## **Does Exchange Rate Uncertainty Reduce International Trade**

Flows?

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## Abstract

My thesis examines the effect of exchange rate volatility on real export flows of the United States to Australia, Canada, Japan and the United Kingdom in the period 1980-2009. The conditional variance of the exchange rate volatility was estimated by a GARCH model. I found evidence for the negative hypothesis in three countries in the long-run by using Johansen cointegration method. I also found evidence for the negative impact applying a vector error correction model. However the effect is rather ambiguous in the short-run. I explain the positive impact explored in the case of Japan by the widespread use of U.S. dollar in invoices in the international trade of East Asia.

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## 1. Introduction

In 1946 the U.S. dollar became the major reserve currency in the international financial system by the establishment of the Bretton Woods system. Until its collapse the currencies of the member countries were pegged to the reserve currency and the monetary authorities were obliged to maintain the fixed exchange rate of the national currencies at its parity in terms of U.S. dollar by foreign exchange market interventions, however, the dollar was still convertible to gold at a fixed rate.

In 1971 the government of the United States abandoned the gold standard that led to the depreciation of the USD with respect to the gold. This depreciation was caused by the fiscal pressure on the federal budget triggered by the vast expenditure for the Vietnam War and the permanent balance of payments deficits of the United States especially towards Japan. After the collapse of the gold-dollar standard and the Smithsonian Agreement, where the Group of Ten<sup>1</sup> agreed to appreciate their currencies against the USD, it became obvious that the maintenance of the pegged exchange rate system was not feasible anymore. The major industrialized countries of the world changed to floating exchange rate regimes where the value of the currencies were determined by the demand and supply powers of the market.

The appearance of the floating exchange rate regimes generated a debate among economists, politicians and policy-makers also. The opposition of the floating exchange rate argues that its biggest drawback is that the variability of exchange rates has a negative effect on the welfare of the world through discouragement of

<sup>&</sup>lt;sup>1</sup> Participant countries in the General Arrangements to Borrow (GAB): Belgium, Canada, France, Germany, Italy, Japan, Netherlands, Sweden, Switzerland, United Kingdom and United States. Switzerland joined the group in 1964 but the name remained unchanged.

international trade flows. The Group of Ten formulated similar opinion about its detrimental influences.<sup>2</sup>

According to most studies the reason for the decrease in external trade due to exchange rate volatility is the risk-averse nature of the exporters on the market. The variability of the exchange rate is considered as the uncertainty about the future cashflows and profits of the trader. Due to this uncertainty the diversion of trade flows occurs. The firm will increase the volume of goods sold on the domestic market and decrease the volume of export goods in order to avoid exchange rate risk. Ethier (1973) and Clark (1973) built theoretical models with similar assumptions and they showed that traders decreased the volume of export goods in the periods when they expected higher volatility of the exchange rate. Demers (1991) and Franke (1991) argued that risk-averse behavior is not necessary to prove that exchange rate volatility has a significant effect on the volume of trade. Although both of them assumed risk-neutral behavior for market agents the former supported the negative hypothesis but the latter developed a model where producers benefit from the increase in exchange rate uncertainty. De Grauwe (1988) argues that both the negative and the positive hypothesis can be possible because the direction of the effect of exchange rate uncertainty depends on the convexity of the marginal utility function of the firm. Baccheta and Wincoop (2000) shows that volatility does not have any significant impact on international trade flows. One may think that the introduction of developed capital markets can ease the debate. Viaene and de Vries (1992) includes developed forward market into their theoretical model and they argued that the volatility can have beneficial and deleterious effects on trade since

<sup>&</sup>lt;sup>2</sup> International Monetary Fund: Group of Ten Report on the functioning of the monetary system [May 16, 1985]

the exporters of domestic country and the importers of foreign country are on the opposite side of the contract. Hence, one of the parties has to be aggrieved.

As the reader can see the theoretical models are very contradictory however the relationship between exchange rate risk and international trade has already been investigated for four decades. The results of empirical research are not less ambiguous. Few of the studies were able to provide consistent results. Most of them could not find statistically significant effect of volatility on trade but the significant results were also contradictory. Only De Grauwe (1988), Caballero and Corbo (1992), Caporale and Doroodian (1994) and McKenzie and Brooks (1997) were able to provide fairly consistent results but with different signs. The detailed survey of McKenzie (1999) enumerated the possible obstacles that the research in the past had met and that could be the cause of the lack of general conclusion about the effect of exchange rate uncertainty on trade.<sup>3</sup>

Reading the vast literature about empirical studies the question reveals why it is important to understand the relationship between the behavior of the exchange rate and international trade flows. If there existed a definite link between these two economic variables the understanding of the mechanism would help decision-makers to implement more efficient economic policies concerning international trade.

The aim of my thesis is to empirically investigate the impact of exchange rate volatility of the USD on the export flows of the United States to its four major partner countries, Australia, Canada, Japan and the United Kingdom in the period 1980-2009. My choice of the importers was influenced by the fact that these countries maintain a floating exchange rate regime since the collapse of Bretton Woods. Therefore they are the most relevant examples of fully floating exchange rate

<sup>&</sup>lt;sup>3</sup> I present these obstacles in Section 2.

systems, however, central banks often intervene in the foreign exchange market in order to stabilize the exchange rate. Canada's exchange rate is regarded as the perfectly floating currency since the Bank of Canada did not intervene in the market since 1998.<sup>4</sup>

Contrary to majority of previous studies I built a Vector Error Correction model used by Chowdury (1993), Arize et al. (2000) that counts for the non-stationary properties of the economic variables. My dataset consists of quarterly variables on a longer sample period. One of the main weaknesses of empirical studies was the lack of sufficient number of observations. I chose the GARCH model for exchange rate volatility estimation that can also be considered as an improvement in the analysis since it has only become popular in recent studies for example Pozo (1992).

