR during the period 01.2005–01.2017. Risk reversals for the exchange rate were positive, indicating that call options on PLN/EUR were more expensive than corresponding put options. The biggest increase in risk reversals were observed after the bankruptcy of Lehman Brothers in September 2008. Then, market participants placed much higher probability to large Polish zloty depreciation. Another spike in risk reversals occurred during the time of European sovereign debt crisis (2010–2012).

It needs to be emphasised that risk reversals may vary substantially over time. Carr and Wu [2007] have shown that risk reversals may be highly changing, even from negative to positive values. This is a unique feature of currency options contracts. Equity options implied volatility skewness also varies over time. However, in comparison to currency options, it stays highly negative across most sample periods [Foresi, Wu, 2005].

Conclusions

Measures of volatility implied in option prices can provide important insight into market participants' perception about the future price movement of the underlying asset. The paper is focused on foreign exchange options risk reversals volatility. Risk reversals reflect the cost of buying insurance against foreign currency appreciation, financed by providing insurance against foreign currency depreciation. Risk reversals are applied to assess how market participants perceive the balance of risks between a large decrease and a large increase in the exchange rate market. When the risk reversal is large and positive it implies that market participants place higher probability to large appreciation of base currency (depreciation of quote currency). On the other hand, when risk reversal is large and negative, it suggests that higher probabilities are attached to large depreciation of base currency (appreciation of quote currency).

Japanese yen is considered to be one of the most popular funding currencies in carry trade strategy. During the period from January 2005 to June 2007, carry traders activities contributed to significant increase in supply of Japanese yen which had significant impact on the yen depreciation. The situation has changed when the sub-prime mortgage crisis began (07.2007). It has been shown that during high-volatility and turbulent periods in financial markets, market participants placed higher probability on Japanese yen appreciation than its depreciation against Australian dollar. This phenomenon was observed even after Pacific typhoon in 2015. Despite the natural disaster in Japan, market participants placed higher probabilities to large appreciation of Japanese yen.

As far as the British pound is concerned, the biggest drop in risk reversal value was observed after Brexit referendum (June 2016), when higher probabilities were attached to large sterling depreciation. Risk reversals implied volatilities plunged the depths it had reached even during the financial crisis (2008–2010).

Last but not least, 25-delta risk reversals of PLN/EUR were positive for the whole sample period. The biggest increase of their values occurred at the height of the global financial crisis, after the bankruptcy of Lehman Brothers. During that time, market expectations were skewed in favour of large Polish zloty depreciation against euro currency.

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Zastosowanie zmienności implikowanej strategii *risk reversal* dla opcji na kurs walutowy do oceny oczekiwań uczestników rynku

Mierniki oparte na zmienności implikowanej opcji są źródłem informacji na temat nastrojów uczestników rynku czy też zmian w ich postrzeganiu ryzyka. Celem artykułu jest przedstawienie zastosowania zmienności implikowanej strategii 25-*delta risk reversal* dla opcji na kurs walutowy w ocenie oczekiwań uczestników rynku odnośnie do kształtowania się przeszłej wartości waluty. Pokazano, jak różne wydarzenia (takie jak kryzys na rynku kredytów hipotecznych *subprime* w USA, upadek banku Lehman Brothers, potężny tajfun na Pacyfiku, referendum w sprawie wyjścia Wielkiej Brytanii z Unii Europejskiej) wpłynęły na oczekiwania rynku odnośnie do kształtowania się kursów walutowych w przyszłości. Co ciekawe, w analizowanym okresie poziom zmienności implikowanej 25-*delta risk reversal* ulegał gwałtownym zmianom.

Extracting Market Expectations from Currency Options' Risk Reversals

Measures of volatility implied in option prices can provide important insight into market participants' perception about the future price movement of the underlying asset. The aim of the paper is to show the application of foreign-exchange options' 25-delta risk reversals to evaluate skewness of market expectations on future changes in currency value. It has been shown that different events, such as the United States subprime mortgage crisis, the collapse of Lehman Brothers, the 2015 Pacific typhoon or the 2016 Brexit referendum, highly affected market view about the balance of risk between a large appreciation and a large depreciation of the currency. In the analysed period, the market quotes on risk reversals were substantially changing.