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Fluctuation of Foreign Exchange Rate by Triangular Arbitrage

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This paper is trying to discover how the triangular arbitrage affect foreign exchange rates among all kind of currencies. Once the triangular arbitrage emerge, money move to arbitrage, while arbitrage opportunity phasing out, the foreign exchange rates among three currencies have been changed, it will cause other arbitrage opportunities. We focus on whether the fluctuation quit, our simulation result shows that fluctuation caused by triangular arbitrage disappeared in the end. Instead of adjusting exchange rates, dealer prefers to quote a high spread to avoid loss and wipe out volatility, it is also consistent with microstructure theory.

1. Introduction

Unpredictable fluctuation of foreign exchange rates undermine the profitability of firms, especially international corporate. Taiwan is a resource shortage country, small and medium-sized enterprise is majority in Taiwan business arena, we try to attribute some reasons to the stochastic fluctuation of foreign exchange rates.

Triangular arbitrage is a factor causes fluctuation that no one discuss before, in this paper we focus on how it affect foreign exchange rate. As statistics doesn't have a proper method to model and verify it, looking for others science area is necessary. Time-evolution equation is a mathematical method that can model foreign exchange rate fluctuation, it simulates the change of foreign exchange rates among several currencies over time.

In order to simplify the complicated interaction among different currency , we assume there is only one trader in the market, manipulating the most profitable arbitrage circle at one time. Research framework is a set of relationship of currency, exploiting a trivial recursive algorithm to list all possible currency exchange routes to arbitrage.

Research data and currency relationships were drawn from OANDA website which updates almost per-minute, plenty of currency relationships and 24 service hours except weekend. Many research have discovered seasonal effects or events impact on foreign exchange rates, but interaction among all of foreign exchange rates was not documented, research data from OANDA allow us to extend research scope, because of 13 currencies and 21 exchange rates on the panel.

The result show that fluctuation will quit, because spreads are the nature of stable factor, it makes every criterion of arbitrage opportunities slight less than unity. Adjusting exchange rates may cause other arbitrage opportunities, enlarging spreads is the best way to wipe out volatility, it also conform to microstructure theory that spread is positively related to volatility but not because of inventory holding costs, the dealer increase spread not only to defense margin from volatility, but also to against speculator.

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2. Literature Review

Fluctuation of foreign exchange rates is random walk in the short run, however, foreign exchange rates is not irrational, Groen(2004) found out Euro exchange rates of Canada, Japan and United States are associated with monetary fundamentals in the long run. Moreover, volatility of foreign exchange rates are predictable, Jorion(1995) took advantage of volatility implied in option price to estimate future volatility, but it still is a biased volatility forecasts. Brooks and Hinich(2003) employed signal coherence function to detect periodicities in time series data of high frequency exchange rates, it is a evidence that fluctuation of foreign exchange rates hold some rules even in short term. DeGennaro and Shrieves(1997) investigated information releasing impacts foreign exchange volatility, spreads increase while unexpected quote arrival, private information and news effect are factors of exchange rate volatility.

The fundamental of bid/ask spreads is microstructure theory, spreads implicit three costs: order processing costs, inventory control costs, asymmetric information costs. It means, aforementioned costs influence spreads quoting behavior. Poskitt(2005) explained the paradox that dealers prefer to quote both single spread and time-varying spread, with an eye on geographic partition, single spread in the intraregional and interregional NZD/USD market is consistent with microstructure theory in inventory holding cost. Huan and Masulis(1999) found that bid/ask spreads in foreign exchange market are positively related to predicted foreign exchange volatility and negatively related to predicted active dealer, they attribute it to dealer competition and it also conform with microstructure theory. Microstructure theory appears to be an essential knowledge in bid/ask spreads research.

Between bid/ask spreads and foreign exchange rates volatility, there must be some intervening variable, we suppose it is triangular arbitrage. In order to test whether triangular arbitrage play a role in foreign exchange rates volatility, we adopt a physics model which was proposed by Aiba, et al(2002), it simulates arbitrage opportunity phasing out and takes the interaction of three exchange rates into consideration. This method jumps off typical statistics way, It allows us to observe whether the fluctuation by arbitrage vanish, not tests of significance.