Some of my assumptions are also different from previous studies. I also assume that exporters in the market are risk-averse but I consider the risk-averse nature of the importers. The destinction between the two sides are important because I want to introduce the vehicle currency role of the U.S. dollar to my analysis. I assume that the producers of the American market price their goods in USD. If the transactions are invoiced in domestic currency the risk of exchange rate volatility is born by the importers. Hence, the effect of exchange rate volatility also depends on the amount of foreign currency in the importer's economy and on the use of vehicle currency.

In Section 2 I present the review of the empirical literature focusing on the most important improvements in the research of the topic such as use of new econometric models, use of new estimation method of exchange rate volatility and significant results. It shows that the empirical studies about the examination of this effect also have given inconclusive results.

<sup>&</sup>lt;sup>4</sup> James Powell – A History of the Canadian Dollar (p.81.), Bank of Canada

In Section 3 I give a detailed description of the variables constructed and used in the model. I also present the GARCH model that I used to capture the conditional volatility of the four nominal exchange rates. Many different volatility measures were applied in the empirical literature. It turned out that the autoregressive conditional heteroskedasticity model might be the best measure of exchange rate variability to proxy uncertainty. The reason is that this type of model generates the conditional variance with respect to the stochastic nature of the process. The conditional volatility represents the conditional expectations about the exchange rate changes of the traders in the market. It is important since the exporters change their behavior according to their expectations about the future that can significantly differ from their past observations.

I also provide a detailed description about Cointegration and Vector Error Correction Model used to estimate the long-run relationship between the variables of the export demand equation and the short-run dynamics of the system. The intuition behind the use of such type of time series model is that the variables included in the export demand equations are non-stationary since each of them are integrated of order one, so the first difference of each time series are stationary. If two time series are nonstationary but there is a linear combination of them that gives stationary process, the two variables are cointegrated which means that there exists a long-run equilibrium relationship betweem them. In order to find such a cointegrating relationship between the variables I carried out the Johansen (1988, 1990, 1995) type of cointegration test that shows in each cases that a long-run relationship exists betweem the series. The use of the error correction term is due to the aim of investigating effects of exchange rate volatility on U.S. export flows in the short-run. When the variables of the system

are cointegrated the deviation of the long-run equilibrium affects the short-run dynamics.

In section 4 I present the results of the unit root and cointegration tests and the outcomes of the vector error correction models. I present in details that I found evidence of the negative impact of exchange rate uncertainty on international trade flow in the long-run and short-run, however positive effect can be detected in Japan in both time horizon. I also explain the possible reasons why the outcome is so different in magnitude and direction in the case of the East Asian country than in any other.

In Section 5 I summarize the findings presented in my thesis and I also suggest the direction of further research in the topic.

## 2. Empirical Literature Review

McKenzie (1999) provided a very detailed survey about the theoretical and empirical research about the topic under study in my thesis. I present the most important improvements and obstacles in the estimation of the effect.

The most important question to answer is which measure of exchange rate volatility is able to reflect the uncertainty in order to obtain the true effect. Many different measures were used in research. Pagan (1984) shows that the majority of the volatility measures suffers from the generated regressor problem. He states that the residuals of the OLS estimation of times series do not give consistent estimates for the volatility. He argues that an instrumental variable approach could solve the consistency problem but it is also very difficult to find a relevant instrument. He also states that the variance of a well specified autoregressive conditional heteroscedasticity model could obtain consistent estimates but they are not necessarily efficient. He points out that most measures used to generate exchange rate volatility suffer from the generated regressor problem. It turns out that the ARCH-type models are the most promising measures to capture the exchange rate volatility, however, other types of estimates are also considered to be useful if they are estimated on a longer time horizon such as the moving average of the standard deviation of the exchange rate.

Another obstacle that could be blamed for the insignificant results in the past is the lack of sufficient length of the sample period. The period examined by several researchers such as Cushman (1983), Hooper and Kohlhagen (1978), Peree and Steinherr (1989) was not homogeneous in the sense that they did not distinguish between the fixed- and floating exchange rate periods that led to misleading results

since in the fixed exchange rate period traders were not affected by the uncertainty of exchange rate.

The solution to this problem was the examination and comparison of the extent of effects obtained seperately from the fixed- and floating periods. Bailey et al. (1987), De Grauwe (1987, 1988), De Grauwe and De Bellefroid (1986), Koray and Lastrapes (1989) and Warner and Kreinin (1982) used such a methodology. Nevertheless they were not able to provide more consistent results than other studies analysing the heterogenous sample period (McKenzie 1999).

Majority of the studies used the standard export equation where the export variables were regressed on the measure of competitiveness, income or some indicator of economic activity and the generated volatility of exchange rate. Some researchers extended the model with new explanatory variables such as Bailey et al. (1986) who included the real export earnings from oil trade or Cushman (1986, 1988) who controlled for the effect of third countries in the bilateral export equation. The former study was not able to detect significant effect while the latter supported the negative hypothesis and Cushman stated that the inclusion of the new variable significantly changed the results. The appearance of the gravity model can be considered as a big improvement in the research since this model counts for many different effects that can influence international trade flows between countries. Besides it approaches the problem from the geographic view of trade. Consumer tastes, transportation cost and the distance between countries were the additional variables in the export demand equation. The model was used by Thursby and Thursby (1987) and Tenreyro (2007). The former provided negative results analysing 17 developed countries while the latter found evidence for the positive hypothesis using dataset for a vast group of countries.

