CRITERIA FOR EXERCISING AND NOT EXERCISING AMERICAN CURRENCY OPTIONS

T. YAMADA*

Department of Computational Intelligence and Systems Science, Tokyo Institute of Technology.
4259 Nagatsuta-cho, Midori-ku, Yokohama, Kanagawa 226-8502, Japan.
**E-mail: tyamada@trn.dis.titech.ac.jp*
www.trn.dis.titech.ac.jp/

This study examines how an American currency option holder judges whether to exercise his/her option. For this purpose, we collect early exercise activities of the USD/JPY currency options traded in Chicago Mercantile Exchange and analyze them. We firstly confirm that decision makings do not depend on the differences of the risk free rates in United States and Japan. Our second finding is that he/she puts more weight on the recent changes in payoff and cumulative return. This is different from the fact by Poteshman and Serbin (2003) in that he/she does not care about whether the underlying spot price attains its highest/lowest level. Instead, we observe that he/she pays more attention to the first and second order differences of payoffs and the most recent return. That implies that the prospect theory is applicable in some cases.

Keywords: FX Market; American Options; Behavioral Finance.

1. Introduction

In a frictionless market, the put-call-parity is expected to be satisfied and exercising American options is irrational with some exceptions. Thus the efficiency of American options market has been tested in some ways (e.g [8]). As a result, the break of put-call-parity (e.g. [3]) and rational or irrational early exercises (e.g. [4]) have been reported. However, most of the earlier studies have presented only the statistical results, not mentioning why an option holder executes an irrational early exercise. The only exception is by Poteshman and Serbin [7], which has revealed that the irrational early exercises could be explained by the prospect theory. Curiously, it seems that there are few researches on early exercises in foreign exchange (FX) market [1] after their milestone work. It may be that although the FX market is one of the largest financial markets, the currency derivatives are

not so popular because they are mostly traded as interbank dealings.

This paper, therefore, attempts to observe whether the past early exercising rules are applicable for the data of FX options market and explore another possibilities to explain early exercising behavior of options holders. In this study, we analyze the data of Chicago Mercantile Exchange USD/JPY calls and puts over the 1990-2006 period. The next section reviews the quantitative methods of exercising American options. Section 3 describes the data. Section 4 presents the empirical results on criteria of early exercises. Section 5 concludes.

2. Estimation of early exercises of American options

From now on, we will use the following notations:

S_t Spot price at time t,
K Strike price,
C_t Settlement price of a call option at time t,
P_t Settlement price of a put option at time t,
H_t Payoff at time t, namely $(S_t - K)_+$ for call option and $(K - S_t)_+$ for put option,
$\Delta \cdot_t$ Difference of $\cdot$, for instance $\Delta H_t = H_t - H_{t-1}$,
$\Delta^2 \cdot_t$ Second order difference of $\cdot$, for instance $\Delta^2 H_t = \Delta H_t - \Delta H_{t-1}$,
τ Days left,
rd_t Domestic risk free rate (the 13-week US Treasury Bill) at time t,
rf_t Foreign risk free rate (the Japanese key rate) at time t.

Table 1 summarizes conditions for rational early exercises; The quantities $Q_{EC,\,.}$ are the efficient conditions and the others are proposed ones. If the inequality expressions are satisfied then the early exercise is considered as rational. In this study, the quantity $Q_{.}$ is defined as the difference of the left term and the right term and the term *cost* is set to zero because the commission for exercising an option is not available. Therefore the quantities $Q_{EC,\,.}$ are the same as the ones $Q_{DF,\,.}$.