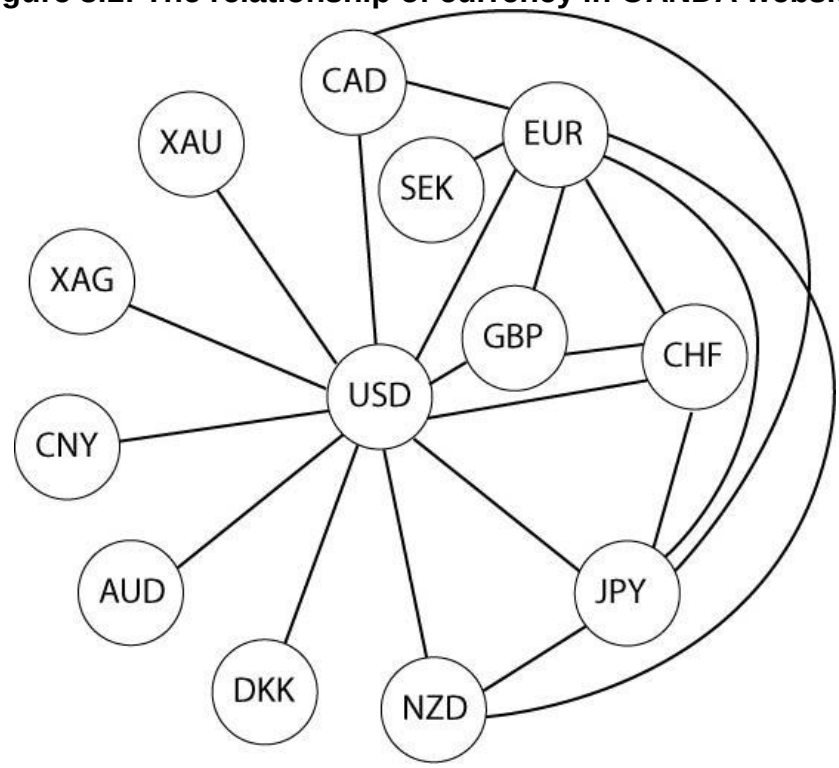
3. The Methodology and Model

3.1 Source of Data and Framework

Time-evolution equation is used to model high frequency data, so our research data must be updated as frequently as possible. Analysing the interaction of exchange rates needs a panel quoting plenty of currency exchange rates. In order to get proper data, online foreign exchange website “OANDA” is a good source of research data, which provides 21 exchange rates, 13 currencies and updates while exchange rates changed.

Currencies arbitrage involving more than two exchange rates, and money should be exchanged back to the original currency. Figure 3.1 depicts the relation of currencies, which on left side are unable to be cycles, however, there are lots of cycle on right side.

Figure 3.1: The relationship of currency in OANDA website.



In order to get all arbitrage routs, currencies relation should be turn into a way readable for computer. Relational matrix comprises relations of objects each other, rows are equal to columns, it is also a symmetric matrix, 0 refers to disconnect and 1 refers to connect.

Table 3.1: The relational table of currency

	USD	EUR	DKK	XAG	GBP	CHF	JPY	SEK	XAU	CAD	AUD	CNY	NZD
USD	1	1	1	1	1	1	1	0	1	1	1	1	1
EUR	1	1	0	0	1	1	1	1	0	1	0	0	1
DKK	1	0	1	0	0	0	0	0	0	0	0	0	0
XAG	1	0	0	1	0	0	0	0	0	0	0	0	0
GBP	1	1	0	0	1	1	0	0	0	0	0	0	0
CHF	1	1	0	0	1	1	1	0	0	0	0	0	0
JPY	1	1	0	0	0	1	1	0	0	1	0	0	1
SEK	0	1	0	0	0	0	0	1	0	0	0	0	0
XAU	1	0	0	0	0	0	0	0	1	0	0	0	0
CAD	1	1	0	0	0	0	1	0	0	1	0	0	0
AUD	1	0	0	0	0	0	0	0	0	0	1	0	0
CNY	1	0	0	0	0	0	0	0	0	0	0	1	0
NZD	1	1	0	0	0	0	1	0	0	0	0	0	1

Note: The relational matrix of currencies which draw from Figure 3.1, the value 1 in the table means connect and 0 is disconnect.