According to some researchers the cause of inconclusive and insignificant results is the analysis of the aggregated international trade flows. It becomes clear that estimating the export equation with aggregated variables gives misleading results since the analyst assumes that the volatility of exchange rate effects the international trade in the same magnitude in every country which is obviously a false assumption. In order to avoid misleading results the examination of bilateral trade flows became more widespread. Numerous studies used bilateral trade flows for analysis, therefore I only enumerate some of them with the most promising results. Bini-Smaghi (1991) Chowdury (1993), De Grauwe and De Bellefroid (1986), Qian and Varangis (1994) found evidence for the negative hypothesis using different methodologies but bilateral trade data between developed countries. Common improvement of these studies is that the effect was more often unambiguously significant than before. Besides the direction of the effect also became more consistent. These studies proved that the disaggregation could be a viable way to solve the problem of insignificance. Moreover the disaggregation did not stop at the bilateral level but many studies were published using sectoral data for examination. Bini-Smaghi (1991), Klein (1990) utilised data disaggregated at the sectoral level and they showed that the impact of exchange rate volatility can differ between industries either in magnitude or direction. It turned out that the effect was minor in industries where the goods were more differentiated. Unfortunately credible data about sectoral international trade is not available for most of the countries.

The most important improvement in the analysis of the exchange rate volatility's effect is the introduction of advanced time series models due to several reasons. Most of the studies did not consider the non-stationarity of the data included in the analysis. Thus, the use of not appropriate econometrical methods can lead to

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misspecification of the economic model and misleading results. After the appearance of advanced time series models their use was progressively becoming widespread. The analysis of trade topics is also not exception of this process since the international trade flows and related times series are likely to be non-stationary. Among other researchers Asseery and Peel (1991), Chowdury (1993), McIvor (1995) and Arize et al. (2000) were aware of the problem of non-stationarity and they applied vector autoregressive and vector error correction models in order to avoid mistakes made by preceding studies. It is also important to mention that most of the studies were examining the short-run effect of the exchange rate on trade flows. By means of cointegration methods the long-run relationship can be analysed between the variables of the export demand function. Reading the recent literature about the topic it turns out that the long-run and short-run dynamics cannot be examined seperately since the deviation from the long-run equilibrium influences the short-run dynamics.

In the last four decades a vast empirical literature accumulated showing the importance of the mechanism between trade and exchange rate uncertainty. Although the empirical studies were not able to provide consistent results about the direction and magnitude of the effect of exchange rate volatility, the improvement of econometric models and new type of volatility measures facilitated the possibility to obtain more accurate and significant results.

In my thesis I aim to consider most of the problems raised by the empirical literature in order to provide significant results and clear insight in the mechanism between volatility and international trade flows.

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### 3. Data and Model Description

#### 3.1 The volatility estimation

I discuss the computation of the foreign exchange rate volatility measure in a separate subsection. As I already presented in the empirical literature review section the main problem in the estimation of exchange rate uncertainty's effect on trade is the unobservability of its volatility. The variable used in the export demand equation must be estimated by some econometric method. The question is which method can provide the best estimate for exchange rate volatility.

I use an ARCH-type model introduced by Engle (1982). The use of such an autoregressive conditional heteroskedasticity model is relevant due to several reasons. First the assumption that the volatility of the exchange rate is homoskedastic is invalid, hence, a model that captures the clustering of high and low volatility periods is needed. Second it models the conditional heteroscedasticity of the time series which means that the volatility at time t depends on the available information at time t-1. It is very useful in the case of exchange rate volatility since my assumption is that American exporters reduce their output in high volatility periods while they raise it in low volatility periods. The conditional variance output of the ARCH-type model gives exactly the exporters' conditional expectation about the future volatility with respect to its past information.

The model I used to estimate the variability of the exchange rate is a GARCH model that is a version of Engle's ARCH model extended by Bollerslev (1986). In GARCH it is allowed to model the conditional variance as an ARMA process. The advantage of this model is that the volatility clustering is more emphasized and the probability of extreme values in the distribution is higher than in the ARCH model. This is very

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important in this case since the exchange rate's distribution similar to other financial variables has fatter tails. It is also an advantage that fewer lagged terms are needed in the GARCH model so the number of estimated parameters is smaller in order to obtain a well fitted model.

The model specification of the AR(I) - GARCH(p,q) model fitted for the exchange rates' series is the following:

$$NER_{ijt} = C + \sum_{k=1}^{l} NER_{ijt-k} + \omega_{ijt}$$
(1)

$$\omega_{ijt} = v_{ijt} \sqrt{h_{ijt}^2}$$
<sup>(2)</sup>

where 
$$v_{ijt} \sim Student(0,1)$$
 and  $\omega_{ijt} \mid I_{ijt-1} \sim Student(0,h_{ijt}^2)$  (3)

I estimated an autoregressive process for all four currency pairs under analysis (Equation 1). As opposed to other variables where I used quarterly frequency I utilized monthly for the estimation of conditional volatility in order to obtain more accurate proxy. After the estimation I calculated the three-month arithmetic averages of the volatility to construct quarterly series. NER<sub>ijt</sub> denotes the nominal exchange rate, C is the constant term and  $\omega_{ijt}$  is the error term. The letter I shows the number of lagged variables in the regression. In order to determine the appropriate number of lags of the AR process I used the Schwarz Information Criterion (SIC). In three equations – Canadian dollar, Japanese yen and British pound – the number of lags is two while I included three lags in the case of the Australian dollar. First I carried out tests to detect ARCH disturbances in the data. Obtaining the squares of the fitted errors and the sample variance of the residuals I calculated the sample autocorrelation of the squared residuals. I used Ljung-Box Q-statistic to test for

significant coefficients. In all four cases I was able to reject the null hypothesis that the squared residuals are uncorrelated while in the case of the residuals of the AR processes I was not able to reject the uncorrelatedness that indicates ARCH disturbances in the data. It is shown in equation 3 that the error term's expected value equals to zero and its variance is the square of  $h_t$  which is the variance conditional on past observations. It was obtained from Equation 4.

