International Journal of Economics and Financial Issues
Vol. 4, No. 4, 2014, pp.909-919
ISSN: 2146-4138
www.econjournals.com

Is Implied Taylor Rule Interest Rate Applicable as a Carry Trade Strategy?

Gokcen Ogruk
School of Business and Professional Studies,
Texas Wesleyan University, Fort Worth, TX, USA.
Email: gogruk@txwes.edu

ABSTRACT: This paper evaluates the performance of carry trade strategies with implied Taylor rule interest rate differentials and compares the performance statistics of them over the naive carry trade strategy with actual interest rates. Carry trade, a currency speculation strategy, between high-interest rate and low-interest rate currencies generates high payoff on average and has a possibility of crash risk. I argue that the crash risk is reduced with implied Taylor rule interest rate differentials as a trading strategy in Yen and Franc trades for the whole sample period. During the recent financial crisis, the carry trading strategies with Taylor rule perform best in terms of mean returns, risk adjusted returns and downside risk.

Keywords: Carry Trade; Taylor Rule Fundamentals.
JEL Classifications: E32; E37; E43; F31; F37; G15.

1. Introduction

This paper studies the comparison between trading strategies based on actual interest rate vs. Taylor rule implied interest rate differentials. The starting point is Taylor rule models of interest rate reaction functions. Taylor rules have been the dominant policy for analyzing and evaluating monetary policy since late 1980s, although no central bank exactly follows a simple Taylor rule at all times. Taylor rule implied interest rate may be a good candidate as a trading strategy if the trading currency countries determine their nominal interest rate by a type of Taylor rule reaction function.

In this paper, I study the carry trade, a currency trading strategy in which an investor borrows low-interest-rate currencies and lends high-interest-rate currencies. The former currency is often called the funding currency and the latter one is called the target currency. The strategy is profitable for an un-hedged carry trade strategy, when the interest rate differentials are high enough to compensate exchange rate fluctuations, so the uncovered interest rate parity (UIP) is not expected to hold. According to UIP, the difference in interest rates between the two countries simply shows how much investors expect the high-interest-rate currency to depreciate against the low-interest-rate currency. Therefore under UIP the profit through interest rate differentials is offset by the exchange rate movements. In reality UIP doesn't hold, so traders enter into the carry trade market, implying exchange rate movements is not offset by interest rate differentials between the countries. Traders make huge profits through carry trade strategies because of this market anomaly.

The profit from the carry trade is the sum of interest rate differential and the forward premium between the two currencies. Exchange rate moves, therefore carry trade involves exchange rate risk. In fact, the target currency may depreciate against the funding currency. In that case the amount initially borrowed in funding currency will rise in terms of target currency which increases the cost of borrowing. However in the literature many papers showed that the currencies that are at a forward premium and have low interest rates tend to depreciate, not appreciate, as the UIP predicts. Similarly other currencies that are at a forward discount and have high interest rates tend to appreciate, not depreciate. This is called forward premium puzzle. This forward premium puzzle has been tested by an extensive literature that includes Frankel (1980), and Fama (1984). However in the long period it is quite difficult to reject UIP, implying that interest rate differentials are arbitraged. Chinn and Meredith (2004) confirm that UIP holds for periods longer than 5 years.

The original Taylor rule states that the federal funds rate is set as the sum of one, 1.5 times the inflation rate and 0.5 times the percentage deviation of GDP from potential GPD (output gap). This simple rule proposes the usage of short term interest that anticipates the arrangement of the interest rate in accordance with the inflation difference from the target level and the changes in production gap. Many researchers and policy makers assess the validity of Taylor rule in developed and developing countries. Clarida et al. (1998) have been examined the validity of the rule by using monthly data for USA, Italy, France, United Kingdom and Japan. They conclude those countries are successful in implementing Taylor rule. Kozicki (1999) finds coefficient estimates very close to the fixed coefficient proposed by Taylor (1993) for the USA. Nelson (2001) assesses the validity of Taylor rule for United Kingdom and he concludes that the coefficients they estimated are really close to the fixed coefficients proposed by Taylor (1993). Osterholm (2005) finds Taylor rule is applicable for countries USA, Sweden and Australia. Bahattaraii (2008) finds the applicability of Taylor rule for the countries Germany, France, Japan, England and USA.