Recursive program can get arbitrage routes out of relational matrix, the pseudo code are shown in appendix. There are 807 arbitrage routes that include duplicated route but different beginning-end, after eliminating duplicated there are 222 arbitrage routes left, the pseudo code for eliminating duplicated route was omitted, because it is easy to be done.

Table 3.2 reports descriptive statistics of bid and ask of the 21 currencies relation, the data was recorded from 22:00:00 on 2 May, 2011 to 06:15:12 on 3 May, 2011, 8 hours is

not a long time, however, we got 25,539 data, it is enough for our research. Bid price is always slight less than ask price, the difference between bid and ask price is spread, which is margin of dealer. There is some clues that spreads is not a constant, skewness of USD/CNY bid and ask is quite different, one is right-skewed, another is left-skewed, kurtosis of EUR/NZD bid and ask also deviate from each other, it implied that bid and ask price are not necessary to shift the same way. Compare with USD/CNY and EUR/NZD, other spreads are more stable, changes of spreads is a important factor in this research.

Table 3.2: Descriptive statistics

Currency relationship	Skewness	Max value	Min value	Median	Kurtosis	Mean
EUR/USD Ask	-0.16326	1.49021	1.48176	1.48645	-1.41227	1.48565
EUR/USD Bid	-0.17635	1.49008	1.48157	1.48634	-1.41282	1.48550
GBP/USD Ask	-0.24618	1.67235	1.66387	1.66863	-1.05952	1.66788
GBP/USD Bid	-0.26647	1.67206	1.66352	1.66836	-1.062699	1.66758
USD/CHF Ask	0.01748	0.86663	0.86311	0.86456	-0.67654	0.86458
USD/CHF Bid	-0.04340	0.86595	0.86287	0.86431	-0.66754	0.86432
USD/JPY Ask	-1.01808	81.40000	81.05400	81.23099	0.78855	81.21514
USD/JPY Bid	-1.07131	81.35200	81.04200	81.21500	0.86395	81.20139
AUD/USD Ask	0.48602	1.10127	1.09311	1.09646	-0.49129	1.09633
AUD/USD Bid	0.45422	1.10108	1.09285	1.09627	-0.53245	1.09612
USD/CAD Ask	0.57837	0.95209	0.94803	0.94947	-1.09072	0.94992
USD/CAD Bid	0.53101	0.9516	0.94772	0.94920	-1.05561	0.94958
XAU/USD Ask	-0.04954	1575.52	1536.58999	1558.36999	-1.02114	1556.39800
XAU/USD Bid	-0.07645	1575.17000	1535.79	1558.01	-1.04570	1555.89807
EUR/JPY Ask	-0.39529	120.881	120.407	120.69	-1.43318	120.63981
EUR/JPY Bid	-0.40014	120.854	120.377	120.66200	-1.42934	120.61183
EUR/GBP Ask	0.06504	0.89210	0.88954	0.89087	-0.95461	0.89086
EUR/GBP Bid	0.08259	0.89197	0.88915	0.89071	-0.99815	0.89070
EUR/CHF Ask	-0.21482	1.28719	1.28101	1.28472	-1.17136	1.28438
EUR/CHF Bid	-0.21836	1.28691	1.28071	1.28443	-1.19274	1.28407
USD/CNY Ask	1.00017	6.46450	6.46100	6.46100	-0.99964	6.46196
USD/CNY Bid	-1.00017	6.44800	6.44449	6.44800	-0.99964	6.44703
EUR/SEK Ask	-0.47614	8.93613	8.91109	8.92637	-0.40713	8.92616
EUR/SEK Bid	-0.58268	8.92889	8.90509	8.91943	-0.16543	8.91904
XAG/USD Ask	-0.34002	47.38750	43.57280	45.92170	-1.49025	45.49841
XAG/USD Bid	-0.34139	47.34949	43.53079	45.88369	-1.49067	45.45572
USD/DKK Ask	0.18116	5.03371	5.00490	5.01757	-1.40990	5.02042
USD/DKK Bid	0.16913	5.03270	5.00415	5.01682	-1.41012	5.01959
NZD/USD Ask	-0.19333	0.81223	0.80539	0.80876	-1.13781	0.80824
NZD/USD Bid	-0.24869	0.81196	0.80488	0.80847	-1.16620	0.80791
CHF/JPY Ask	-0.21082	94.06199	93.82099	93.96200	-0.03726	93.95884
CHF/JPY Bid	-0.21374	94.03400	93.79300	93.93099	-0.21755	93.92882
GBP/CHF Ask	-0.10711	1.44490	1.43880	1.44197	-0.31451	1.44194
GBP/CHF Bid	-0.19484	1.44436	1.43811	1.44147	-0.41363	1.44138
NZD/JPY Ask	-0.41547	65.83299	65.43000	65.65500	-1.29035	65.62099
NZD/JPY Bid	-0.47010	65.78700	65.37999	65.62399	-1.29455	65.58453
EUR/NZD Ask	-0.34656	1.84146	1.83468	1.83881	-0.03275	1.83878
EUR/NZD Bid	-0.47767	1.84067	1.83281	1.83803	0.53931	1.83799
CAD/JPY Ask	-0.04319	85.76500	85.34799	85.51399	-0.58956	85.51024
CAD/JPY Bid	-0.10711	85.70600	85.31300	85.48600	-0.70709	85.48022
EUR/CAD Ask	0.00644	1.41354	1.40802	1.41121	-1.04198	1.41121
EUR/CAD Bid	-0.02037	1.41316	1.40733	1.41077	-1.16580	1.41071

