The Society for Economic Studies
The University of Kitakyushu
Working Paper Series No.2012-13
(accepted in March 25, 2013)

Re-evaluating the Tobin Tax
New evidence from tick-by-tick quotation data on twelve currency pairs

Hiroyuki Ono
Toyo University
hiroono@toyo.jp

Minoru Hayashida
The University of Kitakyushu
hayasida@kitakyu-u.ac.jp

Preliminary
Do Not Quote

Abstract

This paper attempts to reevaluate the Tobin Tax's capability to stabilize the foreign exchange market and to raise revenues, using tick-by-tick quotation data from twelve currencies with an ARFIMA model. The results are that the coefficients for the transaction costs are of the positive sign and highly significant in the model using exchange rate volatility as an objective variable across all currency pairs. However, the results for volume are mixed and do not form a clear picture, while the elasticity is less than unity in absolute value even in cases where negative and significant coefficients are obtained. These imply that the Tobin Tax would not contribute to market stability, but may be useful in raising revenues.

1. Introduction

More than three decades ago, James Tobin (1978) proposed taxing foreign exchange transactions; the proposal is now known as the Tobin Tax. The rationale for such a tax was twofold. First, by raising transaction costs, it would penalize so-called "noise traders," thereby stabilizing the currency market. Second, the tax would raise necessary revenues for international organizations, which are chronically in budgetary shortage. The tax could therefore promote various programs considered publicly beneficial across national borders, addressing matters such as global warming and development aid, carried out by the organizations. After its cool, if not antagonistic reception for more than a decade, Tobin's (1978) proposal has gradually gained serious attention among professional economists and policymakers, while remaining just an idea, rather than a policy option, and without igniting much enthusiasm to date[1].

In the face of very volatile and unpredictable foreign exchange markets, however, the Tobin Tax has received renewed interest in recent years. After the bankruptcy of Lehman Brothers, the US Dollar depreciated more than 17% against the Japanese Yen in just 4 months[2]. Less than a year and half later, the Euro started to depreciate against major currencies after Greece announced its budget problems. Within 6 months, the Euro depreciated 18.5% against the Japanese Yen and 15.8% against the US Dollar[3]. Further, after the great earthquake on March 11, 2011, while most people predicted that the Japanese Yen would *depreciate* against other currencies, it in fact *appreciated* 7.7% against the US Dollar and 8.2% against the Euro within 6 months.

In view of such developments in foreign exchange markets, in recent years several political leaders have openly talked about the Tobin Tax[4]. Some economists have echoed them[5], and the IMF has responded with a proposal for new taxes[6]. In Europe, real actions toward a financial transaction tax have been pushed forward.

---

[1] Tobin (1996) himself writes how his idea has been received since the proposal.

[2] The rate was 107.92 on September 12, 2008, and dropped to 89.13 on January 12, 2009 at the Tokyo market closing.

[3] The rates are from January 15 through June 30, 2011.
http://www.oanda.com/lang/ja/currency/historical-rates/

[4] Angela Merkel, Nicolas Sarközy and Gordon Brown reportedly mentioned it around the time of the G20 Summit meeting in Pittsburgh in 2009.

[5] For instance, economists from all over the United States co-signed "An Open Letter from Economists in Support of Financial Transaction Taxes", in December 2009, which was made public through the Center for Economic Policy Research

[6] The IMF published *Global Financial Stability Report: Meeting New Challenges to Stability and Building a Safer System* right before the G8 Summit meeting in Toronto in 2010.

According to the European Commission[7]:

> As from September 2012 the European Commission received requests of eleven Member States asking it to submit a proposal for a Council Decision to authorize enhanced cooperation. Its objectives and scope were requested to be based on the original Commission FTT proposal. The Commission's analysis provided a positive outcome. On 23 October 2012 the Commission proposed to the Council to authorize the enhanced cooperation in the area of financial transaction tax. The European Parliament gave its consent to the latter proposal on 12 December 2012 and on 22 January 2013 the EU Council adopted a decision authorizing eleven Member States to go ahead with enhanced cooperation on a common system of financial transaction tax (FTT).

Although the proposal does not cover currency transactions, it may lay some ground to cover them if actually made into law in those countries[8].

Since there has been no country that ever taxed currency transactions, rigorous empirical research on the Tobin Tax per se has been very limited; the research on the effects of transaction taxes is largely limited to the stock market. However, a few exceptions indicate a positive relationship between the transaction costs and volatility in the foreign exchange markets. Although not explicitly focusing on the transaction tax, a large volume of literature also offers some implications for currency transactions; most such studies suggest that the bid-ask spread as a proxy of transaction costs and measures of volatility are positively correlated; the evidence for the relationship between the spread and trading activities is mixed and remains unclear.

In view of this, the present paper reinvestigates whether the Tobin Tax, if implemented, would stabilize the market and raise necessary revenues, adding another clinical data point on these issues. To do so, the paper employs an Auto-Regressive Fractionally Integrated Moving Average (referred to as ARFIMA hereinafter) model, using high-frequency, tick-by-tick quotation data across twelve currency pairs. The main conclusions of the paper are that the tax would not contribute to stability; it would rather decrease it. However, the tax may contribute to the raising of revenue.

The rest of the paper is organized as follows. The next section reviews previous literature. Section 3 discusses data and methodology. Section 4 and 5 present estimation results for exchange rate volatility and trading activities, respectively. The final section concludes the paper, with summary, caveats, and venues for future

[7] Excerpt from the European Commission website:
http://ec.europa.eu/taxation_customs/taxation/other_taxes/financial_sector/index_en.htm

[8] These eleven countries are Belgium, Germany, Estonia, Greece, Spain, France, Italy, Austria, Portugal, Slovenia, and Slovakia.

extensions.

2. Literature Review

While the issue of whether a transaction tax enhances market stability has been largely explored in the context of stock trading[9], research focusing on transaction taxes in currency trading has been very scarce. Among the few exceptions, Aliber et al. (2003) examine the relationship between transaction costs measured by the average bid-ask spread, on the one hand, and volatility of exchange rate returns and trading volume, on the other. Using monthly data, constructed from daily futures data from January 1, 1977 to December 31, 1999, they find that volatility is positively associated, while trading volume is negatively associated, with the transaction costs for three major currencies — British Pound, Japanese Yen, and Swiss Franc — against the US Dollar[10].

Improving on some methodological issues in Aliber et al. (2003), Lanne and Vesala (2006) investigate the problem, using HFDF93 data on the German Mark and Japanese Yen against the US Dollar. First, having constructed daily realized variances, by computing the percentage differences of the logarithmic bid and ask prices closest to the end of five-minute intervals, they regress the variances on the transaction cost measures together with a one-period lagged objective variable, Friday dummy, and Holiday dummy. They found a positive correlation between the transaction cost and volatility of exchange rate returns for both currencies. Second, they use the five-minute returns *directly* and conduct the Flexible Fourier form (FFF) regressions [*e.g.* Gallant (1981, 1982), and Andersen and Bollerslev (1997)], and confirm the results above.

Away from the focus on the transaction tax, several other papers also have investigated the relationship between the bid-ask spread as a proxy of transaction costs and exchange rate volatility. Boothe (1988) finds evidence for a positive correlation between them for seven major currencies over the period 1980 to 1981. Bollerslev and Melvin (1994), using over 300,000 quotations in the Deutsche Mark / US Dollar interbank market, present evidence that the size of the bid-ask spread is positively related to the underlying exchange rate uncertainty. Bessembinder (1994) shows evidence that the spread and forecast return variance are positively

[9] There are numerous studies empirically examining the relationship between the transaction tax and stock return volatility. They include, to name a few, Umlauf (1993), Hu (1997), Hayashida and Ono (2010).

[10] They could not find the same relationship for the German Mark, however.

associated[11]. Defining volatility as the log first difference of the middle and closing rates, Hartmann (1999) finds a positive correlation between the spread and predicted return volatility for daily JPY/USD data from December 1989 to January 1995. In contrast to these studies, with data provided by EBS Co. Ltd, for JPY/USD and EUR/USD from 1 January 1999 to 31 December 2001, Ito and Hashimoto (2006) find a *negative* correlation between the spread and volatility, defined as average absolute one-minute change in the log of the midpoint, bid-ask quotes. However, using the same data but in lower frequency (15 minutes) intervals, Hua and Li (2011) estimated PGARCH models and found evidence that bid–ask spreads[12] are *positively* associated with exchange rate volatility for the JPY/USD rate[13].

On the relationship between the spread and trading activities, however, the empirical evidence is much more mixed, despite market microstructure theories' predicting a negative correlation. While Glassman (1987) finds a positive relationship, Bessembinder (1994) and Hartman (1999) show that the relationship is different, whether the volume is expected or not; the expected volume is negatively associated with the spread, while the reverse relationship is found for the unexpected volume. While Lyons (1995) reveals a positive correlation between the dealers' order size and the bid–ask spread, Ding (2007) finds that spreads are independent of order sizes in the inter-dealer market, but that they are negatively correlated in the customer market. Ito and Hashimoto (2006) find that the width of bid-ask spread is negatively correlated with the number of deals during business hours. Hua and Li (2011) also find a negative correlation of the width of bid-ask spread with the number of deals as well as the number of quotation changes.