3. The data

The data analyzed in this study are the end-of-day Chicago Mercantile Exchange Japanese Yen futures, which are used as spot prices, and options on futures, both of which are traded by US dollar, from 1/1/1990 to 31/12/2006. While the spot data contain trade date, maturity, settlement price, open, high, low, and close, the options data have volume, open

Table 1. Conditions for rational early exercises

a. Call

Efficient condition ($Q_{EC,\ Call}$)	$S_t - K > C_t$
Gibson [6] ($Q_{GB,\ Call}$)	$S_t(1 - e^{-rf_t\tau}) > K(1 - e^{-rd_t\tau})$
DeRosa [1] ($Q_{DR,\ Call}$)	$(S_t(1 - e^{rf_t\tau}) - K(1 - e^{-rd_t\tau})) + rd_t\tau C_t - P_t > 0$
Diz and Finucane [2] ($Q_{DF,\ Call}$)	$(S_t - K) - cost > C_t$

b. Put

Efficient condition ($Q_{EC,\ Put}$)	$K - S_t > P_t$
Gibson ($Q_{GB,\ Put}$)	$K(1 - e^{-rd_t\tau}) > S_t(1 - e^{-rf_t\tau})$
DeRosa ($Q_{DR,\ Put}$)	$(K(1 - e^{-rd_t\tau}) - S_t(1 - e^{rf_t\tau})) + rd_t\tau P_t - C_t > 0$
Diz and Finucane ($Q_{DF,\ Put}$)	$(K - S_t) - cost > P_t$

interest, the number of exercise activity, and implied volatility. The maturity dates for the futures are at March quarterly interval (March, June, September, and December) and those for the options are six months in the March Quarterly cycle, and option on futures contracts trade four months in the March cycle and two months not in the March cycle[a]. The expiration day of an option is on the second Friday immediately preceding the third Wednesday of the contract month.

4. Empirical results

In this section, we examine rationality of early exercise activities on currency options based on the framework of earlier studies and explore criteria for exercising and not exercising them. Here, we collected the early exercises which satisfied in-the-money conditions; $S_t > K$ for call, $K > S_t$ for put. However, the data used in this study do not have enough candidates meeting the conditions by Poteshman and Serbin [7]; Some contracts or trading volumes are less than ten, and the intraday spot or options prices are not available. Therefore, we ignored the conditions, "Data are available on the daily high transaction price for the option and the daily low transaction price for the underlying stock." (p. 46) and "The daily trading volume for the option is at least ten contracts." (p. 46).

Table 2 presents the early exercise activities classified by maturity from January 1991 to December 2006. The reason why the number of early exercises for put options is larger is that the differences of risk free rate between the two countries were large, 6% at most. That affects the results of Gibson [6] and DeRosa [1]. Which means, since the Japanese risk free rate had been almost zero since 1994, the moneyness for a rational exercise of call

[a]http://www.cme.com/trading/prd/fx/japanese_OA.html

Table 2. Early exercise activities

	Call	Put
Number of cases	1374	2164
$(Q_{GB,\ .} > 0)$	146	2132
$(Q_{DR,\ .} > 0)$	122	1999
$(Q_{DF,\ .} > 0)$	668	706
Number of contracts exercised	76203	120204

options became low (around 0.1). Therefore, the conditions of Gibson and DeRosa judge the early exercises of call options in the early 1990's and those of put options afterward as rational. On the other hand, since there is no term as to risk free rate in $Q_{DF,\ .}$, there are more possible rational early exercises estimated by Diz and Finucane [2] compared to those in the previous two methods. The implication of this result is simple, but is expected to support the hypothesis, "some investors are slow in responding to changes in the interest differential." (p. 188) [5]

Table 3 shows the variables obtained by Welch's t test with significant differences at 5 % level between the data at the day of early exercise and those at their previous days. The variables used in this analysis were the first and the second order differences of options prices, payoffs, and judgment quantities other than the ones in Poteshman and Serbin [7]. We observe the following points from this table:

- The first differences of payoff at the exercise day, namely change in spot prices, are smaller than those at the previous day,
- That is also true for the second order differences of payoff, and
- The absolute values of the most recent return at the exercise day are larger than those at the previous day.