The starting argument for this paper is come out of the question: why do not investors exploit Taylor rule models as trading strategies, if monetary authorities of these countries are following Taylor rule type of reaction function to determine their nominal interest rate? From the perspective of practitioner, implied Taylor rule interest rate differentials can be a better strategy to follow than actual interest rates differentials for the developed countries' currencies. Implied Taylor rule interest rate can be a good candidate for a trading strategy since high inflation countries will follow tighter monetary policies longer term, which will keep their nominal and as well as real rate higher for a long term, implying traders can exploit the interest rate differentials longer time between high-inflation prone countries and the low inflation ones assuming that monetary authorities of these countries are following Taylor rule type of reaction function to determine their nominal interest rate.

The predictive power of Taylor rule fundamentals in exchange rate movements in currency trading have been studied in the literature, however implied Taylor rule interest rates are not used as trading strategies. Recently, combining the failure of UIP with predictive power of fundamentals, Jorda and Taylor (2012) show that the crash risk, or negative skewness, of the carry trade can be greatly reduced using fundamentals augmented carry trade strategies that take into account not only interest rate differentials, but also relative Purchasing Power Parity. Li (2011) using Taylor rule fundamentals for forecasting of exchange rate, evaluates the profitability of carry trades. He finds that Taylor rule fundamentals increase the profits of carry trade in a monthly frequency in a factor augmented regression framework. He claims that since Taylor rule fundamentals have better predictive power, for better investment the practitioners should take into account these fundamentals for forecasting of exchange rate movements.

This empirical study uses time series data on exchange rates of six major currencies relative to Japanese Yen, Swiss Franc and the US Dollars. For each of six currencies individual currency carry trades are executed and then portfolios are formed by giving equal weights to each individual currency trade returns. The carry trades are executed in the naive sense, meaning only interest rate differentials are used for the decision function of the investor. As an alternative strategy to naive carry trade with actual interest rates, implied Taylor rule interest rates, calculated as proposed by Taylor original formulation, are used as a trading strategy.

The results suggest that crash risk, or negative skewness, of carry trades can be reduced if the investors use implied Taylor rule interest rate differential as a trading strategy. The model with implied Taylor rule interest rates for both funding and target currency performs best in Yen and Franc trades. In Dollar trades, the best results come with the implied Taylor rule interest rate models, although the Dollar trades are riskier than other funding currency trades during the sample period.

During the recent financial crisis, my results suggest that naive strategy based on actual rates produce negative returns with negative Sharpe ratios in Yen and Franc trades where as my proposed strategy of implied Taylor rule interest rate model results in positive mean and risk adjusted returns. Given that carry trading strategies have crash risk; the inclusion of Taylor rule in the trading strategy can reduce this crash risk, making this kind of currency trading strategies less risky and profitable as well during the market turmoil.

The paper is organized as follows. The literature review is in section 2. Section 3 briefly describes the Taylor rule. Then in section 4, currency trading strategies are described. Section 5 evaluates the performance of carry trade strategies, and compares the payoffs of different strategies of portfolio returns for different time periods. Section 6 concludes.

2. Related Literature

The carry trade, buying high-interest currencies and selling low-interest ones, is a direct consequence of the failure of UIP. The overall impression about UIP is that, it is more likely to hold in the long run than in the short run. A large body of empirical literature documents this fact (Cheung et al. (2005), Chinn and Quayyum (2012)). Cheung et al. (2005) investigate both 12 month and 5 year term interest rates and their relation with exchange rate movements for the US, Canada, Germany and the UK over the period of 1980-2000. The authors find negative significant coefficient of UIP for the short term interest rate, however the coefficient of UIP has a correct sign and close to unity for long term bonds. Recently Chinn and Quayyum (2012) examine the failure of UIP including the financial crisis of 2007 and find that UIP holds better in the long term than in the short term.

Meese and Rogoff (1983) show that economic models of exchange rates do not outperform the random walk forecast. On the contrary, the recent literature addresses that exchange rate determination is not inconsistent with the macroeconomic fundamentals if the monetary policy is taken to be endogenous with an interest rate feedback rule. Taylor rule models offer a different explanation to the exchange rate determination. The recent work for Taylor rule models include Engel, Mark and West (2007), Molodtsova and Papell (2009). Engel, Mark and West (2007), use uncovered interest rate parity directly to produce exchange rate forecast. They replace the interest rate differentials in the UIP by the interest rate differentials implied by the Taylor rule, whereas Molodtsova and Papell (2009) use the variables that enter Taylor rule to evaluate exchange rate forecast. Molodtsova and Papell (2009) find out that by assessing the out-of-sample performance of 12 currencies, the predictability of these models with Taylor rule fundamentals are stronger for 8 out of 12 currencies.