3.2 Definition of Triangular Arbitrage opportunities

Before introducing time-evolution equation, we have to clarify the criterion of arbitrage opportunity. If the product of all exchange rates in a arbitrage rout is great than 1, then we conclude it is profitable.

$$\prod_{i=1}^{n} r_i(t) > 1 \tag{1}$$

3.3 Basic Time Evolution

The time-evolution equation simulates all exchange rates in a arbitrage route converging to stable, r_i refers to exchange rate in a arbitrage rout, f_i refers to independent fluctuation. It is a logarithmic model of each rate.

$$\ln r_i(t + \Delta t) = \ln r_i(t) + f_i(t) + g\big(v(t)\big), \qquad (i = 1,2,3 \dots n) \tag{2}$$

where *v* is product of logarithmic rates

$$v(t) \equiv \ln \mu(t) = \sum_{i=1}^{n} \ln r_i(\mathrm{t}) \tag{3}$$

g(v) is a function that makes *v(t)* converge to ε, which is average of all product of every exchange rates in a arbitrage route over all training data.

$$g(v) \begin{cases} < 0 \ \text{ for } v > \ \varepsilon \\ > 0 \ \text{ for } v < \ \varepsilon \end{cases} \tag{4}$$

$$g(v) \equiv -a(v - \varepsilon) \tag{5}$$

The time-evolution equation of *v* is given by summing Eq.(2) over all *i*

$$v(t + \Delta t) - \varepsilon = (1 - na)(v(t) - \varepsilon) + F(t) \tag{6}$$

where

$$F(t) \equiv \sum_{i=1}^{n} f_i(t) \tag{7}$$

F(t) was omitted, because we think the fluctuation was not a stochastic process, it is a side effect of exchange rates exchanged, especially for the purpose of arbitrage.

3.4 Estimation of Parameters

$$1 - \mathrm{na} = \mathrm{c(k)} \equiv \frac{\sum_{\mathrm{i}=1}^{\mathrm{N}-\mathrm{k}} (\mathrm{Y_i} - \overline{\mathrm{Y}})(\mathrm{Y_{i+k}} - \overline{\mathrm{Y}})}{\sum_{\mathrm{i}=1}^{\mathrm{N}} (\mathrm{Y_i} - \overline{\mathrm{Y}})^2}, \qquad (\mathrm{k} = \Delta \mathrm{t}) \tag{8}$$

We fix the time step at $\Delta t=22.5$[sec], and then derive $r_i(t+\Delta t)$ in Eq.(2).

3.5 Research Assumption

Foreign exchange fluctuation caused by countless factors, we made three assumption to reduce its complexity.

1. Only one dealer in the market.
2. The dealer do nothing but currencies arbitrage.
3. They speculate the most profitable arbitrage circle.

3.6 Algorithm of Simulating the Fluctuation of Foreign Exchange Rates

Based on 3.2 and 3.3, we developed a algorithm to simulate the activity of dealer, it was implemented in Python programming language.

Step 1, randomly disarrange exchange rates on the panel and calculate ε:
This is a simple way to get arbitrage opportunity into research data, facilitating the remainder work.