All in all, the existing literature largely, if not unequivocally, suggests a positive correlation between the spread and volatility, but the evidence for trading activities remains unclear. This motivates the present paper. In comparison with these studies, the paper distinguishes itself in the following manners. First, it covers a wider range of currency exchange rates. Second, in view of a long memory property of the variables in question, the paper employs ARFIMA models. Third, the paper uses tick-by-tick quotation data recorded in the frequency of 1/100th of a second.

---

[11] The forecast return variance here is a one-step-ahead conditional return variance estimated from a GARCH(1,1) specification.

[12] Defined here to be the difference between the last quoted ask and bid in each interval, and thus different from Ito and Hashimoto's (2006) definition.

[13] Exchange rates are defined to be the (last) ask quotes in each interval, and their variances within each interval are used for the volatility measure.

3. Data and Methodology

3-1 Data

The data used in this study are on a tick-by-tick quotation basis, drawn from Thompson Reuters' *Tick History*©. There are eleven series for each pair of foreign exchanges in the data set on the GMT basis: price, volume, bid price, bid size, ask price, ask size, open, high, low, accumulated volume, and turnover. Among these, bid price, bid size, ask price, and ask size are recorded whenever new orders are made, while price, volume, and turnover are recorded every time deals are made, timed to 1/100th of a second. Accumulated volume is the sum of turnover of transactions made up to the point. Turnover is the product of the price and volume. Open is the opening price of the day. High and Low are the highest and lowest prices of the day up to the point. A sample for JPY/USD is shown in Table A-1 in the Appendix.

The data to analyze are the following twelve pairs of foreign exchange rates: (1) EUR/USD, (2) JPY/USD, (3) GBP/USD, (4) CHF/USD, (5) EUR/JPY, (6) EUR/GBP, (7) EUR/AUD, (8) EUR/CHF, (9) GBP/JPY, (10) AUD/JPY, (11) ZAR/JPY and (12) GBP/AUD[14]. There are roughly 140,000 data points for each of these pairs[15]. The period for the analysis is from April 25, 2010 to August 31, 2011.

To date, no country has ever taxed currency transactions, so there are no actual data for a transaction tax on currency exchange. However, it is an established practice to treat the bid-ask spread as a measure of transaction costs [*e.g.* Glassman (1987), Boothe (1988), and Lanne and Vesala (2006)], and to view it as a proxy for the transaction tax. The rationale behind this is that, once the tax is levied, traders would include the amount to be taxed away in bid and ask prices when offering them; so, the bid-ask spread would increase when the tax is imposed. We employ this strategy. More specifically, the transaction cost, referred to as COST, is defined as:

$$\mathrm{COST} = \frac{ASK - BID}{ASK + BID}$$

Here, ASK and BID refer to the arithmetic means of quoted ask and bid prices in each five-minute interval, respectively. The volatility measure, referred to as VOL,

---

[14] The abbreviation for each currency is as follows. USD: the United States Dollar, EUR: Euro, JPY: the Japanese Yen, GBP: the Great Britain Pound, CHF: Swiss Franc, AUD: the Australian Dollar, and ZAR: the South African Rand.

[15] In executing ARFIMA estimations, we delete missing data, i.e. intervals in which there is no observation of at least one of these four variables; therefore, the total number of observations used in the actual estimation is smaller.

is the standard deviation of prices within the five-minute intervals[16]. The data on volume itself is used and summed over the same five-minute intervals. It is referred to as TO.

Descriptive statistics are presented in Table 1 below. Together, the results of the unit root (ADF) tests are presented. For all of the twelve pairs, VOL, COST, and TO are stationary.

Table 1: Descriptive Statistics

	(1) EUR/USD			(2) JPY/USD			(3) GBP/USD			(4) CHF/USD		
	VOL	SPREAD	TO	VOL	SPREAD	TO	VOL	SPREAD	TO	VOL	SPREAD	TO
Mean	0.000228	0.000142	7.765375	0.013001	0.014463	12.22432	0.000263	0.000247	5.397821	0.000223	0.000273	4.948259
Median	0.000196	0.00014	4.428571	0.01077	0.013893	8.444444	0.000212	0.000239	2	0.000173	0.00026	2
Maximum	0.004809	0.001233	500	0.424939	0.23686	502	0.003114	0.002667	300.3333	0.004738	0.005575	500
Minimum	0	−0.00026	1	0	−0.024273	1	0	−0.000313	1	0	−0.0000809	1
SD	0.000166	0.0000374	14.75503	0.009423	0.004408	15.61478	0.000219	0.0000715	12.75667	0.00022	0.0000868	11.03716
ADF	−41.4763	−30.32089	−38.4352	−34.5766	−24.90011	−55.5144	−121.923	−28.46215	179.4821	−72.9373	−33.34474	−130.811
lag	9	27	14	18	22	17	0	25	0	0	25	0
P-value	0	0	0	0	0	0.0001	0.0001	0	0.0001	0.0001	0	0.0001

	(5) EUR/JPY			(6) EUR/GBP			(7) EUR/CHF			(8) EUR/AUD		
	VOL	SPREAD	TO	VOL	SPREAD	TO	VOL	SPREAD	TO	VOL	SPREAD	TO
Mean	0.024358	0.023552	8.854247	0.000158	0.000179	4.992337	0.000326	0.000334	4.700905	0.000255	0.000257	5.491593
Median	0.020226	0.022816	6.494426	0.000141	0.000173	1	0.000252	0.000321	1.690476	0.000207	0.000235	1.571429
Maximum	0.593169	0.300952	536.3333	0.002748	0.001741	400	0.006904	0.0041	300	0.00512	0.005234	550
Minimum	0	−0.034089	1	0	−0.0000627	1	0	−0.000137	1	0	−0.000112	1
SD	0.016932	0.006754	10.46026	0.000162	0.0000491	15.69498	0.000341	0.000105	10.5778	0.000267	0.0001	13.19215
ADF	−29.5156	−19.36188	−58.4789	−3.48694	−32.13199	−84.6066	−53.7253	−35.73439	−34.6322	−58.0225	−13.68827	−101.985
lag	18	33	15	2	20	0	0	21	2	0	36	0
P-value	0	0	0.0001	0.009	0	0.0001	0.0001	0	0	0.0001	0	0.0001

	(9) JPY/GBP			(10) JPY/AUD			(11) JPY/ZAR			(12) GBP/AUD		
	VOL	SPREAD	TO	VOL	SPREAD	TO	VOL	SPREAD	TO	VOL	SPREAD	TO
Mean	0.028519	0.032722	7.741521	0.02081	0.022182	10.10834	0.00643	0.017729	4.25709	0.000338	0.000431	3.967701
Median	0.024133	0.031506	5.433333	0.017187	0.021475	7.75	0.006124	0.015983	2.230769	0.000265	0.000381	1
Maximum	0.782366	0.537027	500	0.546718	0.471613	261.5	0.132952	0.235	210	0.005508	0.007842	290
Minimum	0	−0.019401	1	0	−0.026091	1	0	−0.006335	1	0	−0.0000749	1
SD	0.019518	0.010272	10.21529	0.014034	0.007288	9.074758	0.005184	0.008221	6.314362	0.000353	0.000158	10.35992
ADF	−17.1669	−38.47533	−68.1296	−12.863	−35.84689	−27.1738	−21.3316	−40.74617	−100.739	−0.35819	−18.28017	−102.075
lag	35	17	11	59	19	36	9	15	3	14	27	0
P-value	0	0	0.0001	0	0	0	0	0	0.0001	0.8962	0	

3-2 Methodology

It is well known that volatility has a long memory. In such cases, ARFIMA models are now widely used. ARFIMA(p,d,q) is in general defined to be:

$$\Phi(L)(1-L)^d(y_t-\mu)=\mathrm{H}(L)u_t,$$
$$u_t \sim WN(0,\sigma_u^2)$$

where $\Phi(L)$ and $\mathrm{H}(L)$ are polynomial equations of lag operator L with dimensions p and q respectively, and absolute values of roots of characteristic equations are larger than 1. $WN(0,\sigma_u^2)$ is white noise with mean zero variance σ_u^2, and d is a difference parameter to take fractional values. Note that

$$(1-L)^d=1+\sum_{k=1}^{\infty}\frac{d(d-1)\cdots(d-k+1)}{k!}(-L)^k.$$

[16] There is a period of roughly 10 minutes where there are no data for every date.

If $0 < d < \frac{1}{2}$, y_t has a long memory; if $d < \frac{1}{2}$, y_t is stationary; and if $d > -\frac{1}{2}$, y_t is invertible.

As shown in Table A-2 in the Appendix, both VOL and TO exhibit a long memory property for all twelve pairs, justifying the use of the ARFIMA model. In the analyses below, we set p = q = 0 as a first approximation for the current paper. For the exchange rate volatility as an objective variable, we estimate two models: one with constant and transaction cost only (Model 1) as explanatory variables, and one with volume and linear time trend in addition (Model 2). For the turnover as an objective variable, Model 1 is the same, but Model 2 only adds linear time trend.