Taylor rule fundamentals augmented exchange rate models have stronger predictability power than random walk in the short run. Li (2011) evaluates exchange rate models with Taylor rule fundamentals from the perspective of the carry trader. The author claims that if the macro fundamental models of exchange rate including Taylor rule fundamentals do better than random walk, this predictability power of exchange rate models may increase the profitability of carry trade strategies. He finds that carry trades with economic fundamentals have lower Sharpe ratio and better downside risk when the economic fundamentals are used in a factor augmented regression.

In this paper, I examine whether Taylor rule fundamentals can be used as a trading strategy and increase the performance of carry trade in terms of profitability and risk. The reason why implied Taylor rule interest rates may be a good candidate for a trading strategy is related to applicability of Taylor rule fundamentals in nominal interest rate determination. In this perspective, Wang et al. (2012) show economic fundamentals are useful in interval forecasting of exchange rates and find Taylor rule model perform better than other economic fundamentals models. Recently, Molodtsova and Papell (2012) evaluate out-of-sample performance of Taylor rule models in exchange rate forecasting through the recent financial crises. They find Taylor rule models are still better than the interest rate differentials, monetary and purchasing power parity models although the interest rate hits the zero level bound during that period.

The main issue in the carry trade market is to identify the nature of the risk and determine whether this risk is associated with the excess returns in this market. Brunnermeier et al. (2008) show that exchange rate movements of carry trades are negatively skewed and therefore carry trades are subject to crash risk. The authors claim when there is a change in the availability of funding liquidity, for instance a reduction, and then there is a rapid unwinding of the trader's position, which leads to crashes in exchange rates. To decrease this risk, Burnside et al. (2007) propose diversification, whereas Jorda and Taylor (2012) propose a strategy based on fundamentals. Burnside et al. (2007) find out that equally-weighted portfolio is less skewed than currency specific carry trade strategy.

Following fundamentals augmented carry trade strategy, Jorda and Taylor (2012) show that the crash risk of the carry trade can be reduced substantially. They find that nominal interest differential can help to predict exchange rate movements in the short run, but the forecast of exchange rates can be enhanced by the inclusion purchasing power parity (PPP). The deviation from the PPP helps to forecast the movements of nominal exchange rate as the real exchange rate adjusts its long run level. The authors show that there is a profitable trading strategy which includes a forecast that real exchange rate will return its long run level when its deviations from the mean are large.

Crash risk in carry trade strategies may be explained alternatively, as compensations for the risk of rare disasters with significant loses. This problem is known in the literature as “Peso Problem”.

Burnside et al. (2011) find that large positive payoffs of equally weighted portfolio are not correlated with either standard risk factors or cannot be explained by stochastic discount factors. They argue these large payoffs should be a compensation for the negative payoffs of peso event risk.

Based on the literature, in this paper, I will not try to find out the reasons of excess returns to carry trade strategies or try to identify the sources of the risk that is prevailing in the currency carry trading strategies; however I will try to find out if we can design a better trading strategy based on interest rates implied by the Taylor rule.

3. Taylor Rule

The rule that proposes the usage of short term interest that anticipates the arrangement of the interest rate in accordance with the inflation difference from the target level and the changes in production gap is the Taylor Rule. This paper assesses the performance of Taylor rule implied interest rate as a carry trade strategy. Implied Taylor rule interest rates of eight developed countries are calculated and then these interest rates are used in the execution of carry trades.

Following Taylor (1993), central banks follow the below reaction function for the monetary policy rule;

$$i_t = \pi_t + \phi(\pi_t - \bar{\pi}) + \gamma y_t + \bar{r} \quad (1)$$

where i_t is the federal funds rate, π_t is the inflation rate, $\bar{\pi}$ is the target level of inflation, y_t is the output gap and $\bar{r}$ is the equilibrium level of real interest rate.

The parameters $\bar{\pi}$ and $\bar{r}$ are constant and can be sum up to form single term $\mu = \bar{r} - \phi\bar{\pi}$. Therefore the equation (1) will be:

$$i_t = \mu + \lambda\pi_t + \gamma y_t \quad (2)$$

where $\lambda = 1 + \phi$. Assuming that inflation gap and output gap with an equal weight of 0.5 in the central bank's reaction function and the equilibrium interest rate and inflation rate to be two percent, the reaction function will be calculated as:

$$i_t = 1.0 + 1.5\pi_t + 0.5y_t \quad (3)$$

4. Designing Carry Trade Strategies

Carry trade has been become one of the major currency trading strategies since mid-1990s. The currency carry trade is designed to exploit the failure of UIP and consist of borrowing a low-interest-rate currency and lending a high-interest rate currency.