Step 2, compute all arbitrage level of possible arbitrage circle:
Arbitrage level means *v(t)* which we have defined in Eq.(1).

Step 3, select the most profitable circle to speculate.
Profitability is arbitrage level minus 1, which refers to $v(t) - 1$. According to research assumption, the only one dealer can do only one arbitrage at the same time. So, we have to behave as a rational dealer who select the most profitable circle to speculate.

Step 4, repeat time-evolution equation until $v(t) - 1 <= 0$.
With time-evolution running, r_i were changed in each generation. This step mainly devote to get r_i in the arbitrage circle.

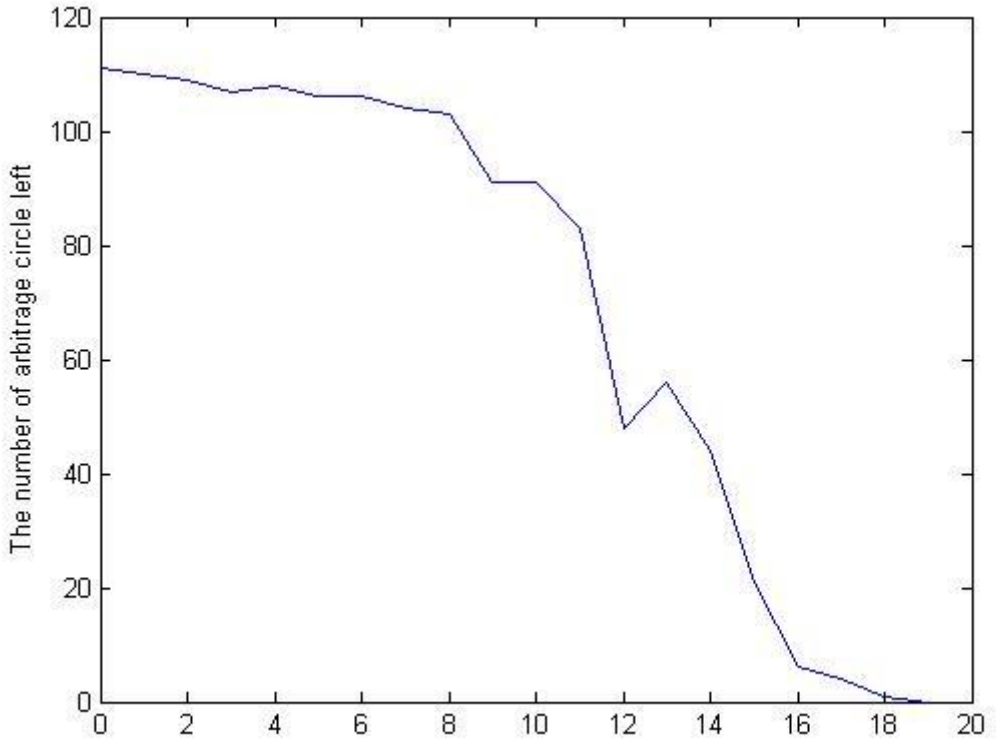
Step 5, repeat step 2, until all the arbitrage opportunity disappear.
To observe whether arbitrage will halt or not is our objective, if it is infinite, we could conclude the fluctuation caused by triangular arbitrage is ceaseless.

4. The Findings

4.1 Result of Simulation

The simulation algorithm was expecting to show all the triangular arbitrage opportunity would vanish, so that triangular arbitrage is not able to make foreign exchange rate fluctuate. Figure 4.1 is the result of simulation, the line is number of arbitrage circle left over time, it dropped slightly at the beginning and then converged to 0. The number of arbitrage circle did not go down straight, it tried to recover but failed, this is a evidence that triangular arbitrage can influence each other.

Figure 4.1: The line is number of arbitrage circle left while times goes by.



4.2 Reasons for Volatility by Triangular Arbitrage

If wiping out one arbitrage opportunity would trigger others, foreign exchange market might easily to misprice, there is possibility exchange rates might go far from the price it should be, foreign exchange market are on the razor's edge. In fact, market won't crash because of arbitrage, the simulation algorithm was designed to adjust foreign exchange rates not spreads, so the reason of market still stable is spread.