4. Transaction Costs and Exchange Rate Volatility

It is shown in Table 2 that, across twelve currency pairs, the estimated coefficients of COST are of the positive sign and highly significant; the P-values are less than 1% in all cases. The d-parameter falls between 0 and 1/2, confirming the stationary property in Table 1. This is true for both Model 1 and Model 2. This implies, in line with much of the literature, that transaction cost increases with exchange rate volatility.

Table 2: Transaction Costs and Exchange Rate Volatility

	EUR/USD		JPY/USD		GBP/USD		CHF/USD		EUR/JPY		EUR/GBP	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
d-parameter	0.124519	0.124014	0.122879	0.122348	0.115281	0.114222	0.150552	0.150153	0.112684	0.112708	0.10015	0.100703
	0.0000	0	0	0	0	0	0	0	0	0	0	0
constant	8.08026	7.26012	10.4632	9.5796	5.81804	6.77606	5.35494	4.75675	8.85389	9.01562	6.20727	6.03434
	0	0	0	0	0	0	0	0	0	0	0	0
COST	-4110.4	-3945.7	20809.1	21009.1	-4090.67	-6054.27	-1005.5	-1625.58	-317.633	-384.939	-5647.58	-5338.78
	0.394	0.414	0	0	0.29	0.123	0.635	0.449	0.857	0.827	0.447	0.478
Time trend	-	21.0754	-	18.1124	-	-47.4541	-	73.7516	-	-3.2401	-	38.4688
		0.003		0.002		0.004		0.099		0.354		0.818
log likelihood	-309576	-309569	-395415	-395408	-130931	-130924	-68693.2	-68688	-355211	-355210	-30663.1	-30658
number of observations	77,048	77,048	95,681	95,681	34,245	34,245	18,674	18,674	95,574	95,574	7,450	7,450
number of parameters	4	5	4	5	4	5	4	5	4	5	4	5
AIC.T	619159.2	619148.5	790837.7	790826.5	261,869	261857.5	137394.3	137386	710430.9	710429.5	61334.21	61325.92
AIC	8.036019	8.035881	8.265358	8.265241	7.646931	7.646591	7.357518	7.357074	7.433307	7.433292	8.23278	8.231667
σ	13.4528	13.4521	15.087	12.2347	11.0759	11.0748	9.5854	9.58496	9.95213	9.95213	14.8625	14.8635

	EUR/AUD		EUR/CHF		GBP/JPY		AUD/JPY		ZAR/JPY		GBP/AUD	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
d-parameter	0.206385	0.204575	0.122178	0.118368	0.110482	0.108007	0.139564	0.138198	0.086363	0.086452	0.125867	0.125147
	0.0000	0	0	0	0	0	0	0	0	0	0	0
constant	6.57537	8.77874	5.31255	4.24554	8.14308	9.35164	9.34218	8.29412	4.11262	4.08328	4.01964	3.33406
	0.00000	0	0	0	0	0	0	0	0	0	0	0
COST	-7205.28	-7606.27	668.175	-1172.67	-3027.97	-3867	5056.46	5547.3	589.928	591.864	477.011	755.820
	0.061	0.048	0.774	0.623	0.029	0.005	0	0	0	0	0.821	0.721
Time trend	-	-279.394	-	233.392	-	-23.6444	-	20.3996	-	0.979209	-	112.06
		0.01		0.001		0		0		0.77		0.07
log likelihood	-60268.3	-60260.4	-41828.4	-41818.8	-347315	-347291	-345263	-345248	-182297	-182296	-41454.7	-41448.9
number of observations	15,499		11,352	11,352	93,577	93,577	96,423	96,423	57,021	57,021	11,621	11,621
number of parameters	4	5	4	5	4	5	4	5	4	5	4	5
AIC.T	120544.6	120530.7	83664.88	83647.6	694638.3	694591.6	690533.5	690505.8	364602.5	364602	82917.32	82907.8
AIC	7.777574	7.776677	7.370056	7.368534	7.423173	7.422675	7.161502	7.161215	6.394179	6.39417	7.135128	7.134309
σ	11.828	11.8258	9.64835	9.64416	9.90181	9.89942	8.68742	8.68625	5.91916	5.9192	8.57859	8.57775

(Note) The lower entries for the d-parameter, a constant, COST and time trend are P-values associated with the estimated coefficients in the upper entry.

It is worth investigating whether the above results remained the same before the earthquake on March 11, 2011. As mentioned earlier, most people predicted the Japanese Yen would depreciate against major currencies in the aftermath of the earthquake, but in fact it appreciated. This may suggest some anomaly in the movement of exchange rates involving the Japanese Yen after the earthquake. Therefore, for those exchange rates, the models are also estimated with the sample before March 11. The results are shown in Table 3. There is not much difference between the results in Table 2 and Table 3. Therefore, the above conclusion holds: an increase in transaction costs would increase exchange rate volatility.

Table 3: Transaction Costs and Exchange Rate Volatility

(Currency Pairs involving the Japanese Yen before March 11, 2011)

	JPY/USD		EUR/JPY		GBP/JPY		AUD/JPY		ZAR/JPY	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
d-parameter	0.314969	0.313336	0.308407	0.305391	0.296391	0.292497	0.309902	0.306086	0.145196	0.137234
	0	0	0	0	0	0	0	0	0	0
constant	0.009213	0.012551	0.018197	0.027557	0.019845	0.030794	0.014197	0.022207	0.000336	0.001504
	0	0	0	0	0	0	0	0	0	0
COST	49.7461	48.5993	63.0378	62.7098	82.6266	82.6995	49.7217	48.8741	8.45726	8.38003
	0	0	0	0	0	0	0	0	0	0
TO	-	69.2319	-	107.127	-	92.7279	-	150.467	-	31.3916
		0		0		0		0		
Time trend	-	-0.13135	-	-0.33199	-	-0.38598	-	-0.30159	-	-0.07338
		0		0		0		0		0
log likelihood	216150.8	216812.9	180829	181082.4	166890.8	167038.2	196463.8	197033	136627	136691.7
number of observations	62,114	62,114	61,923	61,923	60,759	60,759	62,601	62,601	34,332	34,332
number of parameters	4	6	4	6	4	6	4	6	4	6
AIC.T	-432294	-433614	-361650	-362153	-333774	-334064	-392920	-394054	-273246	-273371
AIC	-6.95968	-6.98093	-5.84032	-5.84844	-5.4934	-5.49819	-6.27657	-6.29469	-7.95893	-7.96258
σ	0.007453	0.007374	0.013045	0.012991	0.015515	0.029605	0.010488	0.010393	0.00452	0.004512

(Notes) See the notes in Table 2.

As mentioned before, the tax on transactions would increase the bid-ask spread, as traders would include the amount to be taxed away in bid and ask prices when proposing them. In so much as it is true, the above results imply that the Tobin Tax would increase, not decrease, the foreign exchange volatility.

5. Transaction Cost and Trading Volume

The results in the previous section suggest that the Tobin Tax, raising transaction costs, would not contribute to the stability of foreign exchange rates, as Tobin (1978) and his proponents expected. That does not mean that the tax is useless, however, because another case for the tax is that it may raise revenue to be used for various international programs, such as global warming or development aid. Whether the tax is a good revenue source is the subject of this section.

To examine that, an ARFIMA model is estimated as before, because TO also exhibits a long memory, as Table A-2 in the Appendix shows. The results are reported in Table X. As is the case with previous studies, the results are mixed, and show no clear-cut picture. The estimated coefficients for COST are: negative and significant for EUR/AUD and GBP/JPY, positive and significant for JPY/USD, AUD/JPY, and ZAR/JPY, and insignificant for the other seven currency pairs. It is difficult to draw any conclusive statements from these results.

Table 4: Transaction Costs and Trading Volume

	EUR/USD		JPY/USD		GBP/USD		CHF/USD		EUR/JPY		EUR/GBP	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
d-parameter	0.124519	0.124014	0.122879	0.122348	0.115281	0.114222	0.150552	0.150153	0.112684	0.112708	0.10015	0.100703
	0.0000	0	0	0	0	0	0	0	0	0	0	0
constant	8.08026	7.26012	10.4632	9.5796	5.81804	6.77606	5.35494	4.75675	8.85389	9.01562	6.20727	6.03434
	0	0	0	0	0	0	0	0	0	0	0	0
COST	-4110.4	-3945.7	20809.1	21009.1	-4090.67	-6054.27	-1005.5	-1625.58	-317.633	-384.939	-5647.58	-5338.78
	0.394	0.414	0	0	0.29	0.123	0.635	0.449	0.857	0.827	0.447	0.478
Time trend	-	21.0754	-	18.1124	-	-47.4541	-	73.7516	-	-3.2401	-	38.4688
		0.003		0.002		0.004		0.099		0.354		0.818
log likelihood	-309576	-309569	-395415	-395408	-130931	-130924	-68693.2	-68688	-355211	-355210	-30663.1	-30658
number of observations	77,048	77,048	95,681	95,681	34,245	34,245	18,674	18,674	95,574	95,574	7,450	7,450
number of parameters	4	5	4	5	4	5	4	5	4	5	4	5
AIC.T	619159.2	619148.5	790837.7	790826.5	261,869	261857.5	137394.3	137386	710430.9	710429.5	61334.21	61325.92
AIC	8.036019	8.035881	8.265358	8.265241	7.646931	7.646591	7.357518	7.357074	7.433307	7.433292	8.23278	8.231667
σ	13.4528	13.4521	15.087	12.2347	11.0759	11.0748	9.5854	9.58496	9.95213	9.95213	14.8625	14.8635