The payoff to an investment in the foreign currency financed by borrowing in the domestic currency is denoted by:

$$x_{t+1} = i_t^* - i_t + \Delta e_{t+1} \quad (4)$$

The logarithm of nominal exchange rate (units of foreign currency per domestic currency) by e_t, interest rate by i_t, and foreign interest rate by i_t^*. $\Delta e_{t+1} = e_{t+1} - e_t$ is the appreciation of the foreign currency (for instance Δe is the change in yen exchange rate). Equation (4) is the excess return that is gained by carry trade where UIP is violated. If UIP holds this excess return will not be forecasted and $E_t(x_{t+1}) = 0$. Therefore x can be considered as abnormal return to carry trade strategy where foreign currency is the investment currency and Japanese Yen, Swiss Franc and US Dollars are the funding currency.

In this paper, a carry trade is defined as a binary trading strategy that is based on expected returns. There is a trade between the funding currency country and the target currency country if the interest rate differential between the target country and funding country is positive and the expected return is positive as predicted by the model. The execution of carry trade is denoted by $\hat{b}_{i,t}$=1 :

$$\hat{b}_{i,t+1} = \begin{cases} 1 & if\ \ i_{i,t}^* - i_{i,t} + E_t(\Delta e_{i,t+1}) > 0 \\ 0 & otherwise \end{cases} \quad (5)$$

Consider the case where e_t follows a random walk:

$$E_t(\Delta e_{t+1}) = 0 \quad (6)$$

Under the random walk model, the carry trade, in its simplest form, depends solely on the interest rate differentials. This carry trade is called *naive* since it is unrelated to fundamentals other than the interest rate. This naive carry trade with actual rates is the benchmark model (Model 1).

I propose three carry trade strategies alternative to the benchmark model. The first one is designed by replacing actual interest rate differentials with implied Taylor rule interest rates (Model 2):

$$\hat{b}_{i,t+1} = \begin{cases} 1 & i_{i,t}^{*implied} - i_{i,t}^{implied} > 0 \\ 0 & otherwise \end{cases} \tag{7}$$

The second strategy is constructed by the difference between the actual interest rate for the target country and implied Taylor rule interest rate for the funding country (Model 3):

$$\hat{b}_{i,t+1} = \begin{cases} 1 & i_{i,t}^{*} - i_{i,t}^{implied} > 0 \\ 0 & otherwise \end{cases} \tag{8}$$

For this alternative mixed strategy, I am assuming that only funding currency country follows Taylor rule reaction function for the interest rate determination. The third strategy, on the contrary assumes only target currency country follows Taylor rule (Model 4):

$$\hat{b}_{i,t+1} = \begin{cases} 1 & i_{i,t}^{*implied} - i_{i.t} > 0 \\ 0 & otherwise \end{cases} \tag{9}$$

For one unit of borrowed investment currency, the returns for the different specifications of a carry trade are computed with the realized exchange rates and interest rates:

$$x_{i,t+1} = \begin{cases} i_{i,t}^{*} - i_{i,t} + \Delta e_{i,t+1} & if\ \hat{b}_{i,t+1} = 1 \\ 0 & if\ \hat{b}_{i,t+1} = 0 \end{cases} \tag{10}$$

where $x_{i,t+1}$ is the return from binary trading strategy at time $t+1$.

5. Emperical Results

5.1. The Data

The empirical analysis uses monthly data. The sample period includes the month-end daily exchange rate data from FRED between January 1971 and January 2012 for pairs of the eight major currencies: The Australian Dollar (AUD), the Canadian Dollar (CAD), the Norwegian Krone, the British Pound (GBP), the New Zealand Dollar (NZD), the Japanese Yen (JPY), the Swiss Franc (CHF), and the US Dollar (USD). Exchange rates of the target currency measured in the funding currency are computed as cross-rates from their original dollar values. Of the eight currencies, six CHF and JPY cross-rates are formed and five USD exchange rates are used. The data for macroeconomic fundamentals are constructed from the International Financial Statistics (IFS) and OECD Main Economic Indicators (MEI) databases. The seasonally adjusted Industrial Production Index is used as for countries' GDP, since GDP data is only available at quarterly frequency[1]. The inflation rate is calculated from the Consumer Price Index, and is the annual rate measured as the 12 month difference of the CPI[2]. The Money Market Rate is used for the monthly interest rate, which central banks set every period.