$$h_{ijt}^{2} = \chi_{0} + \sum_{m=1}^{p} \chi_{m} \omega_{ijt-m}^{2} + \sum_{m=1}^{q} \psi_{m} h_{ijt-m}^{2}$$
(4)

The constant term is denoted by  $\chi_0$  and the coefficients of the ARCH terms which are the lagged squared residuals from equation 1 are represented by  $\chi_m$ . The coefficients of the GARCH terms are denoted by  $\psi_m$ . The p and q parameters of the GARCH model were also determined by the Schwarz Information Criterion (SIC). According to the SIC values I included one ARCH and one GARCH term in the conditional volatility equations – that is the most frequently used GARCH specification. In order to obtain positive variances I have to make non-negativity conditions such as the constant term has to be strictly bigger than zero and the ARCH and GARCH terms' coefficients have to be non-negative numbers. The results of the conditional variance equations and the graphs of the GARCH residual series are provided in Appendix A and B.

#### 3.2 The export demand equation

In order to explore the long-run effect of exchange rate volatility on U.S. export flows I use the following export demand equation that was used by many researchers such as Asseery and Peel (1991), Pozo (1992), Chowdury (1993), Arize et al. (2000):

$$Exp_{ijt} = \beta_0 + \beta_1 GDP_{jt} + \beta_2 RER_{ijt} + \beta_3 Vol_{ijt} + \varepsilon_{ijt}$$
<sup>(5)</sup>

Exp<sub>ijt</sub> denotes the real export of the United States to country j (Australia, Canada, Japan and United Kingdom) which is the dependent variable in the export demand equation.  $\beta_0$  denotes the intercept coefficient while  $\beta_x$  denotes the coefficients of the explanatory variables of the regression. The first explanatory variable GDP<sub>it</sub> is the real gross domestic product of the importer countries. This variable helps to proxy the economic activity of the trading partners of the United States. I expect positive sign for its coefficient since the increase in economic activity of a country ceteris paribus increases its demand for foreign goods. The second variable, RER<sub>ijt</sub> is the producer price level based real exchange rate of the USD against foreign currencies that I use as a proxy in order to measure the competitiveness of the U.S relative to the importer countries. The rise of the RER indicates the relative appreciation of the USD. I expect a negative sign of  $\beta_2$  since an increase indicates that the American products become more expensive that generates lower demand for them in foreign markets. The last explanatory variable in the export equation is the variable of my main interest. Voliit denotes the conditional standard deviation of the foreign nominal exchange rate between countries i and j in period t while  $\varepsilon_{ijt}$  is the disturbance term. The natural logarithms of each variable were included in the export demand equation.

#### 3.3 Dataset description

In this subsection I show the computation of the variables included in the analysis and I also provide the sources of the dataset. The frequency of all variables is quarterly with the exception of the nominal exchange rates that are monthly series.

The data about the bilateral export flows of the United States was downloaded from the International Monatery Fund's Direction of Trade database.<sup>5</sup> The use of bilateral flows instead of sectoral is due to unavailability of data. I calculated the real export value shown in equation 6.

$$Exp_{ijt} = \log\left(\frac{X_{ijt}}{X_{l}v_{it}} * 100\right)$$
(6)

 $X_{ijt}$  denotes the nominal export of the United States to country j and  $Xuv_{it}$  represents the export unit value of the U.S. in period t. The data for the latter variable was collected from the IMF's International Financial Statistics database.<sup>6</sup>

$$GDP_{jt} = \log\left(\frac{Ngdp_{jt}}{GDPdef_{jt}} * 100\right)$$
(7)

Equation 7 shows the calculation of the real GDP of importer country j. Ngdp<sub>jt</sub> is the nominal gross domestic product devided by the GDP deflator (GDPdef<sub>jt</sub>) in period t. The source of the nominal GDP is the Penn World Table<sup>7</sup> while the GDP deflator was downloaded from the IFS database. Before calculating the real GDP I had to transform the annual nominal GDP data into quarterly frequency by using the quarterly industrial production index of each country due to the lack of quarterly data denominated in USD. The source of the industrial production index is also the IFS database of the IMF.

<sup>&</sup>lt;sup>5</sup> Direction of Trade Database. 2011. IMF. http://www.imfstatistics.org/DOT/. (accessed date April 15, 2011)

<sup>&</sup>lt;sup>6</sup> International Financial Statistics. 2011. IMF. http://www.imfstatistics.org/IFS/. (accessed date April 15, 2011)

<sup>&</sup>lt;sup>7</sup> Penn World Table. 2011. Center for International Comparisons at the University of Pennsylvania.

http://pwt.econ.upenn.edu/php\_site/pwt70/pwt70\_form.php. (accessed date April 15, 2011)

$$RER_{ijt} = NER_{ijt} * \frac{PPI_{it}}{PPI_{jt}}$$
(8)

To obtain the bilateral real exchange rates I used the USD/foreign currency rates (NER<sub>ijt</sub>) multiplied by the domestic producer price index (PPI<sub>it</sub>) divided by the foreign producer price index (PPI<sub>jt</sub>). Hence, an increase in the real exchange rate indicates the real appreciation of the U.S. dollar against the foreign currency that worsens the competitiveness of export goods of the U.S.