	EUR/AUD		EUR/CHF		GBP/JPY		AUD/JPY		ZAR/JPY		GBP/AUD	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
d-parameter	0.206385	0.204575	0.122178	0.118368	0.110482	0.108007	0.139564	0.138198	0.086363	0.086452	0.125867	0.125147
	0.0000	0	0	0	0	0	0	0	0	0	0	0
constant	6.57537	8.77874	5.31255	4.24554	8.14308	9.35164	9.34218	8.29412	4.11262	4.08328	4.01964	3.33406
	0.00000	0	0	0	0	0	0	0	0	0	0	0
COST	-7205.28	-7606.27	668.175	-1172.67	-3027.97	-3867	5056.46	5547.3	589.928	591.864	477.011	755.820
	0.061	0.048	0.774	0.623	0.029	0.005	0	0	0	0	0.821	0.721
Time trend	-	-279.394	-	233.392	-	-23.6444	-	20.3996	-	0.979209	-	112.06
		0.01		0.001		0		0		0.77		0.07
log likelihood	-60268.3	-60260.4	-41828.4	-41818.8	-347315	-347291	-345263	-345248	-182297	-182296	-41454.7	-41448.9
number of observations	15,499		11,352	11,352	93,577	93,577	96,423	96,423	57,021	57,021	11,621	11,621
number of parameters	4	5	4	5	4	5	4	5	4	5	4	5
AIC.T	120544.6	120530.7	83664.88	83647.6	694638.3	694591.6	690533.5	690505.8	364602.5	364602	82917.32	82907.8
AIC	7.777574	7.776677	7.370056	7.368534	7.423173	7.422675	7.161502	7.161215	6.394179	6.39417	7.135128	7.134309
σ	11.828	11.8258	9.64835	9.64416	9.90181	9.89942	8.68742	8.68625	5.91916	5.9192	8.57859	8.57775

(Note) The lower entries for the d-parameter, a constant, COST and time trend are P-values associated with the estimated coefficients in the upper entry.

It should be reminded that the period after March 11, 2011 could be anomalous for the Japanese Yen. That may be seen in that the coefficient is positive and significant for three out of five pairs involving the currency, despite the microstructure literature expectation of a negative relation. So it is worth investigating, as before, excluding data after the earthquake. The results are shown in Table 5. There is not much difference between the results in Table 4 and Table 5.

Therefore, the above conclusion holds: no conclusive statements are drawn[17].

Table 5: Transaction Costs and Trading Volume

(Currency Pairs involving the Japanese Yen before March 11, 2011)

	JPY/USD		EUR/JPY		GBP/JPY		AUD/JPY		ZAR/JPY	
	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2	Model 1	Model 2
d-parameter	0.135977	0.135391	0.110843	0.110867	0.117768	0.117041	0.135642	0.125791	0.0843	0.081919
	0	0	0	0	0	0	0	0	0	0
constant	10.989	9.99619	8.98121	8.78533	8.55316	9.28552	9.62415	6.90221	4.23558	3.69748
	0	0	0	0	0	0	0	0	0	0
COST	12743.1	12922.8	-1167.24	-1033.42	-3359.34	-3823.17	3351.88	4370.18	517.408	570.413
	0	0	0.603	0.646	0.07	0.039	0.011	0	0	0
Time trend	-	31.4625	-	5.88039	-	-22.2106	-	82.1057	-	29.072
		0.009		0.367		0.002		0		0
log likelihood	-257373	-257367	-232382	-232380	-229116	-229110	-226082	-226006	-111084	-111074
number of observations	62,114	62,114	61,923	61,923	60,759	60,759	62,601	62,601	34,332	34,332
number of parameters	4	5	4	5	4	5	4	5	4	5
AIC.T	514754.2	514744.4	464772.1	464769.5	458240.8	458229.5	452171.7	452021.3	222176.7	222157.3
AIC	8.287249	8.287092	7.505645	7.505604	7.541942	7.541756	7.223075	7.220673	6.471418	6.470853
σ	15.2539	15.2532	10.3192	10.3192	10.5082	10.5074	8.95941	8.94883	6.15249	6.15101

(Notes) See the notes in Table 4

Taken at face value, the above results imply that, since an increase in transaction costs through a transaction tax does not reduce the trading volume, the tax would certainly raise revenues for the 10 cases, except for EUR/AUD and GBP/YEN. It is of interest, in these two cases where the negative and significant coefficients are estimated, to calculate the tax elasticity of trading volume. Even if the coefficient is negative and significant, the tax may be a good revenue source if elasticity is less than unity in the absolute value. Here, because the transaction cost is approximated by the spread, our linear elasticity measure, η, is defined:

$$\eta = \frac{(VO_t - VO_{t-1})/VO_{t-1}}{(SPREAD_t - SPREAD_{t-1})/SPREAD_{t-1}} = \frac{Y_t}{X_t}$$

Here, $Y_t \equiv (VO_t - VO_{t-1})/VO_t$ and $X_t \equiv (SPREAD_t - SPREAD_{t-1})/SPREAD_t$. The estimate for η is obtained by regressing Y on X with a constant.

The results are the following:

[EUR/AUD]

$$\hat{Y}_t = 1.709699 \quad - 0.302522\, X_t$$

(0.0000) (0.1864)

N=18,705 R^2=0.000040

[GBP/JPY]

$$\hat{Y}_t = 0.750683 \quad - 0.030664\, X_t$$

(0.0000) (0.1436)

[17] The reasons for these mixed results would require further scrutiny, but are left for future investigations.

$N=94{,}423 \qquad R^2=0.000012$

The figures in the parenthesis are the P values associated with the estimated coefficients above them. In both cases, the estimated η is of the negative sign and less than unity in absolute value. This implies that, even in these two cases where the transaction costs are negatively correlated with trading volume, the transaction tax would still be a useful vehicle for raising revenues.

6. Concluding remarks

This paper investigates whether the Tobin Tax would contribute to the stability of foreign exchange markets and would be capable of raising revenues. The data used are tick-by-tick quotation data for 12 currency pairs drawn from Thompson Reuters' *Tick History* © for the period from April 25, 2010 to August 31, 2011. Since the Tobin Tax would increase transaction costs, which are approximated by the average bid-ask spread over five-minute intervals, average bid-ask spread serves as our "hypothetical" rate of the Tobin Tax. The market stability is measured by standard deviation of deal prices over the same intervals. Given that both the stability measure and the average of the deal volumes in the same intervals exhibit a long-memory property, the paper employs ARFIMA models.

The results are that coefficients for the transaction costs are positive and highly significant unanimously in the models with the stability measure as an objective variable. This would imply that the Tobin Tax would damage market stability, rather than ameliorate it. However, in the models with trading volumes as an objective variable, the results do not show any uniform tendency one way or the other: out of 12 cases, the coefficients for the transaction costs are negative and significant for 2 cases, positive and significant for 3 cases, and insignificant for 7 cases. If the tax would not affect or increase the trading volume, it would raise revenues, but if the tax decreases the volume, the degree to which it does so matters. If elasticity is greater than unity in absolute value, the tax revenue, which is the product of the tax rate and volume, would not be raised. In the two cases where the coefficients were negative and significant, the elasticity is calculated to be less than unity in absolute value. Therefore, taking these results at face value, they imply that the Tobin Tax would be useful in raising revenues, even if it does not contribute to stability.

In concluding the paper, it is worth mentioning some caveats and future extensions. This paper defines the stability of the market as that of the price *level* and examines the volatility of deal prices, but a number of studies examine the volatility of price *return*. To see the robustness of the present results, it may be useful to examine return volatility as well. Also, the paper takes deal volume as an indicator for market activity, but the number of deals within the five-minute interval and other related variables, subject to availability, are worth investigating. This paper use five minutes as a frequency of estimation, but it may be interesting to examine how the results change when the frequency is altered to, say, one minute or thirty minutes. Further, if the twelve foreign exchange markets under study should be viewed as closely interrelated, estimating them independently may be inappropriate; the Seemingly Unrelated Estimation (SURE) may be necessary to obtain efficient estimates. These are all interesting topics to explore, but are left to future investigations.

References

Aliber, R. Z., Chaodhry, B. and Yan S. (2003) Some evidence that a Tobin tax on foreign exchange transactions may increase volatility, *European Finance Review*, 7, 481-510.

Andersen, T. G. and Bollerslev, T. (1997) Intraday periodicity and volatility persistence in financial markets, *Journal of Empirical Finance*, 4, 115–158.

Bessembinder, H. (1994) Bid–ask spreads in the interbank foreign exchange markets, Journal of Financial Economics, 35, 317–48.

Bollerslev, T. and Melvin, M. (1994) Bid–ask spreads and volatility in the foreign exchange market: an empirical analysis, *Journal of International Economics*, 36, 355–72.