Table 4 is the result of logit regression as Poteshman and Serbin have done[b]. Unlike the findings by Poteshman and Serbin, that the spot price is the maximum/minimum value at the exercise day in a whole life of the option is not the criterion for whether an option holder exercises his/her right. This is because only about 20% of early exercise cases correspond to the case. Instead, it appears that the first and second order differences of payoff function, ΔH_t and $\Delta^2 H_t$, and the most recent cumulative return, $RetWeek1$, are principal factors for the judgment. In other words, an option

[b]Note that the reason why the first and the second order differences of option prices are not in the table is that they are derived from the payoff and the estimator by Diz and Finucane.

Table 3. Results of two-sample t-test.

	a. Call			b. Put		
	Exercise	Non-exercise	p-value	Exercise	Non-exercise	p-value
ΔH_t	6.593	23.311	0.000	10.294	28.234	0.000
$\Delta^2 H_t$	−13.746	−1.171	0.007	−14.814	9.118	0.000
$\Delta C_t/\Delta P_t$	0.594	22.999	0.000	7.176	22.604	0.000
$\Delta^2 C_t/\Delta^2 P_t$	–	–	–	−12.374	7.189	0.000
RetWeek1	0.907	0.713	0.006	−0.890	−0.684	0.000
RetWeek2	–	–	–	−0.629	−0.542	0.028
RetWeek3	–	–	–	−0.601	−0.487	0.007
RetWeek4	0.718	0.519	0.031	–	–	–

RetWeek*is* ($\times 10^{-2}$) are from Poteshman and Serbin.
The variables whose p-values are less than .05 are listed.

holder puts more weight on the changes in spot prices, not on whether the spot prices at the top/bottom level in the life of the option. Besides, Table 4 also tells us that the Diz and Finucane quantity $Q_{DF,\ .}$, namely the change in option prices, is not so important as expected, unlike the results of two-sample t-test.

Next, we classified the execution and non-execution data into the following four groups and implemented the same analyses in order to see whether there were some relations between the spot price situation and judgment for early exercises:

case (a) The spot prices are the highest/lowest values at both the day of exercising the rights and the previous day of it.
case (b) The spot price is the highest/lowest value at the day of exercising the rights, but not at the previous day.
case (c) The spot price is not the highest/lowest value at the day of exercising the rights while it is at the previous day.
case (d) The spot prices are not the highest/lowest values at neither the day of exercising the rights or the previous day of it.

The fact that almost all the coefficients are zero w.r.t case (c) implies that the loss aversion led an option holder to exercise the option because he/she set the spot price at the previous day as the "reference point". On the other hand, the results of case (b) present that the changes in payoff, ΔH_t, at the day of exercising are significantly larger those at the previous day of it in addition that both the payoffs are positive values. That is to say, the third case by Poteshman and Serbin, "Extreme for large gains", is applicable to this result, namely an option holder executes his/her right because the spot price reaches the peak/bottom. By the way, the implications for cases (a)

and (d) are different from those for cases (b) and (c), even if the 'applied' prospect theory holds for the results of logit regression; The one is that the second order differences of payoff function at the day of exercising the rights are negative while those at the previous day are positive. The other point is that the first order differences of payoff functions are positive at both the day and the previous day of exercising. These facts lead that an option holder may assume that the spot price is increasing but it will go down because it grows at a sluggish pace. Though this is not always true for all the situations of cases (a) and (d), similar results are observed from the results of the most recent return, $RetWeek1$, and the difference of payoff, ΔH_t. Thus it would be more natural to think that an option holder exercises the right because the spot price turns flat, not simply because the spot price is the highest/lowest level in the life of an option.

5. Concluding remarks

This study examines how an American currency option holder judges whether to exercise his/her option and compares the results to the findings in the earlier studies. For this purpose, we collected early exercise activities of USD/JPY currency option traded in Chicago Mercantile Exchange and analyzed them by fundamental statistics, two-sample t-test, and logit regression. We have firstly confirmed that decision makings do not depend on the differences of the risk free rates in the two countries. Our second finding is that he/she puts more weight on the recent changes in payoff and cumulative return. This is different from the fact by Poteshman and Serbin [7] that the underlying stock price attains its highest/lowest level over the past year. Instead, when conducting logit regression with respect to the situations of spot prices at the day and the previous day of exercising rights, we observe that the prospect theory for early exercise by Poteshman and Serbin is applicable when the spot price is at the highest/lowest level at either the day or the previous day of execution.