Let's begin with a double triangular arbitrage circle sharing one exchange rate, figure 4.2 consist four currencies and five exchange rates, r refers to bid price and r+s refers to ask price. Considering a triangular circle of EUR/GBP/USD, its bilateral unprofitable threshold are:

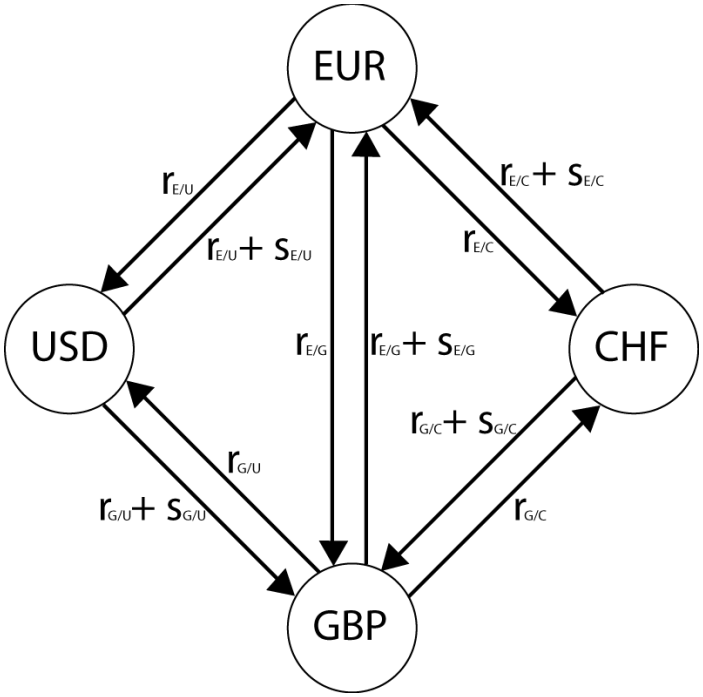
Clockwise of EUR/GBP/USD:

$$\frac{r_{E/G}r_{G/U}}{(r_{E/U}+S_{E/U})} \leq 1 \tag{9}$$

Anticlockwise of EUR/GBP/USD:

$$\frac{r_{E/U}}{(r_{G/U}+S_{G/U})(r_{E/G}+S_{E/G})} \leq 1 \tag{10}$$

Figure 4.2: Four courencies and five relationship.



Note:It is abbreviated from figure 3.1 and to illustrate how the market deal with volitality caused by triangular arbitrage.

Multiplying equation (9) and (10), then we get an inequality, this condition holds every time.

$$r_{E/G}r_{G/U}r_{E/U} \leq (r_{E/U} + S_{E/U})(r_{G/U} + S_{G/U})(r_{E/G} + S_{E/G}) \qquad (11)$$

Assuming there is arbitrage opportunity in clockwise of EUR/GBP/USD, and deriving inequality (12) and (13) form (9), (10) and (11).

$$1 < \frac{r_{E/G}r_{G/U}}{(r_{E/U} + S_{E/U})} \leq \frac{(r_{G/U} + S_{G/U})(r_{E/G} + S_{E/G})}{r_{E/U}} \qquad (12)$$

$$\frac{r_{E/U}}{(r_{G/U} + S_{G/U})(r_{E/G} + S_{E/G})} \leq \frac{(r_{E/U} + S_{E/U})}{r_{E/G}r_{G/U}} < 1 \qquad (13)$$

Aforementioned two inequalities indicate that there is three ways to recover stable, first, decrease $r_{E/G}r_{G/U}$ in numerator; second, increase $r_{E/U}$ in denominator; third, increase $S_{E/U}$ in denominator. Adjusting exchange rates $r_{E/G,}$ $r_{G/U}$ and $r_{E/U}$ are likely to trigger anticlockwise arbitrage opportunity, arbitrage circles EUR/GBP/USD and EUR/GBP/CHF share the same exchange rate $r_{E/U}$, it means changing $r_{E/U}$ may also cause arbitrage opportunity in other circles, that is the reason arbitrage opportunity did not drop straight.

Recalled the finding of Huan and Masulis, spreads are positively related to volatility, the third method adjusting $S_{E/U}$ is the best way to eliminate all arbitrage opportunity. Adjusting $S_{E/U}$ will leave all of other arbitrage inequality untouched, that is the reason foreign exchange rate volatility goes with high spread.