Boothe, P. (1988) Exchange rate risk and the bid–ask spread: a seven country comparison, *Economic Inquiry*, 26, 485–92.

Ding, L. (2007) Bid–ask spread and order size in the foreign exchange market: an empirical investigation, Working Paper, Macalester College, St. Paul, MN.

Glassman, D. (1987) Exchange rate risk and transaction costs: evidence from bid–ask spreads, *Journal of International Money and Finance*, 6, 481–90.

Gallant, A. R. (1981) On the basis in flexible functional forms and an essentially unbiased form: the Fourier flexible form, *Journal of Econometrics*, 15, 211-245.

Gallant, A. R. (1982) Unbiased determination of production technologies, *Journal of Econometrics*, 20, 285-323.

Hayashida, M, and Ono, H. (2010) Tax reform and stock return volatility: the case of Japan, *The Society of Economic Studies Working Paper Series,* No. 2010-1, the University of Kitakyushu.

Hartmann, P. (1999) Trading volumes and transaction costs in the foreign exchange market: evidence from daily dollar–yen spot data, *Journal of Banking and Finance*, 23, 801–24.

Hu, S. Y. (1998). The effects of the stock transaction tax on the stock market: experiences from Asian markets. *Pacific Basin Finance Journal*, 6, 347-364.

Hua, M. and Li, C.Y. (2011) The intraday bid-ask spread behavior of the JPY/USD exchange rate in the EBS electronic brokerage system, *Applied Economics*, 43, 2003-2013.

Ito, T. and Hashimoto, Y. (2006) Intraday seasonality in activities of the foreign exchange markets: evidence from the electronic broking system, *Journal of the Japanese and International Economies*, 20, 637–64.

Lanne, M, and Vesala, T. (2006) The effect of a transaction tax on exchange rate volatility, *Bank of Finland Research Discussion Papers,* 11, 2006.

Lyons, R. K. (1995) Tests of microstructural hypotheses in the foreign exchange market, Journal of Financial Economics, 39, 321–51.

Tobin, J. (1978) A proposal for international monetary reform, *Eastern Economic Journal*, 4, 153-159.

Tobin, J. (1996) Prologue, in Haq, M, Kaul, I. and Grunberg, I. eds: *The Tobin tax: coping with financial volatility*, Oxford University Press.

Umlauf, S. R. (1993) Transaction taxes and the behavior of the Swedish stock market, *Journal of Financial Economics*, 33, 227-240.

APPENDIX

Table A-1: Sample of the original data

	_RIC	Date_G_	Price	Volume	Bid_Price	Bid_Size	Ask_Price	Ask_Size	Open	High	Low	Acc_Volume	Turnover
2545977	JPY=TF	[illegible]			87.72	2790	87.73	1090					
2545978	JPY=TF	[illegible]				2290		1590					
2545979	JPY=TF	[illegible]				1290		2590					
2545980	JPY=TF	[illegible]				1289							
2545981	JPY=TF	[illegible]			87.71	3290	87.72	949					
2545982	JPY=TF	[illegible]	87.72	1					87.79	88.22	87.30	74970	6578556.78
2545983	JPY=TF	[illegible]	87.72	51					87.79	88.22	87.30	75021	[illegible]
2545984	JPY=TF	[illegible]				4790	87.73	4190					
2545985	JPY=TF	[illegible]						2390					
2545986	JPY=TF	[illegible]			87.72	1490		1590					
2545987	JPY=TF	[illegible]				2790							
2545988	JPY=TF	[illegible]			87.71		87.72	949					
2545989	JPY=TF	[illegible]						946					
2545990	JPY=TF	[illegible]	87.72	1					87.79	88.22	87.30	75022	6583121.22
2545991	JPY=TF	[illegible]				2690	87.73	4440					
2545992	JPY=TF	[illegible]						4740					
2545993	JPY=TF	[illegible]				4390		4440					
2545994	JPY=TF	[illegible]				2690		4740					
2545995	JPY=TF	[illegible]				2590	87.72	590					
2545996	JPY=TF	[illegible]			87.72	390	87.73	2440					
2545997	JPY=TF	[illegible]				2790	87.74	4440					
2545998	JPY=TF	[illegible]	87.71	1					87.79	88.22	87.30	75023	[illegible]
2545999	JPY=TF	[illegible]				4390							
2546000	JPY=TF	[illegible]				2690	87.73	946					
2546001	JPY=TF	[illegible]				1690		1940					
2546002	JPY=TF	[illegible]				4590	87.74	4440					
2546003	JPY=TF	[illegible]				4299		3940					
2546004	JPY=TF	[illegible]	87.72	1					87.79	88.22	87.30	75024	[illegible]
2546005	JPY=TF	[illegible]						2440					
2546006	JPY=TF	[illegible]				3299		4240					
2546007	JPY=TF	[illegible]				4299		2940					
2546008	JPY=TF	[illegible]			87.73	1090		3240					
2546009	JPY=TF	[illegible]			87.72	2799		4740					
2546010	JPY=TF	[illegible]				2690							
2546011	JPY=TF	[illegible]				4299		3240					
2546012	JPY=TF	[illegible]	87.72	1					87.79	88.22	87.30	75025	[illegible]

Table A-2: Long memory property of VOL and TO

	(1) EUR/USD								(2) JPY/USD							
	VOL				VO				VOL				VO			
	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.338	0.338	8794.2	0	0.097	0.097	807.79	0	0.504	0.504	24303	0	0.14	0.14	1880.3	0
2	0.293	0.202	15410	0	0.088	0.079	1469.7	0	0.407	0.205	40124	0	0.076	0.058	2440.5	0
3	0.269	0.143	20974	0	0.056	0.041	1737.5	0	0.371	0.147	53327	0	0.059	0.042	2779.4	0
4	0.251	0.108	25822	0	0.072	0.058	2189.2	0	0.347	0.108	64822	0	0.048	0.032	3005.8	0
5	0.24	0.09	30268	0	0.054	0.036	2444.7	0	0.325	0.081	74926	0	0.042	0.026	3173.9	0
6	0.225	0.067	34159	0	0.055	0.036	2701.3	0	0.317	0.078	84548	0	0.037	0.022	3309.4	0
7	0.208	0.049	37495	0	0.054	0.035	2951.6	0	0.305	0.061	93456	0	0.035	0.02	3426	0
8	0.205	0.051	40726	0	0.042	0.021	3101.9	0	0.292	0.049	101638	0	0.03	0.016	3513	0
9	0.198	0.044	43735	0	0.06	0.041	3414.6	0	0.276	0.034	108947	0	0.029	0.015	3591.8	0
10	0.188	0.034	46446	0	0.047	0.025	3607.6	0	0.276	0.047	116247	0	0.026	0.013	3657.4	0
11	0.175	0.023	48808	0	0.035	0.012	3715.6	0	0.269	0.037	123191	0	0.031	0.019	3748.5	0
12	0.177	0.033	51219	0	0.04	0.02	3852.1	0	0.263	0.033	129791	0	0.026	0.012	3812.6	0
13	0.166	0.021	53345	0	0.044	0.023	4016.1	0	0.251	0.021	135829	0	0.029	0.017	3894.2	0
14	0.159	0.018	55294	0	0.052	0.031	4248	0	0.242	0.019	141442	0	0.031	0.018	3987.6	0
15	0.158	0.023	57229	0	0.051	0.029	4475.1	0	0.24	0.025	146947	0	0.028	0.014	4064.1	0
16	0.152	0.018	59019	0	0.04	0.016	4616.6	0	0.236	0.023	152276	0	0.025	0.011	4123.6	0
17	0.148	0.016	60708	0	0.036	0.013	4729.6	0	0.233	0.023	157470	0	0.029	0.016	4206.8	0
18	0.145	0.016	62324	0	0.042	0.019	4880.5	0	0.236	0.03	162794	0	0.028	0.014	4284.9	0
19	0.138	0.011	63793	0	0.038	0.014	5004.9	0	0.232	0.022	167935	0	0.022	0.007	4329.5	0
20	0.132	0.008	65128	0	0.037	0.014	5120.9	0	0.221	0.01	172609	0	0.028	0.015	4404.7	0
21	0.134	0.016	66506	0	0.024	0.001	5170.3	0	0.218	0.016	177166	0	0.025	0.011	4463.4	0
22	0.126	0.007	67726	0	0.036	0.015	5281	0	0.216	0.017	181650	0	0.019	0.005	4496.5	0
23	0.122	0.007	68868	0	0.033	0.012	5374.9	0	0.211	0.012	185924	0	0.021	0.009	4538.5	0
24	0.117	0.006	69932	0	0.034	0.012	5474.9	0	0.206	0.01	190000	0	0.02	0.008	4578.9	0
25	0.115	0.007	70944	0	0.026	0.005	5533.6	0	0.2	0.006	193821	0	0.023	0.011	4630.5	0
26	0.111	0.006	71902	0	0.032	0.012	5622.3	0	0.198	0.01	197555	0	0.021	0.008	4673	0
27	0.112	0.01	72869	0	0.025	0.004	5676.8	0	0.199	0.017	201360	0	0.015	0.002	4694.8	0
28	0.105	0.004	73724	0	0.028	0.008	5746.3	0	0.201	0.019	205238	0	0.021	0.01	4738.7	0
29	0.102	0.004	74532	0	0.021	0.001	5783.1	0	0.195	0.008	208886	0	0.012	-0.001	4751.8	0
30	0.098	0.002	75274	0	0.024	0.005	5831.6	0	0.196	0.015	212564	0	0.017	0.007	4778.2	0
31	0.095	0.003	75977	0	0.026	0.008	5890.1	0	0.191	0.008	216057	0	0.018	0.007	4808.4	0
32	0.093	0.004	76645	0	0.025	0.006	5943.4	0	0.184	0.003	219303	0	0.016	0.005	4832.1	0
33	0.091	0.003	77277	0	0.027	0.009	6005.6	0	0.18	0.004	222411	0	0.015	0.005	4855.1	0
34	0.086	0.001	77847	0	0.026	0.008	6064	0	0.182	0.011	225580	0	0.011	0.001	4867.2	0
35	0.083	0.001	78383	0	0.021	0.003	6102.3	0	0.179	0.007	228639	0	0.015	0.005	4887.5	0
36	0.087	0.009	78965	0	0.014	-0.004	6118.7	0	0.181	0.014	231783	0	0.013	0.004	4905	0