#### **3.4 Cointegration**

The 1980's are considered as an important turning-point in time series analysis. The rule how non-stationary variables were treated in regressions was the use of their first differenced series. It turned out that this practice in multivariate models could lead to misspecification error. The milestone in time series analysis was the development of cointegration by Engle and Granger (1987).

They showed that a long-run relationship, an equilibrium might exist between nonstationary variables. More precisely the linear combination of these integrated variables is stationary, so the error term of the long-run equation - the deviation from long-run equilibrium – is stationary. If cointegration holds  $\varepsilon_{ijt}$  must be stationary in the export demand equation. Even if the stochastic trends of the real export, real GDP, real exchange rates and the exchange rate volatility differ, their trends must be linked to each other if they form a long-run equilibrium.

In order to test the existance of such a relationship between the variables of the export demand equation I had to test all variables' series for unit roots. If the variables in each equation are integrated of the order 1 – which means that the series of the variables are non-stationary and show stochastic trends but their first

differences are stationary – there might exist an equilibrium relationship betweem them.

I carried out three different unit root tests for each variable. The first is the Augmented Dickey-Fuller (ADF) test where the regressors are the lagged first differences of the variable and its lagged term. The necessary condition to use this test is that the entered regressors should be separately stationary. The reason why I carry out two more unit root tests is that the ADF test assumes that the error terms are independent and their variance is constant which is not necessarily true. I also used the Phillips – Perron (PP) tests that is able to handle the autocorrelation of the residuals and heteroscedasticity by the correction of test statistics. The last unit root test utilized is the Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test where the null hypothesis is not the presence of a unit root but the stationarity or trend-stationarity of the variable. It is a one-sided test so the null hypothesis must be rejected if the test statistics is higher than the critical value.

After testing the data for stochastic trends I applied the most frequently used cointegration test, the Johansen (1988, 1990, 1995) Full Information Maximum Likelihood (FIML) cointegration method. The advantages of this method are the following:

- invariant to the normalization of the cointegrating vector
- multiple cointegrating relationships can be tested
- the estimation is robust to simultaneity bias
- parametric correction of serial correlation

#### 3.5 The Vector Error Correction Model

The cointegration test shows if long-run relationship exists between the variables of interest or not. Nevertheless I also aim to show the short-run dynamics of the model. If the variables in the export demand equation were cointegrated I would make a misspecification mistake if I chose a VAR model for the first differences of the variables since the existance of the long-run equilibrium effects the behavior of the short-term dynamics. According to Granger's Representation Theorem (Engle and Granger 1987) if the variables are cointegrated, thus, the error term of the equation is stationary and the process can be represented by a vector autoregressive process then there must exist a vector error correction model where the short-run dynamics of a variable in the system is affected by its own and all other variables lagged first differences and the deviation from the long-run equilibrium from previous period. Accordingly the lagged error term of the long-run equation enters into the short-run dynamic model. The short-run dynamics are represented by the following error correction equation:

$$\Delta \mathsf{Exp}_{ijt} = \alpha_0 + \alpha_1 \mathsf{ECT}_{ijt-1} + \sum_{s=1}^{n_2} \lambda_s \Delta \mathsf{Exp}_{ijt-1} + \sum_{s=1}^{n_3} \mu_s \Delta \mathsf{GDP}_{jt-s} + \sum_{s=1}^{n_4} v_s \Delta \mathsf{RER}_{ijt-s} + \sum_{s=1}^{n_5} \xi_s \Delta \mathsf{Vol}_{ijt-s} + \mathsf{u}_{ijt}$$
(9)

The constant term is denoted by  $\alpha_0$  and the coefficient of the lagged deviation from the long-run equilibrium (ECT<sub>ijt-1</sub>) is  $\alpha_1$ . The other variables are the lagged first differences of the regressors of the export demand equation with coefficients  $\lambda_s$ ,  $\mu_s$ ,  $v_s$ ,  $\xi_s$ . Letter s denotes the number of lagged terms in the error correction model while  $u_{iit}$  is the disturbance term.

### 4. Results

#### 4.1 Unit Root Tests

Before carrying out the cointegration test the levels and the first differences of the variables included in the export demand equation should be checked for unit roots. I used three different unit root tests, the ADF, the PP and the KPSS due to different properties of the tests. I present the p-values and lag length for the ADF, the p-values and the Newey-West bandwidth for the PP test and the LM-statistics and the Newey-West bandwidth for the ADF test. In the case of the PP and KPSS tests I used the bartlett kernel while in the ADF test the lag length was determined by the Schwarz Information Criterion. I also included the assumptions concerning the intercept and the trend in the tests with respect to the graph of the time series. Finally I provide the order of integration of the variables.

The results are shown in Table 1. In all level tests I assumed the presence of intercept and trend except in the case of the standard deviation of the USD against the Canadian dollar where only intercept was included. In all first difference tests I solely assumed intercepts. According to the ADF and PP tests I was not able to reject the presence of a unit root at any conventional significance level. The only exception is the U.S. export towards Australia but the hypothesis can be rejected only at the 7.43% level. The results of the KPSS tests differ in several cases. In the level tests the null hypothesis of stationarity cannot be rejected at least at the 10% significance level in two cases: the real exchange rate and the nominal exchange rate volatility of USD against Australian dollar. In the first difference tests I was only able to reject the stationarity of Japanese real GDP.