The output gap calculations are based on potential output. The output gap is calculated as percentage deviations of actual output from a quadratic time trend, since there is no consensus about which definition of output is used by central banks. I use Quasi-real time data in the output gap estimation. The quasi-real time estimate is constructed in two steps. The first step begins with taking the final vintage of the output series with the observations up to, and including, $t-1$ computing the quasi-real time estimate for period t. Then, in each period, the sample period is extended by one observation and OLS is used for de-trending. In the second step, the first available estimate of the output gap at each point in time that is constructed in the first step is collected. The final sequence of output gap series will be the quasi-real time estimation of output gap data[3].

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[1] The industrial production series for Australia, New Zealand and Switzerland and the CPI series for Australia and New Zealand are only available at quarterly frequency. They are transformed into monthly frequency data with the "quadratic-match average" option in E-views 6.0.

[2] The Taylor rule estimation for U.S depends on forward looking nature of policymaking. Therefore, using ex-post realized values of inflation, such as in Orphanides (2001) will be appropriate. However, ex-post data and central bank forecasts are not available for other countries; we will use actual inflation rates.

[3] Policy makers estimate output gaps using the data available to them at the time they are making decision. However, real time data is not available for most of the countries throughout the period that we are studying. Orphanides et al. (2002) find the correlation between real time and quasi real time output gap is high. Thus, using quasi real time output gap will be appropriate. The output gap for the first series is calculated from 1971:1 to 1980:1.

5.2. Statistical Evaluations of Carry Trades

The carry trades are executed with Japanese Yen, Swiss Franc and the US dollars being funding currency. For Japanese Yen, six carry trades are executed with Australia, Canada, England, New Zealand, Norway, and USA being target currency countries. For Switzerland, six carry trades are executed with all countries except Japan, and for the USA five carry trades are executed excluding Japan and Switzerland being target currency countries.

Performance statistics of carry trade returns include *Mean Return*, *Standard Deviation*, *Sharpe Ratio*, *Return Skewness*, *Return Kurtosis* and *Maximum Drawdown* of returns from the period 1986:1 to 2012:01

Sharpe Ratio is calculated as a ratio of returns normalized by the standard error. The Sharpe ratio is good for evaluating how well the return of an asset compensates the investor for the risk taken. A portfolio or a return may have high mean returns than its peers; however it is better when it does not have additional risk.

The exchange rate movements are not symmetric when it goes up and when it falls down. This asymmetry of exchange rate movement is associated with a crash risk. Return *Skewness* and *Kurtosis* are used as measures of the risk of large amount of losses. Skewness shows the risk of large losses by carry traders in case of market crashes and kurtosis to show that whether these changes are abrupt or not. Large negative skewness means that there is higher probability of these large losses, while positive big kurtosis shows that these changes are fast. *Maximum Drawdown* measures the largest single drop from the peak to bottom before a new peak is reached. Large maximum drawdowns indicate higher risk.

5.3. Performance Statistics of Carry Trades

The sample period starts from 1986 and ends at 2012. I choose this period for implementing the Taylor rule interest rates as a strategy, since it is emphasized that Taylor rule is followed by the central banks of the countries of interest between early 1990s to early 2000s in the literature.

In practice an investor can apply the carry trade to individual currencies or the portfolios of currencies. Burnside et al. (2011) claim that the risk in carry trade strategies is reduced with diversifying the carry trade across different currencies. They claim that the gains from diversification are large. This paper takes the perspective of an individual currency trader, and examine whether this trader gains more by diversifying carry trade across different currencies. I consider equally weighted carry trade strategies where Yen, Franc and Dollar positions give equal weight at each point in time to all the currencies for which x_t is not equal to zero.

The performance statistics of equally-weighted portfolio returns for Japanese Yen are shown in Table I Panel A. Carry trade strategies with implied Taylor rule interest rate differentials have identical mean returns and lower standard errors.

One of the important measures of return per unit of risk is the Sharpe ratio. It is the ratio of mean excess return per unit of volatility. The Sharpe ratios of carry trade strategies are usually small, since although mean excess returns for carry trade strategies are high, the volatility for those returns is high. It is shown that carry trade strategies with both actual interest rate and implied Taylor rule interest rate (Model 2) have small Sharpe ratios (Table I). The standard errors for the Taylor rule models are lower than the benchmark model (Model 1); and the mean returns for Taylor rule strategies are similar to the naive strategy with actual rates (Model 1). This results in larger Sharpe ratios for the Taylor rule models (Model 2, Model 3, and Model 4).