	(3) GBP/USD								(4) CHF/USD							
	VOL				VO				VOL				VO			
	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.134	0.134	614.21	0	0.076	0.076	323.5	0	0.196	0.196	714.17	0	0.041	0.041	65.969	0
2	0.106	0.09	1000.7	0	0.055	0.049	493.19	0	0.115	0.08	962	0	0.066	0.065	234.12	0
3	0.081	0.058	1227.7	0	0.037	0.029	568.78	0	0.109	0.076	1185.3	0	0.021	0.016	251.79	0
4	0.068	0.044	1387.8	0	0.037	0.03	646	0	0.105	0.067	1390.9	0	0.046	0.041	334.65	0
5	0.059	0.034	1505.1	0	0.033	0.025	706.88	0	0.082	0.039	1516.1	0	0.023	0.018	355.63	0
6	0.057	0.033	1615.9	0	0.024	0.016	738.92	0	0.068	0.029	1602.7	0	0.015	0.008	364.44	0
7	0.055	0.031	1719.7	0	0.027	0.02	779.73	0	0.073	0.037	1701.7	0	0.009	0.004	367.57	0
8	0.05	0.025	1804.3	0	0.023	0.015	808.75	0	0.075	0.037	1806	0	0.017	0.013	378.74	0
9	0.048	0.024	1882.8	0	0.026	0.019	846.96	0	0.065	0.026	1885.8	0	0.013	0.009	385.1	0
10	0.039	0.016	1936.2	0	0.017	0.009	863.89	0	0.051	0.013	1935.1	0	0.021	0.017	402.59	0
11	0.046	0.024	2008.4	0	0.013	0.006	874.02	0	0.056	0.022	1993.5	0	0.023	0.019	422.12	0
12	0.043	0.02	2072.7	0	0.018	0.011	891.81	0	0.044	0.009	2029.5	0	0.014	0.009	430.14	0
13	0.045	0.022	2141.2	0	0.021	0.014	915.62	0	0.046	0.015	2068.5	0	0.027	0.021	457.59	0
14	0.047	0.024	2217.3	0	0.017	0.01	932.79	0	0.054	0.025	2123.1	0	0.018	0.013	470.76	0
15	0.047	0.022	2292.9	0	0.018	0.011	951.61	0	0.051	0.019	2172.3	0	0.022	0.015	488.98	0
16	0.034	0.009	2333.6	0	0.012	0.005	960.21	0	0.039	0.006	2200.6	0	0.009	0.003	491.98	0
17	0.028	0.004	2360.6	0	0.021	0.015	984.77	0	0.047	0.018	2241.4	0	0.017	0.011	503.61	0
18	0.038	0.017	2410.6	0	0.018	0.01	1002.1	0	0.054	0.024	2295.3	0	0.011	0.006	508.1	0
19	0.036	0.014	2455	0	0.018	0.011	1020	0	0.047	0.015	2337	0	0.015	0.009	516.86	0
20	0.028	0.005	2481	0	0.01	0.002	1025.2	0	0.045	0.015	2375.6	0	0.014	0.009	524.03	0
21	0.028	0.007	2507.8	0	0.01	0.004	1031.1	0	0.042	0.01	2407.9	0	0.013	0.008	530.78	0
22	0.027	0.007	2531.9	0	0.013	0.007	1040.3	0	0.034	0.003	2429.4	0	0.018	0.013	543.24	0
23	0.025	0.007	2554.2	0	0.012	0.006	1048.3	0	0.027	-0.001	2443.2	0	0.012	0.006	548.48	0
24	0.023	0.004	2571.6	0	0.018	0.012	1066.2	0	0.033	0.009	2463.7	0	0.002	-0.004	548.62	0
25	0.02	0.002	2585	0	0.012	0.005	1073.7	0	0.033	0.007	2483.4	0	0.016	0.011	558.71	0
26	0.019	0.002	2596.8	0	0.005	-0.001	1075.2	0	0.033	0.009	2504.3	0	0.009	0.004	562.02	0
27	0.015	0	2604.9	0	0.006	0.001	1077.1	0	0.027	0.002	2517.8	0	0.018	0.012	573.86	0
28	0.022	0.008	2621.3	0	0.006	0.002	1079.5	0	0.028	0.005	2532.3	0	0.006	0.001	575.35	0
29	0.023	0.009	2639.9	0	0.005	0.001	1080.9	0	0.028	0.005	2546.6	0	0.016	0.01	584.91	0
30	0.025	0.01	2662.2	0	0.01	0.006	1087.1	0	0.032	0.011	2565.2	0	0.017	0.012	595.83	0
31	0.012	-0.004	2667.2	0	0.005	0	1088.3	0	0.031	0.009	2583.7	0	0.017	0.011	607.43	0
32	0.013	-0.001	2673	0	0	-0.004	1088.3	0	0.025	0.001	2595	0	0.001	-0.006	607.45	0
33	0.021	0.009	2687.9	0	0.011	0.008	1095.3	0	0.023	0.002	2605.2	0	0.008	0.003	610.1	0
34	0.023	0.01	2705.7	0	0.016	0.012	1109.8	0	0.026	0.006	2618	0	0.006	0.002	611.54	0
35	0.009	-0.006	2708.4	0	0.005	0	1111.5	0	0.038	0.018	2644.7	0	0.008	0.003	613.84	0
36	0.014	0.003	2715.4	0	0.01	0.006	1117.4	0	0.025	0.002	2656.8	0	0.01	0.006	617.85	0