Unit root tests										
Importer	lvl-dif	variable	assumption	lags	ADF	Ban	РР	Ban	KPSS LM	order
	level	exp	intercept & trend	0	0.0743*	4	0.1268	8	0.16377**	I(1)
	diff	exp	intercept	0	0.0000	22	0.0000	25	0.27399	I(0)
Australia	level	rer	intercept & trend	1	0.4139	4	0.6174	9	0.09173	I(1)
	diff	rer	intercept	0	0.0000	12	0.0000	6	0.11504	I(0)
	level	gdp	intercept & trend	0	0.4010	5	0.5635	9	0.17490**	I(1)
	diff	gdp	intercept	1	0.0000	12	0.0000	17	0.14393	I(0)
	level	vol	intercept & trend	0	0.2963	0	0.2963	8	0.07368	I(1)
	diff	vol	intercept	0	0.0000	7	0.0000	5	0.07089	I(0)
	level	gdp	intercept & trend	0	0.2551	3	0.2584	8	0.11829*	I(1)
	diff	gdp	intercept	0	0.0000	1	0.0000	2	0.09062	I(0)
	level	rer	intercept & trend	1	0.4337	3	0.6012	9	0.12181*	I(1)
Canada	diff	rer	intercept	0	0.0000	10	0.0000	5	0.08920	I(0)
	level	exp	intercept & trend	2	0.9569	4	0.7249	8	0.2644***	I(1)
	diff	exp	intercept	1	0.0000	2	0.0000	2	0.12958	I(0)
	level	vol	intercept	0	0.1717	9	0.2465	8	1.1212***	I(1)
	diff	vol	intercept	0	0.0000	36	0.0000	33	0.26465	I(0)
	level	gdp	intercept & trend	1	0.5017	15	0.6923	9	0.3081***	I(1)
	diff	gdp	intercept	0	0.0000	9	0.0000	7	0.52821**	I(0)
	level	rer	intercept & trend	3	0.5336	5	0.6000	9	0.2508***	I(1)
Ianan	diff	rer	intercept	2	0.0001	4	0.0000	5	0.09908	I(0)
Japan	level	exp	intercept & trend	0	0.9337	10	0.9578	9	0.2991***	I(1)
	diff	exp	intercept	0	0.0000	10	0.0000	11	0.30338	I(0)
	level	vol	intercept & trend	1	0.8605	0	0.9421	9	0.2443***	I(1)
	diff	vol	intercept	0	0.0000	3	0.0000	0	0.21405	I(0)
	level	gdp	intercept & trend	0	0.7846	0	0.7846	8	0.18650**	I(1)
	diff	gdp	intercept	0	0.0000	0	0.0000	2	0.17206	I(0)
	level	rer	intercept & trend	1	0.1953	2	0.3924	8	0.15634**	I(1)
UK	diff	rer	intercept	0	0.0000	2	0.0000	1	0.06729	I(0)
UK	level	exp	intercept & trend	0	0.1682	6	0.2022	9	0.17810**	I(1)
	diff	exp	intercept	1	0.0000	5	0.0000	4	0.09718	I(0)
	level	vol	intercept & trend	0	0.6055	13	0.6183	6	0.2615***	I(1)
	diff	vol	intercept	0	0.0000	13	0.0000	13	0.06576	I(0)

Table 1

Notes: The asterisks (\*),(\*\*),(\*\*\*) denotes the rejection of the null hypothesis at the 10, 5 and 1% significance level in the KPSS test.

With respect to the results I conclude that all variables under examination have unit root and they are integrated of order one.

#### **4.2 Cointegration Tests**

After testing the variables of the dataset for stochastic trends I applied the Johansen Full Information Maximum Likelihood (FIML) cointegration method to find evidence for the long-run equilibrium held between the non-stationary variables of the system. Before testing for cointegrating vectors I had to make an assumption about the trend in the data and about the form of the export demand equation. However the Akaike (AIC) and Schwarz Information Criterion can be used to find the most suitable specification of the test they led to contradiction in each case. For this reason I rather relied on the economic theory and previous research. Out of the five possibilities I choose the assumption which allows for linear deterministic trend in the data and assume only intercept in the long-run relationship. I used the AIC to define the number of lags in the cointegration.

I calculated both the trace and the maximum eigenvalue statistics to test the presence of cointegration and the number of cointegrating vectors. In Table 2 I provide the results and the corresponding p-values of the tests for each country.

Table	2
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			Trace st	tatistic		Max. Eigenvalue statistic			
Importer H <sub>o</sub>		r=0	r≤1	r≤2	R≤3	r=0	r≤1	r≤2	r≤3
Australia	statistic	44.12	15.34	5.130	0.354	28.77**	10.21	4.77	0.35
	p-values	0.1074	0.7570	0.7949	0.5514	0.0350	0.7238	0.7699	0.5514
Canada	statistic	50.55**	14.98	5.541	1.522	35.56***	9.445	4.01	1.52
Canada	p-values	0.0273	0.7809	0.7489	0.2173	0.0038	0.7950	0.8573	0.2173
Japan	statistic	48.87**	22.82	8.004	1.211	26.04*	14.82	6.79	1.21
	p-values	0.0400	0.2547	0.4649	0.2711	0.0776	0.3016	0.5138	0.2711
UK	statistic	57.15***	26.76	10.56	4.130**	30.38**	16.20	6.42	4.13**
	p-values	0.0053	0.1075	0.2401	0.0421	0.0212	0.2132	0.5587	0.0421

Notes: The asterisks (\*),(\*\*),(\*\*\*) denotes the rejection of the null hypothesis of zero coefficient at the 10, 5 and 1% significance level.

The null hypothesis of the test is the number of cointegrating vectors that is denoted by r in the Table 1. I was able to reject the null hypothesis at the conventional significance levels that there is no relationship in the long-run between the variables included in the export demand equation in three cases. Only the Maximum eigenvalue statistic shows that there exists such an equilibrium between the U.S. and Australia, however the p-value of the Trace statistic is very close to reject the hypothesis. I conclude that in all four country cases a long-run relationship holds between the non-stationary variables in equation 1. However, the r  $\leq$  3 hypothesis is rejected by both statistics in favour of the alternative hypothesis r = 4 I neglect the result since I cannot reject the hypothesis r  $\leq$  1 and r  $\leq$  2 so the number of cointegrating vectors cannot exceed one.