5. Summary

Trying to discover how triangular arbitrage influence foreign exchange rates is the main idea in this study. Huan and Masulis found that spread has positive relation to volatility, and Aiba, et al(2002) provide a good solution to simulate the change of foreign exchange rates.

First, we showed the criterion of arbitrage opportunity, and introduced time-evolution equation as our simulation model. Next, three assumptions were necessary to simplify the foreign exchange market, and proposed a algorithm to test whether the fluctuation vanish or not. Finally, the result showed that fluctuation caused by triangular will quit, manipulating exchange rates are able to stop volatility, but not a effective way.

The result is consistent with microstructure theory that spreads are positive relative to volatility, not because of costs they have to bear, increasing spreads are the most efficient method to wipe out volatility by triangular arbitrage. Descriptive statistics of EUR/NZD is an evidence that dealer took advantage of spreads to deal with volatility.

This research suggests dealer that spreads are a good weapon against speculator, it can make foreign exchange market acts more rational. Spreads are an important issue in foreign exchange rates research, but rare paper have documented about it. How to quote spreads that maximize margin and minimize cost and risk is our future work.

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Appendix

Pseudo code for counting arbitrage route

```
function circle_recursive(traversal_row)
    stack.append(traversal_row)
    if length of stack > 1
        if stack's first element is equal to last element
            if length of stack > 3
                set_of_arbitrage_rout.push(stack)
            stack.pop()
            return

    traversal_column = 0
    while traversal_column < length_of_ relation _column
        if traversal_row isn't equal to travesal_col and relation_table[traversal_row][traversal_col] is 1
            for currency in stack[1:]
                if travesal_col is equal to currency
                    break
            else:
                circle_recursive (travesal_col)

        traversal_column += 1
    stack.pop()
```

All of arbitrage rout eliminating duplicated

	Arbitrage route
1	USD→EUR→GBP→USD
2	USD→EUR→GBP→CHF→USD
3	USD→EUR→GBP→CHF→JPY→USD
4	USD→EUR→GBP→CHF→JPY→CAD→USD
5	USD→EUR→GBP→CHF→JPY→NZD→USD
6	USD→EUR→CHF→USD
7	USD→EUR→CHF→GBP→USD
8	USD→EUR→CHF→JPY→USD
9	USD→EUR→CHF→JPY→CAD→USD
10	USD→EUR→CHF→JPY→NZD→USD
11	USD→EUR→JPY→USD
12	USD→EUR→JPY→CHF→USD
13	USD→EUR→JPY→CHF→GBP→USD
14	USD→EUR→JPY→CAD→USD
15	USD→EUR→JPY→NZD→USD
16	USD→EUR→CAD→USD
17	USD→EUR→CAD→JPY→USD
18	USD→EUR→CAD→JPY→CHF→USD
19	USD→EUR→CAD→JPY→CHF→GBP→USD
20	USD→EUR→CAD→JPY→NZD→USD
21	USD→EUR→NZD→USD
22	USD→EUR→NZD→JPY→USD
23	USD→EUR→NZD→JPY→CHF→USD
24	USD→EUR→NZD→JPY→CHF→GBP→USD
25	USD→EUR→NZD→JPY→CAD→USD
26	USD→GBP→EUR→CHF→USD
27	USD→GBP→EUR→CHF→JPY→USD
28	USD→GBP→EUR→CHF→JPY→CAD→USD
29	USD→GBP→EUR→CHF→JPY→NZD→USD
30	USD→GBP→EUR→JPY→USD
31	USD→GBP→EUR→JPY→CHF→USD