	(5) EUR/JPY								(6) EUR/GBP								(7) EUR/AUD								(8) EUR/CHF							
	VOL				VO				VOL				VO				VOL				VO				VOL				VO			
	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.524	0.524	26200	0	0.117	0.117	1317.8	0	0.053	0.053	20.901	0	0.04	0.04	37.41	0	0.155	0.155	372.43	0	0.136	0.136	656.7	0	0.233	0.233	617.15	0	0.081	0.081	173.55	0
2	0.463	0.26	46675	0	0.056	0.043	1625.2	0	0.048	0.045	38.054	0	0.033	0.031	62.161	0	0.109	0.087	555.2	0	0.093	0.076	963.67	0	0.153	0.104	882.33	0	0.044	0.038	225.97	0
3	0.438	0.181	65004	0	0.08	0.07	2245.6	0	0.029	0.025	44.449	0	0.032	0.029	85.324	0	0.097	0.07	700.94	0	0.075	0.055	1164.9	0	0.152	0.102	1144.6	0	0.038	0.032	264.58	0
4	0.421	0.137	81960	0	0.054	0.036	2528.7	0	0.046	0.042	60.503	0	0.029	0.026	104.54	0	0.081	0.051	803.23	0	0.081	0.06	1398	0	0.143	0.082	1375.9	0	0.029	0.022	286.67	0
5	0.406	0.106	97752	0	0.038	0.022	2668	0	0.031	0.025	67.88	0	0.017	0.013	111.37	0	0.065	0.034	868.51	0	0.074	0.049	1594.7	0	0.132	0.067	1574.8	0	0.029	0.023	309.65	0
6	0.394	0.085	112592	0	0.032	0.017	2767.6	0	0.026	0.019	72.819	0	0.027	0.023	127.62	0	0.08	0.052	968.15	0	0.057	0.03	1711	0	0.121	0.053	1741.6	0	0.033	0.026	338.52	0
7	0.379	0.064	126352	0	0.04	0.027	2923	0	0.018	0.011	75.269	0	0.014	0.009	132	0	0.066	0.033	1035.1	0	0.057	0.032	1827.3	0	0.107	0.038	1872.3	0	0.026	0.018	356.04	0
8	0.37	0.057	139451	0	0.035	0.02	3038	0	0	-0.006	75.269	0	0.022	0.019	143.58	0	0.054	0.022	1080.2	0	0.057	0.031	1941.7	0	0.106	0.04	2001.1	0	0.017	0.01	363.87	0
9	0.357	0.042	151626	0	0.026	0.012	3101.9	0	0.014	0.01	76.799	0	0.013	0.008	147.35	0	0.059	0.029	1134.7	0	0.057	0.031	2058.8	0	0.111	0.045	2141	0	0.025	0.018	380.23	0
10	0.356	0.052	163771	0	0.029	0.016	3181.2	0	0.015	0.011	78.493	0	0.015	0.011	152.68	0	0.048	0.017	1170.8	0	0.047	0.019	2135.9	0	0.097	0.027	2248.3	0	0.012	0.004	383.76	0
11	0.35	0.043	175482	0	0.028	0.015	3258	0	0.006	0.001	78.749	0	0.023	0.019	164.46	0	0.038	0.009	1192.8	0	0.047	0.022	2215.7	0	0.101	0.035	2364	0	0.018	0.012	392.12	0
12	0.346	0.042	186946	0	0.021	0.009	3300.7	0	0.009	0.006	79.391	0	0.015	0.01	169.44	0	0.037	0.011	1214	0	0.033	0.007	2255.6	0	0.085	0.016	2446.9	0	0.015	0.009	398.36	0
13	0.336	0.028	197716	0	0.028	0.017	3375.2	0	0.009	0.006	80.013	0	0.012	0.008	173.01	0	0.032	0.007	1229.8	0	0.036	0.013	2301.9	0	0.077	0.013	2514.7	0	0.014	0.009	403.9	0
14	0.321	0.013	207573	0	0.029	0.017	3456.3	0	0.015	0.012	81.754	0	0.008	0.003	174.49	0	0.045	0.024	1261.2	0	0.032	0.009	2338.2	0	0.074	0.013	2577.8	0	0.013	0.007	408.05	0
15	0.317	0.021	217201	0	0.023	0.01	3505.8	0	0.011	0.007	82.661	0	0.009	0.005	176.4	0	0.04	0.016	1286.5	0	0.033	0.011	2376	0	0.088	0.03	2664.9	0	0.015	0.01	414.12	0
16	0.313	0.021	226538	0	0.03	0.019	3595.4	0	0.007	0.003	82.985	0	0.008	0.004	177.85	0	0.043	0.019	1314.7	0	0.035	0.014	2419.5	0	0.085	0.024	2746.2	0	0.018	0.013	423	0
17	0.31	0.024	235752	0	0.039	0.025	3738.4	0	0.009	0.005	83.539	0	0.007	0.003	178.93	0	0.038	0.013	1337.3	0	0.032	0.011	2456.2	0	0.081	0.021	2820.7	0	0.014	0.008	428.03	0
18	0.311	0.029	244990	0	0.022	0.007	3786.9	0	0.002	-0.001	83.582	0	0.011	0.007	181.47	0	0.042	0.018	1364.6	0	0.032	0.012	2493.9	0	0.083	0.023	2898.8	0	0.016	0.01	434.87	0
19	0.304	0.019	253832	0	0.024	0.011	3844.1	0	0.001	-0.002	83.598	0	0.017	0.013	187.84	0	0.04	0.015	1389.4	0	0.026	0.006	2518.2	0	0.078	0.016	2967.3	0	0.018	0.012	443.4	0
20	0.295	0.01	262124	0	0.02	0.006	3883.3	0	0.004	0.002	83.741	0	0.011	0.007	190.57	0	0.041	0.016	1415.9	0	0.032	0.013	2554	0	0.074	0.014	3030.1	0	0.005	-0.001	444.17	0
21	0.29	0.012	270163	0	0.024	0.011	3938.1	0	0.003	0.001	83.813	0	0.01	0.007	193.08	0	0.034	0.008	1433.7	0	0.032	0.013	2591.2	0	0.064	0.004	3076.8	0	0.006	0.001	445.1	0
22	0.289	0.017	278131	0	0.023	0.01	3989.5	0	0.003	0.002	83.899	0	0.007	0.003	194.17	0	0.03	0.005	1447.2	0	0.036	0.017	2638.1	0	0.07	0.016	3133.2	0	0.016	0.012	452.07	0
23	0.281	0.008	285679	0	0.018	0.005	4020.3	0	0.005	0.004	84.081	0	0.004	0.001	194.62	0	0.043	0.021	1475.9	0	0.033	0.013	2677.4	0	0.062	0.005	3176.7	0	0.013	0.007	456.34	0
24	0.274	0.005	292838	0	0.013	0.001	4037.9	0	-0.003	-0.005	84.146	0	0.01	0.006	196.73	0	0.026	0	1486.6	0	0.027	0.007	2704.2	0	0.063	0.01	3221.8	0	0.012	0.006	459.97	0
25	0.27	0.008	299817	0	0.016	0.005	4061.2	0	0.006	0.005	84.395	0	0.013	0.01	200.85	0	0.043	0.021	1515.2	0	0.023	0.003	2722.4	0	0.063	0.011	3267.4	0	0.011	0.006	463.38	0
26	0.265	0.007	306552	0	0.013	0.002	4076.4	0	0.009	0.007	84.952	0	0.01	0.006	202.92	0	0.032	0.006	1530.7	0	0.022	0.003	2739	0	0.074	0.023	3329.2	0	0.007	0.002	464.75	0
27	0.269	0.02	313483	0	0.022	0.013	4124.4	0	0.002	0	84.989	0	0.019	0.015	211.11	0	0.036	0.013	1551.1	0	0.029	0.012	2769.2	0	0.064	0.009	3376.1	0	0.006	0.001	465.7	0
28	0.264	0.01	320123	0	0.015	0.004	4145.2	0	-0.001	-0.002	84.995	0	0.013	0.009	215.21	0	0.034	0.01	1568.7	0	0.017	-0.001	2780	0	0.053	0	3408.4	0	0.007	0.002	466.91	0
29	0.262	0.012	326662	0	0.019	0.009	4179.7	0	0	-0.002	84.997	0	0.012	0.007	218.45	0	0.034	0.01	1586.4	0	0.02	0.004	2794	0	0.053	0.004	3440.3	0	0.009	0.005	469.12	0
30	0.263	0.018	333286	0	0.017	0.006	4209.1	0	0.01	0.009	85.79	0	0	-0.004	218.45	0	0.042	0.019	1613.5	0	0.025	0.01	2816.2	0	0.053	0.005	3472	0	0.012	0.007	472.77	0
31	0.256	0.007	339573	0	0.017	0.006	4236.4	0	0.004	0.002	85.901	0	0.009	0.006	220.48	0	0.038	0.013	1635.8	0	0.026	0.01	2840.5	0	0.05	0.003	3500.6	0	0.012	0.007	476.54	0
32	0.25	0.003	345550	0	0.015	0.004	4256.9	0	0.014	0.012	87.37	0	0.008	0.004	221.97	0	0.029	0.003	1648.6	0	0.022	0.005	2857.5	0	0.048	0.003	3527	0	0.007	0.002	477.78	0
33	0.248	0.007	351446	0	0.014	0.004	4276.5	0	0.014	0.012	88.771	0	0.004	0	222.34	0	0.019	-0.005	1654.1	0	0.021	0.005	2873.1	0	0.052	0.009	3558.1	0	0.004	0	478.22	0
34	0.245	0.007	357206	0	0.014	0.004	4296.6	0	0.004	0.001	88.881	0	0.007	0.004	223.35	0	0.028	0.007	1666.4	0	0.025	0.009	2895	0	0.044	-0.001	3580.1	0	0.009	0.006	480.59	0
35	0.244	0.009	362896	0	0.01	0	4306.5	0	0.013	0.01	90.125	0	0.001	-0.003	223.37	0	0.022	0	1673.6	0	0.018	0.002	2907	0	0.043	0.001	3601.1	0	0.009	0.005	482.81	0
36	0.246	0.015	368666	0	0.016	0.007	4330.5	0	0.011	0.007	91.041	0	0	-0.003	223.37	0	0.025	0.006	1683.4	0	0.014	-0.001	2914.4	0	0.043	0.002	3621.7	0	0.017	0.012	490.13	0