Table	3
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Cointegrating vectors normalized to U.S. exports (Expt)									
Importer	GDPt	RER <sub>t</sub>	Vol <sub>t</sub>	lag interval					
Australia	0.733997***	0.017564	-0.105228*	2					
Australia	[21.2344]	[0.10103]	[-1.76117]	2					
Canada	1.934472***	0.645101	-1.934830***	З					
Canada	[13.0016]	[0.81689]	[-6.19538]	5					
lanan	1.385731***	-1.025841***	1.376718**	4					
Japan	[4.66253]	[-6.61347]	[3.16347]	4					
UK	0.475287***	-0.639411*	-1.202874***	4					
	[4.35747]	[-1.80196]	[-4.65668]	+					

Notes: The asterisks (\*),(\*\*),(\*\*\*) denotes the rejection of the null hypothesis of zero coefficient at the 10, 5 and 1% significance level. Numbers in parantheses are t-statistics.

In Table 3 I provide the coefficients of the export demand function normalized to the export variable.<sup>8</sup> They mostly appear with the expected signs. The coefficients of the real gross domestic products are all positive and significant at the 1% significance level. Results confirm the economic theory that an increase in foreign income raises

<sup>&</sup>lt;sup>8</sup> Exploiting that the Johansen procedure is invariant to the normalization of the cointegrating vector.

the demand for domestic export goods. The elasticities are smaller in Australia and the United Kingdom while the effect is stronger in Japan and Canada where *ceteris paribus* 1% change in the income level increases the demand for export goods from the U.S. by 1.3857% and 1.9344% respectively. The real exchange rates have positive but statistically insignificant coefficients in the long-run equation of Australia and Canada. In Japan and the United Kingdom the export goods of the U.S. become more expensive in the foreign markets due to the the real appreciation of the USD, hence, it negatively influences the exports of the U.S. as I expected. Besides both coefficients are significant.

Moreover three out of four coefficients of the exchange rate volatilities are negative and significant which is evidence for the adverse effect of exchange rate uncertainty on the export flows of the U.S. in the long-run. In two cases the effect is strong (Japan, United Kingdom) while in Canada it is intense. In the East Asian country the volatility positively influences the demand for import goods. This sign can be interpreted by De Grauwe's (1988) idea that the income effect of exporters might be stronger than their level of risk-aversion. Finally the effect of the Australian dollar's variability on U.S. export flow is modest, though, it also has a negative sign. A 10% increase in the expected exchange rate volatility reduces the demand by 1.05%.

The magnitude of the effect is higher than in many of the empirical literature. Arize et al. (2000) reported coefficients between the range of 0.1 to 0.85. The results of Chowdury (1993) were also moderate between 0.07 and 0.82. However, recent studies in the topic reported similar results for example Baak et al. (2007) who examined the East Asian countries exports to Japan and to the U.S. Their coefficients ranges from -1.829 to 0.456.

In three out of four cases the data and the model support the assumption that due to the expectation of future exchange rate volatility American exporters reduce their output in order to avoid bearing exchange rate risk. They rather increase the proportion of goods sold on the domestic market in periods when a shock occures in the foreign exchange markets.

#### 4.3 Short-run Dynamics

After discussing the long-run relationship between the variables I present the results of the estimated Vector Error Correction Model in order to show the short-run dynamics of the system. The number of lags was determined according to the AIC. Since the SIC and AIC in almost all the cases contradicted to each other I prefered the lag length given by AIC because according to Gonzalo (1994) the loss in efficiency of an overparametrized model is smaller when important lags are omitted. I present the results of the error correction model in Table 4.

The signs of the error correction terms in all four cases are negative as I expected. The negativity of the coefficient is necessary if the long-run relationship exists between real export, real income, real exchange rate and volatility. The reason is that the coefficient of the error correction term shows the speed of adjustment of the dependent variable – in this case the real export – to the equilibrium. If the coefficient was positive it would mean that the bigger the deviation from the long-run equilibrium in period t-1 the more the export would diverge from this equilibrium in the next period, thus, the system would explode. The positive sign of the error correction term would indicate the absence of long-run relationship.

Three out of four cases the error correction terms are statistically significant at the conventional significance levels. However, the speed of adjusment in the case of