32	USD→GBP→EUR→JPY→CAD→USD
33	USD→GBP→EUR→JPY→NZD→USD
34	USD→GBP→EUR→CAD→USD
35	USD→GBP→EUR→CAD→JPY→USD
36	USD→GBP→EUR→CAD→JPY→CHF→USD
37	USD→GBP→EUR→CAD→JPY→NZD→USD
38	USD→GBP→EUR→NZD→USD
39	USD→GBP→EUR→NZD→JPY→USD
40	USD→GBP→EUR→NZD→JPY→CHF→USD
41	USD→GBP→EUR→NZD→JPY→CAD→USD
42	USD→GBP→CHF→USD
43	USD→GBP→CHF→EUR→JPY→USD
44	USD→GBP→CHF→EUR→JPY→CAD→USD
45	USD→GBP→CHF→EUR→JPY→NZD→USD
46	USD→GBP→CHF→EUR→CAD→USD
47	USD→GBP→CHF→EUR→CAD→JPY→USD
48	USD→GBP→CHF→EUR→CAD→JPY→NZD→USD
49	USD→GBP→CHF→EUR→NZD→USD
50	USD→GBP→CHF→EUR→NZD→JPY→USD
51	USD→GBP→CHF→EUR→NZD→JPY→CAD→USD
52	USD→GBP→CHF→JPY→USD
53	USD→GBP→CHF→JPY→EUR→CAD→USD
54	USD→GBP→CHF→JPY→EUR→NZD→USD
55	USD→GBP→CHF→JPY→CAD→USD
56	USD→GBP→CHF→JPY→CAD→EUR→NZD→USD
57	USD→GBP→CHF→JPY→NZD→USD
58	USD→GBP→CHF→JPY→NZD→EUR→CAD→USD
59	USD→CHF→EUR→JPY→USD
60	USD→CHF→EUR→JPY→CAD→USD
61	USD→CHF→EUR→JPY→NZD→USD
62	USD→CHF→EUR→CAD→USD
63	USD→CHF→EUR→CAD→JPY→USD
64	USD→CHF→EUR→CAD→JPY→NZD→USD
65	USD→CHF→EUR→NZD→USD
66	USD→CHF→EUR→NZD→JPY→USD
67	USD→CHF→EUR→NZD→JPY→CAD→USD
68	USD→CHF→GBP→EUR→JPY→USD
69	USD→CHF→GBP→EUR→JPY→CAD→USD
70	USD→CHF→GBP→EUR→JPY→NZD→USD
71	USD→CHF→GBP→EUR→CAD→USD
72	USD→CHF→GBP→EUR→CAD→JPY→USD
73	USD→CHF→GBP→EUR→CAD→JPY→NZD→USD
74	USD→CHF→GBP→EUR→NZD→USD
75	USD→CHF→GBP→EUR→NZD→JPY→USD
76	USD→CHF→GBP→EUR→NZD→JPY→CAD→USD
77	USD→CHF→JPY→USD
78	USD→CHF→JPY→EUR→CAD→USD
79	USD→CHF→JPY→EUR→NZD→USD
80	USD→CHF→JPY→CAD→USD
81	USD→CHF→JPY→CAD→EUR→NZD→USD
82	USD→CHF→JPY→NZD→USD
83	USD→CHF→JPY→NZD→EUR→CAD→USD
84	USD→JPY→EUR→CAD→USD
85	USD→JPY→EUR→NZD→USD
86	USD→JPY→CHF→EUR→CAD→USD
87	USD→JPY→CHF→EUR→NZD→USD
88	USD→JPY→CHF→GBP→EUR→CAD→USD
89	USD→JPY→CHF→GBP→EUR→NZD→USD
90	USD→JPY→CAD→USD

91	USD→JPY→CAD→EUR→NZD→USD
92	USD→JPY→NZD→USD
93	USD→JPY→NZD→EUR→CAD→USD
94	USD→CAD→EUR→GBP→CHF→JPY→NZD→USD
95	USD→CAD→EUR→CHF→JPY→NZD→USD
96	USD→CAD→EUR→JPY→NZD→USD
97	USD→CAD→EUR→NZD→USD
98	USD→CAD→JPY→EUR→NZD→USD
99	USD→CAD→JPY→CHF→EUR→NZD→USD
100	USD→CAD→JPY→CHF→GBP→EUR→NZD→USD
101	USD→CAD→JPY→NZD→USD
102	EUR→GBP→CHF→EUR
103	EUR→GBP→CHF→JPY→EUR
104	EUR→GBP→CHF→JPY→CAD→EUR
105	EUR→GBP→CHF→JPY→NZD→EUR
106	EUR→CHF→JPY→EUR
107	EUR→CHF→JPY→CAD→EUR
108	EUR→CHF→JPY→NZD→EUR
109	EUR→JPY→CAD→EUR
110	EUR→JPY→NZD→EUR
111	EUR→CAD→JPY→NZD→EUR

Note: This table only reports one of each bilateral arbitrage circles.