While the Sharpe ratios suggest that all carry trade strategies do not have attractive risk-return profiles, they do not account for the crash risk or downside risk, which is also crucial for the trader. The maximum drawdown measures the largest possible loss, whereas skewness measures the possibility of large losses or gains during the market crashes. From Table I all carry trade returns are negatively skewed and have excess kurtosis; implying carry trade returns have a crash risk and fat tails.

The recent literature emphasizes the importance of market-wide distress in carry trading strategies. Carry traders have significant losses during the periods of the market distress. This is the main reason why the returns of carry trades are negatively skewed. The results show that the negative skewness is improved when the traders use implied Taylor rule interest rate as a trading strategy for both funding and target currency (Table I, Model 2). The skewness of the returns is improved more than 50 percent.

Table I. Performance Statistics of Carry Trade Returns (1986-2012)

	Actual Interest Rates (Model 1)	**Implied Interest Rates (Model 2)**	**Implied Rate Funding (Model 3)**	**Implied Rate Target (Model 4)**
Panel A: Japanese Yen is the Funding Currency				
Mean Return	0.02	0.02	0.02	0.02
Standard Error	0.09	0.08	0.08	0.08
Sharpe Ratio	0.18	0.24	0.20	0.23
Skewness	-1.02	-0.35	-0.55	-1.31
Kurtosis	3.7	1.69	1.62	6.46
Max Drawdown	0.38	0.39	0.41	0.35
Panel A: Swiss Franc is the Funding Currency				
Mean Return	0.02	0.02	0.02	0.02
Standard Error	0.07	0.06	0.07	0.06
Sharpe Ratio	0.27	0.37	0.26	0.4
Skewness	-0.31	-0.21	-0.22	-0.45
Kurtosis	1.42	1.95	1.24	2.78
Max Drawdown	0.27	0.22	0.24	0.25
Panel A: US Dollar is the Funding Currency				
Mean Return	0.04	0.04	0.04	0.02
Standard Error	0.06	0.05	0.06	0.05
Sharpe Ratio	0.66	0.73	0.74	0.44
Skewness	-1.02	-1.78	-1.07	-2.34
Kurtosis	6.72	16.39	8.14	17.9
Max Drawdown	0.27	0.24	0.26	0.25

(1) The sample period is from 1986:01 to 2012:01. The total number of observations is 312. (2) The Sharpe Ratio is the mean returns divided by standard deviations. (3) All returns are annualized. (4) Equally weighted portfolio is calculated as giving equal weights to each currency trade in time (Funding currencies are: the Australian Dollar, Canadian Dollar, UK Pound, Norwegian Krone, New Zealand Dollar, US Dollar for Panel A and B.)

Table I Panel B shows the performance statistics of carry trade returns with Swiss Franc as funding currency. The results are similar to the Yen trades. Carry trade strategies with implied Taylor rule interest rate differentials have lower standard errors, and identical mean returns to the benchmark model. The crash risk for the carry trades with actual interest rate is improved with the trading strategies using implied Taylor rule interest rate for both the funding and target currency countries (Model 2).

The payoffs in Swiss Franc trades have probability of large losses in a case of market crash. The portfolio returns with all models are negatively skewed. The implementation of Taylor rule interest rate in both funding and target currency country as a trading strategy improves the downside risk: Table I (Panel B) shows skewness is improved 30 percent and maximum drawdown drops 2 percent.

Table I, Panel C shows the performance of Dollar trades. The results are similar to Yen and Franc trades. Taylor rule models have identical mean returns to the benchmark model. Trade strategy with implied interest rates for both funding and target currency has larger Sharpe ratio, lower standard errors and lower maximum drawdown (Model 2). Following implied interest rate for target currency model performs worse than other trade models.

The results with implied Taylor rule interest rate model (Model 2) displays a clear pattern. For all funding currencies, the mean return of this model is similar to benchmark model and standard errors are lower. Model 2 performs relatively better in terms of risk adjusted returns, however Sharpe ratios are not large enough for an investor to execute the carry trade. In Yen and Franc trades this model has better skewness and kurtosis than naive model with actual rates. Implied interest rate in the funding currency model (Model 3) is similar to the benchmark model in terms of mean returns, standard errors and Sharpe ratio. This model performs better in terms of downside risk for Yen and Franc trades.