Acknowledgments

The author thanks Kevin Brady for generous assistance with the data used in this study. I am also grateful for helpful comments from Hiroyuki Moriya and one anonymous referee. I would like to thank the Ishii Memorial Securities Research Promotion Foundation for their financial support[c].

[c]http://www.tachibana.or.jp/ (in Japanese)

Table 4. Logit regression of early exercise activities

a. Call

	Total	Case (a)	Case (b)	Case (c)	Case (d)
Constant	3.304**	−2.146**	−2.672**	−0.000	0.608
$Q_{DF,\ Call}$	0.846**	1.224	2.292**	0.000	0.605
RefPoint	−0.792	–	–	–	–
ΔH_t	−4.753**	−0.248	3.682**	−0.002	−2.384*
$\Delta^2 H_t$	2.653**	−2.090**	−2.252**	−0.001	3.049**
$\Delta Q_{DF,\ Call}$	2.469*	−0.663	0.745	−0.000	2.232*
$\Delta^2 Q_{DF,\ Call}$	−1.184	1.328	0.549	0.001	−1.798·
RetWeek1	3.516**	2.140**	−0.680	−0.000	0.626
RetWeek2	1.260	1.108	1.472	−0.000	−0.624
RetWeek3	0.357	1.416	1.847·	−0.000	−0.862
RetWeek4	2.770**	2.186**	0.650	0.000	0.253
RetMonth2	1.539	0.567	2.016*	0.001	−0.166
CashFlowLoss	−1.139	0.378	−2.735**	−0.000	−0.516

b. Put

	Total	Case (a)	Case (b)	Case (c)	Case (d)
Constant	3.723**	−0.468	−4.830**	0.001	−0.113
$Q_{DF,\ Put}$	−0.694	1.224	1.809·	−0.001	−0.248
RefPoint	−1.100	–	–	–	–
ΔH_t	−4.124**	−2.646**	6.492**	−0.005	−1.149
$\Delta^2 H_t$	−1.941·	−3.157**	0.315	0.001	−0.251
$\Delta Q_{DF,\ Put}$	0.810	1.265	4.262	0.000	0.613
$\Delta^2 Q_{DF,\ Put}$	1.763	1.434	−3.061**	−0.000	−0.683
RetWeek1	−3.606**	−3.372**	−1.493	0.001	−0.352
RetWeek2	−2.592**	0.991	−0.677	0.001	−0.739
RetWeek3	−2.427*	0.788	0.248	−0.000	0.196
RetWeek4	−1.458	−0.226	1.771	0.001	0.555
RetMonth2	−1.275	0.056	−3.619**	−0.001	−0.084
CashFlowLoss	0.318	1.011	−2.599*	0.001	0.211

Variables are from Poteshman and Serbin [7].
∗∗: z-value $< .01$, ∗: z-value $< .05$, ·: z-value $< .10$.

References

1. D. F. DeRosa, *Options on foreign exchange*, (John Wiley & Suns, 2000).
2. F. Diz, T. J. Finucane, *Rev. Finan. Studies* **6**, 765, (1993).
3. M. El-Mekkaoui, M. D. Flood, *J. Int. Finan. Markets, Inst. Money* **8** 357, (1998).
4. M. Engström, L. Nordén, *J. Multinational Finan. Manag.* **10**, 461, (2000).
5. K. A. Froot, R. H. Thaler, *J. Econ. Perspectives* **4**, 179, (1990).
6. R. Gibson, *Option valuation*, (McGraw-Hill, 1991).
7. A. M. Poteshman, V. Serbin, *J. Finan.* **58**, 37, (2003).
8. K. Shastri, K. Tandon, *J. Int. Money Finan.* **4**, 455, (1985).