	(9) GBP/JPY								(10) AUD/JPY								(11) ZAR/JPY								(12) GBP/AUD							
	VOL				VO				VOL				VO				VOL				VO				VOL				VO			
	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob	AC	PAC	Q-Stat	Prob
1	0.507	0.507	24067	0	0.117	0.117	1312	0	0.554	0.554	29627	0	0.159	0.159	2452.9	0	0.246	0.246	3502.9	0	0.067	0.067	341.87	0	0.118	0.118	161.94	0	0.087	0.087	226.18	0
2	0.44	0.246	42149	0	0.071	0.058	1798.5	0	0.489	0.263	52718	0	0.115	0.091	3721.2	0	0.22	0.169	6290.8	0	0.033	0.029	425.21	0	0.063	0.05	207.99	0	0.054	0.047	313.43	0
3	0.418	0.179	58473	0	0.046	0.031	1997.5	0	0.467	0.187	73708	0	0.108	0.079	4839.2	0	0.198	0.122	8549.6	0	0.029	0.025	490.59	0	0.041	0.029	227.7	0	0.06	0.052	419.92	0
4	0.397	0.129	73232	0	0.037	0.025	2128.3	0	0.448	0.138	93095	0	0.104	0.07	5886.3	0	0.182	0.094	10471	0	0.023	0.019	530.72	0	0.035	0.024	241.89	0	0.025	0.014	438.81	0
5	0.384	0.104	87030	0	0.038	0.028	2269.4	0	0.43	0.102	110965	0	0.095	0.057	6767.9	0	0.178	0.084	12301	0	0.022	0.018	568.95	0	0.042	0.033	262.8	0	0.044	0.036	497.36	0
6	0.381	0.098	100608	0	0.034	0.022	2378.4	0	0.419	0.085	127880	0	0.094	0.054	7623.7	0	0.178	0.079	14123	0	0.024	0.02	612.96	0	0.034	0.022	276.2	0	0.034	0.023	532.28	0
7	0.369	0.074	113358	0	0.026	0.015	2444.4	0	0.405	0.066	143725	0	0.095	0.052	8489.6	0	0.177	0.072	15923	0	0.02	0.015	642.56	0	0.028	0.017	285.52	0	0.018	0.008	541.64	0
8	0.361	0.065	125579	0	0.029	0.019	2523.5	0	0.396	0.058	158845	0	0.09	0.044	9270.6	0	0.169	0.059	17571	0	0.016	0.011	662.71	0	0.019	0.008	289.59	0	0.025	0.016	559.6	0
9	0.343	0.039	136616	0	0.031	0.02	2614	0	0.378	0.036	172654	0	0.086	0.039	9980.4	0	0.154	0.04	18933	0	0.005	0.001	664.73	0	0.025	0.017	297.13	0	0.025	0.016	577.81	0
10	0.341	0.048	147494	0	0.032	0.021	2711.4	0	0.376	0.047	186275	0	0.085	0.037	10671	0	0.15	0.038	20231	0	0.014	0.01	678.84	0	0.03	0.021	307.8	0	0.027	0.018	599.01	0
11	0.336	0.044	158090	0	0.022	0.01	2759.3	0	0.37	0.042	199502	0	0.081	0.033	11309	0	0.156	0.046	21630	0	0.007	0.003	682.86	0	0.017	0.006	311.35	0	0.021	0.011	611.51	0
12	0.334	0.044	168540	0	0.027	0.016	2827	0	0.362	0.034	212158	0	0.085	0.036	12005	0	0.143	0.03	22815	0	0.009	0.006	689.5	0	0.022	0.013	316.97	0	0.054	0.046	696.94	0
13	0.326	0.032	178462	0	0.02	0.009	2865.3	0	0.354	0.029	224276	0	0.078	0.028	12599	0	0.14	0.028	23952	0	0.011	0.007	697.94	0	0.018	0.009	320.57	0	0.02	0.006	708.27	0
14	0.314	0.019	187671	0	0.015	0.005	2888.1	0	0.345	0.022	235789	0	0.074	0.024	13135	0	0.139	0.028	25063	0	0.013	0.01	711.5	0	0.017	0.008	323.88	0	0.015	0.005	715.36	0
15	0.312	0.028	196773	0	0.02	0.011	2924.9	0	0.339	0.021	246847	0	0.076	0.026	13688	0	0.142	0.033	26225	0	0.011	0.008	721.2	0	0.023	0.015	329.97	0	0.025	0.015	734.18	0
16	0.306	0.023	205552	0	0.021	0.012	2966.1	0	0.336	0.025	257725	0	0.075	0.025	14229	0	0.129	0.017	27182	0	0.006	0.003	724.25	0	0.025	0.016	337.22	0	0.042	0.033	786.19	0
17	0.305	0.027	214246	0	0.018	0.009	2998.2	0	0.335	0.029	268526	0	0.068	0.017	14670	0	0.128	0.019	28123	0	0.006	0.003	726.64	0	0.021	0.011	342.35	0	0.004	-0.01	786.76	0
18	0.302	0.025	222809	0	0.016	0.007	3024	0	0.329	0.022	278983	0	0.073	0.024	15190	0	0.129	0.023	29087	0	0.009	0.007	733.21	0	0.016	0.006	345.26	0	0.023	0.014	802.3	0
19	0.3	0.024	231236	0	0.015	0.006	3046	0	0.327	0.025	289320	0	0.067	0.017	15626	0	0.123	0.017	29962	0	0.007	0.004	736.85	0	0.013	0.004	347.24	0	0.043	0.034	857.97	0
20	0.291	0.013	239166	0	0.018	0.009	3075.4	0	0.315	0.007	298901	0	0.075	0.026	16168	0	0.12	0.015	30794	0	0.014	0.011	750.96	0	0.023	0.016	353.48	0	0.041	0.029	907.18	0
21	0.285	0.011	246753	0	0.016	0.007	3099.4	0	0.313	0.017	308380	0	0.057	0.006	16486	0	0.12	0.017	31626	0	0.004	0	752.1	0	0.02	0.01	357.93	0	0.018	0.002	916.59	0
22	0.285	0.019	254347	0	0.014	0.005	3118.1	0	0.307	0.01	317459	0	0.062	0.014	16862	0	0.114	0.011	32375	0	0.005	0.003	754.11	0	0.013	0.003	359.96	0	0.022	0.01	931.44	0
23	0.283	0.017	261828	0	0.02	0.012	3155.1	0	0.302	0.011	326270	0	0.059	0.011	17201	0	0.112	0.012	33101	0	0.007	0.005	757.84	0	0.016	0.008	362.89	0	0.021	0.01	944.21	0
24	0.272	0.004	268743	0	0.018	0.009	3186	0	0.294	0.004	334613	0	0.062	0.015	17579	0	0.113	0.015	33840	0	0.009	0.007	764.53	0	0.015	0.007	365.61	0	0.018	0.005	953.39	0
25	0.27	0.01	275563	0	0.01	0.001	3195.5	0	0.29	0.007	342716	0	0.062	0.015	17953	0	0.11	0.012	34534	0	0.013	0.01	777.91	0	0.021	0.012	370.55	0	0.027	0.016	974.91	0
26	0.262	0.003	281999	0	0.016	0.009	3220.7	0	0.287	0.011	350680	0	0.062	0.015	18323	0	0.112	0.016	35259	0	0.008	0.005	783.14	0	0.01	0.001	371.77	0	0.015	0.003	981.22	0
27	0.265	0.016	288565	0	0.01	0.001	3229.7	0	0.287	0.016	358639	0	0.061	0.014	18686	0	0.103	0.006	35876	0	0.007	0.004	786.58	0	0.012	0.004	373.35	0	0.021	0.011	993.73	0
28	0.264	0.015	295076	0	0.013	0.006	3245.5	0	0.286	0.016	366535	0	0.061	0.014	19048	0	0.105	0.011	36507	0	0.011	0.008	795.77	0	0.02	0.013	377.99	0	0.038	0.025	1035.9	0
29	0.263	0.016	301574	0	0.014	0.007	3264.3	0	0.282	0.012	374231	0	0.057	0.01	19361	0	0.108	0.016	37180	0	0.006	0.003	798.69	0	0.013	0.004	379.82	0	0.009	-0.003	1038.5	0
30	0.268	0.024	308275	0	0.016	0.009	3289.5	0	0.285	0.021	382066	0	0.062	0.016	19733	0	0.105	0.012	37815	0	0.007	0.003	801.96	0	0.015	0.007	382.45	0	0.011	-0.001	1041.8	0
31	0.254	0	314311	0	0.013	0.005	3305.3	0	0.279	0.01	389597	0	0.057	0.01	20045	0	0.11	0.018	38509	0	0.007	0.004	806.03	0	0.01	0.002	383.65	0	0.014	0.002	1047.6	0
32	0.252	0.008	320272	0	0.011	0.004	3317.7	0	0.272	0.003	396735	0	0.055	0.009	20337	0	0.106	0.014	39164	0	0.005	0.002	807.7	0	0.014	0.007	385.97	0	0.009	-0.001	1050.2	0
33	0.25	0.007	326103	0	0.009	0.002	3325.3	0	0.268	0.004	403664	0	0.059	0.014	20670	0	0.105	0.012	39799	0	0.006	0.004	810.81	0	0.017	0.009	389.18	0	0.014	0.007	1056.3	0
34	0.246	0.006	331776	0	0.015	0.008	3346.5	0	0.268	0.011	410617	0	0.059	0.013	21006	0	0.102	0.009	40396	0	0.007	0.005	814.87	0	0.011	0.003	390.56	0	0.021	0.012	1069.9	0
35	0.246	0.009	337425	0	0.015	0.007	3366.8	0	0.269	0.015	417612	0	0.063	0.017	21387	0	0.098	0.007	40953	0	0.01	0.007	822.78	0	0.014	0.007	392.92	0	0.007	-0.004	1071.1	0
36	0.248	0.016	343194	0	0.006	-0.002	3370	0	0.272	0.02	424747	0	0.056	0.008	21686	0	0.098	0.008	41508	0	0.001	-0.002	822.85	0	0.012	0.005	394.71	0	0.013	0.005	1076.4	0