I argue that, with the implied Taylor rule interest rate as a trading strategy, carry trade is profitable as much as carry trade with the benchmark model. In Yen and Franc trades, the crash risk of carry trading improves with implemented interest rate models. The results are similar for Dollar trades in terms of mean return, Sharpe ratio but not in terms of downside risk.

5.4. Performance Statistics of Carry Trades Before and During the Recent Financial Crises

The performance statistics of carry trade returns before the financial crisis are presented in Table II. Yen and Franc trades have similar results. For my benchmark model, mean returns are higher, standard errors are lower, and Sharpe ratio is larger than the whole sample period. Implied Taylor rule interest rate for both funding and target currency as a strategy does not perform as good as our benchmark model during this period in mean returns and risk adjusted returns.

Dollar trades follow relatively different pattern than Yen and Franc trades during this period. Taylor rule implied interest rate strategy performs best when Taylor rule is implemented for both funding and target currency's interest rate (Model 2). Sharpe ratio exceeds one, skewness is positive, and maximum drawdown decreases to six percent.

Taylor rule is a policy that is designed to respond both the deviations of inflation from its target level and the output from it is natural level. During the financial crisis of 2008, when the federal funds rate hit the zero lower bound, it is assumed that Taylor rule was no longer a relevant policy for the FED. Similarly, it is expected that, carry trade strategies with implied Taylor rule interest rates may not perform as well as the naive model with actual rates during this period.

The 2008-2009 financial crisis is a telling example of a severe period of market stress or tail event. The carry traders have high probability of crash risk in this period. The performance statistics of portfolios during this period are presented in Table III. For the benchmark model, mean returns are negative, implying a negative Sharpe ratio for Yen and Franc trades. The payoffs to portfolios are negatively skewed except Franc trades. The returns have fat tails for all funding currencies.

Taylor rule implied interest rate strategy for both funding and target currency surprisingly performs well in terms of mean returns, downside risk and risk adjusted returns during the financial crisis except the Dollar trades. Mean return of this strategy is positive and higher than the benchmark model. The returns of Model 2 are positively skewed and do not have fat tails. For Dollar trades the best performance comes with the strategy where Taylor rule implied interest rate is followed by the funding currency country, but not followed by the target currency country (Model 3). In this exceptional case, Panel C of Table III, the payoffs to portfolio returns of the Dollar trades are two percent higher than the benchmark model. This is interesting, since contrary to arguments that FED doesn't follow Taylor rule during the financial crises, Model 3 performs better than the benchmark model.

Table II. Performance Statistics of Carry Trade Returns (1986-2007)

	Actual Interest Rates (Model 1)	**Implied Interest Rates (Model 2)**	**Implied Rate Funding (Model 3)**	**Implied Rate Target (Model 4)**
Panel A: Japanese Yen is the Funding Currency				
Mean Return	0.03	0.02	0.02	0.04
Standard Error	0.09	0.08	0.08	0.08
Sharpe Ratio	0.39	0.25	0.29	0.52
Skewness	-0.54	-0.46	-0.49	-0.52
Kurtosis	1.06	1.43	1.14	1.89
Max Drawdown	0.38	0.39	0.41	0.25

Panel A: Swiss Franc is the Funding Currency				
Mean Return	0.03	0.02	0.03	0.03
Standard Error	0.07	0.06	0.07	0.06
Sharpe Ratio	0.43	0.37	0.34	0.48
Skewness	-0.43	-0.44	-0.40	-0.52
Kurtosis	0.67	1.03	0.33	1.87
Max Drawdown	0.16	0.22	0.24	0.18
Panel A: US Dollar is the Funding Currency				
Mean Return	0.04	0.04	0.04	0.03
Standard Error	0.05	0.03	0.05	0.04
Sharpe Ratio	0.89	1.12	0.95	0.89
Skewness	0.22	0.43	0.32	0.15
Kurtosis	0.64	1.46	1.32	1.14
Max Drawdown	0.14	0.06	0.11	0.11

(1) The sample period is from 1986:01 to 2007:01. The total number of observations is 252. (2) The Sharpe Ratio is the mean returns divided by standard deviations. (3) All returns are annualized. (4) Equally weighted portfolio is calculated as giving equal weights to each currency trade in time (Funding currencies are: the Australian Dollar, Canadian Dollar, UK Pound, Norwegian Krone, New Zealand Dollar, US Dollar for Panel A and B.)

Table III. Performance Statistics of Carry Trade Returns (2007-2012)

	Actual Interest Rates (Model 1)	**Implied Interest Rates (Model 2)**	**Implied Rate Funding (Model 3)**	**Implied Rate Target (Model 4)**
Panel A: Japanese Yen is the Funding Currency				
Mean Return	-0.05	0.01	-0.01	-0.07
Standard Error	0.13	0.06	0.09	0.10
Sharpe Ratio	-0.40	0.22	-0.12	-0.62
Skewness	-1.34	0.65	-0.82	-2.41
Kurtosis	3.89	3.2	3.35	9.41
Max Drawdown	0.37	0.09	0.23	0.35
Panel A: Swiss Franc is the Funding Currency				
Mean Return	-0.02	0.02	-0.01	-0.02
Standard Error	0.09	0.06	0.08	0.07
Sharpe Ratio	-0.22	0.34	-0.08	-0.33
Skewness	0.10	1.18	0.46	-0.14
Kurtosis	2.19	8.23	4.59	4.87
Max Drawdown	0.27	0.13	0.21	0.25
Panel A: US Dollar is the Funding Currency				
Mean Return	0.02	0.02	0.04	-0.03
Standard Error	0.09	0.09	0.09	0.07
Sharpe Ratio	0.25	0.26	0.44	-0.49
Skewness	-1.46	-1.73	-1.46	-3.34
Kurtosis	4.26	6.8	4.39	14.29
Max Drawdown	0.27	0.24	0.26	0.25

(1) The sample period is from 2007:01 to 2012:01. The total number of observations is 60. (2) The Sharpe Ratio is the mean returns divided by standard deviations. (3) All returns are annualized. (4) Equally weighted portfolio is calculated as giving equal weights to each currency trade in time (Funding currencies are: the Australian Dollar, Canadian Dollar, UK Pound, Norwegian Krone, New Zealand Dollar, US Dollar for Panel A and B.)

Implied Taylor rule interest rate differentials are successful as a carry trading strategy compare to the benchmark model during the financial crisis and before the financial crisis for the Dollar trades. However their performances are not as good as the benchmark model for Yen and Franc trades before the financial crisis of 2008. The returns have lower Sharpe Ratio, due to lower mean returns and they are negatively skewed and have fat tails.

6. Conclusion

This paper provides evidence of applicability of implied Taylor rule interest rate as a currency trading strategy. I design alternative carry trade strategies with interest rate differentials implied by the Taylor rule, and document that these alternative trading strategies are profitable as well as the naive carry-trade strategy with actual rates. These strategies are performing better over the benchmark model in terms of risk adjusted returns and downside risk in Franc and Yen trades. The crash risk of Japanese Yen carry trades is reduced to 50 percent. In case of Franc trades crash risk is reduced to 30 percent. In Dollar trades, implied Taylor rule interest rate model performs good except the case where implied Taylor rule interest rate strategy is followed by only target currency country (Model 4).This result is parallel to the argument that US follows Taylor rule type of reaction function in determination of its interest rate during the sample period.

While I provide returns with better performance in terms of downside risk and risk adjusted returns with implied Taylor rule interest rates in Yen and Franc trades, my analysis does not find profitable payoffs to these trading strategies when we consider the period before the financial crisis of 2008-2009. Dollar trades follow a different pattern and have identical mean returns to the benchmark model but better risk adjusted returns with Taylor rule implied interest rates. Sharpe ratio of Model 2 exceeds one during that period.

The recent literature emphasizes the importance of market-wide distress in carry trade strategies. Carry traders have significant losses during the periods of the market distress. During the recent crisis, the mean returns and adjusted risk returns are negative for the benchmark model. The returns have negative skewness and fat tails. Although 2008-2009 financial crisis was clearly not a good period for the carry trade investors, from Table 3, implied Taylor rule interest rate model (Model 2) for both funding and target currency is performing surprisingly good. Mean returns, Sharpe ratio and skewness turned into a positive number. This result holds for all funding currencies. The results suggest that likelihood of crash risk during the periods of market distress can be decreased with the adopting of implied Taylor rule interest rate as a carry trading strategy.

Overall, the results are consistent with the view that, returns to carry trade have high mean returns and low Sharpe ratios with a possibility of crash risk. This crash risk is reduced with the Taylor rule implied interest rate trading strategies for the whole sample in Yen and Franc trades. Finally, my finding that trading strategies with implied Taylor rule interest rate have better performance in terms of crash risk, would be helpful for the practitioner, since these trading strategies are profitable on average as much as benchmark model and they provide better statistical performance in terms of downside risk, especially during the market distress.

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