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Error Correction model Results for U.S. Export									
Importer	s	constant	ECT <sub>t-s</sub>	ΔExp <sub>t-s</sub>	∆GDP <sub>t-s</sub>	ΔRER <sub>t-s</sub>	∆Vol <sub>t-s</sub>	R <sup>2</sup>	
	0	0.016252							
	Ľ	[ 1.25092]							
Australia	1		-0.3997***	-0.19555*	0.604425	-0.029490	0.000570	38.9	
/ dott and	_		[-3.82941]	[-1.67910]	[ 1.35861]	[-0.13518]	[ 0.00936]	00,0	
	2			0.079438	-0.78016*	-0.247332	-0.1196**		
	_			[ 0.81124]	[-1.75529]	[-1.09030]	[-2.00633]		
	0	0.0166**							
	Ľ	[ 2.28246]							
	1		-0.025702	0.099615	0.5139**	-0.5156**	-0.06423*		
Canada	_		[-1.50031]	[ 0.97940]	[ 2.09080]	[-2.18497]	[-1.66880]	32.4	
Canada	2			-0.18011*	-0.6323**	-0.059792	0.025434	02,1	
	_			[-1.72627]	[-2.44492]	[-0.24034]	[ 0.64521]		
	3			0.120591	-0.299650	-0.239490	0.025586		
	Ľ			[ 1.19228]	[-1.18513]	[-0.96131]	[ 0.68943]		
	0	-0.002866							
	Ľ	[-0.35766]							
	1		-0.1519***	-0.086829	0.286529	0.099606	0.39068*		
			[-3.09166]	[-0.82087]	[ 1.07196]	[ 0.71179]	[ 1.66228]		
Japan	2			-0.2009**	0.306687	0.189549	0.106327	287	
Capan				[-2.02219]	[ 1.16573]	[ 1.33842]	[ 0.44019]	20,1	
	3			-0.122918	0.201335	-0.074643	-0.322086		
				[-1.21879]	[ 0.73684]	[-0.53828]	[-1.37725]		
	4			-0.127427	0.025268	0.044357	-0.222854		
	_			[-1.25685]	[ 0.09345]	[ 0.31008]	[-0.95304]		
	0	0.012099							
	_	[ 0.78285]							
	1		-0.0923**	-0.195046*	0.195468	0.020835	0.039583		
	_		[-2.39759]	[-1.95966]	[ 0.35682]	[ 0.12347]	[ 0.63309]		
UK	2			-0.038896	0.227098	-0.304489*	0.068358	27.6	
••••	_			[-0.38285]	[ 0.45697]	[-1.73636]	[ 1.09608]	,•	
	3			0.155414	-1.1993**	-0.142013	0.1242**		
	Ĺ			[ 1.60518]	[-2.51367]	[-0.78296]	[ 2.00349]		
	4			0.154559	0.400938	0.171603	0.018380		
				[ 1.57785]	[ 0.78334]	[ 0.95866]	[ 0.29291]		

Table 4

Notes: The asterisks (\*),(\*\*),(\*\*\*) denotes the rejection of the null hypothesis of zero coefficient at the 10, 5 and 1% significance level. Numbers in parantheses are t-statistics. Canada is not significant.<sup>9</sup> It means that Canada's export does not adjust to equilibrium which might indicate the lack of long-run relationship. Considering the number of observations and the number of estimated coefficients the rejection of the equilibrium might be a false decision. The interpretation of the coefficients is that the disequilibrium of Australian import is equated by 39.97% in each quarter which is a fairly rapid adjustment to equilibrium. In other words the real import needs less than nine month to adjust in case of shock to any variable of the system. The speed of adjustment is markedly slower in Japan where it is 15.19% per quarter and in the United Kingdom where the response is only 9.23% in each quarter.

As Table 4 shows, most of the coefficients of short-run dynamics are insignificant which is in accordance with preceding empirical studies using similar error correction models. The negative sign of the lagged real exports in the short-run and the magnitude of the impact which is moderate also presented by other papers but the negativity of the income's effect is not expected. It is negative in Australia, UK and the second lag of Canada but the first lag is positive. Thus, the impact seems ambiguous. The increase of the real exchange rate in the short-run also has a negative effect on U.S. exports in two countries (Canada and United Kingdom) which is consistent with the long-run effect.

Finally the effect of exchange rate volatility is negative in two examples (Australia and Canada), though their magnitudes are considered minor. In the United Kingdom the volatility of the U.S. dollar against the British pound has a positive impact on demand for U.S. export goods but the magnitude is also moderate. Nevertheless the magnitude in Japan is notable and the impact is very fast. A 1% change in the

<sup>&</sup>lt;sup>9</sup> The p-value of the error correction term in Canada's export demand function equals to 0.154

exchange rate volatility induces 0.39% increase in real exports from the U.S. in the following quarter.

In order to check the residuals of the model for serial correlation I carried out LM test. Since the p-values of the test are higher than 0.05 with very few exceptions (Canada) I was able to reject the presence of serial correlation. The tests' results can be found in Appendix C.

#### 4.4 Interpretation

As the results of the cointegration and error correction model show I found evidence for the negative effect of exchange rate uncertainty on international trade flows, however, in the case of Japan I detected very strong positive influence in the shortrun and long-run.

The aim of this subsection is to explore the presumptive causes of such a positive effect. I present the differences between the international trade flows and trade connections of Japan and the other countries.

I consider the currency that the countries invoice as a crucial cause in the change of the sign of volatility. Goldberg and Tille (2008) showed that 99.8% share of U.S. export are invoiced in U.S. dollar in 2003, hence, the American exporters do not bear the exchange rate risk if they price in U.S. dollar. It is interesting to look at the other countries' USD-invoicing share in imports and exports. Half of the Australian import was invoiced in USD while 67.9% of the exports in 2002. Japan surprisingly shows higher share in dollar invoicing in imports. 70.7% of Japanese import and 52.4% of export were invoiced in USD in 2001. One may ask why such a big share of Japanese transactions in international trade is denominated in U.S. dollar. One answer is that the transactions between Japan and the United States are invoiced in

USD in both direction.<sup>10</sup> It means that the exchange rate risk is born by the Japanese importers instead of the U.S. exporters.

I assumed that the importers in the market were also risk-averse, thus, in the period of higher expected exchange rate volatility the Japanese firms should be diverted to domestic products instead of purchasing the U.S. export goods. Even so their demand for U.S. export goods increased with the rise of volatility.

There can be two reasons why they do not decrease the demand for export goods. First the income effect offsets the substitution effect in case of an increase of exchange rate uncertainty. If the former is bigger than the latter, more volatile exchange rate can induce international trade. Second the Japanese importers are not concerned by the volatility. This scenario happens if the importers use the same currency in export activity as well. Hence, they do not need to exchange the U.S. dollar to Japanese yen and they are able to pay the U.S. imports in USD while they avoid bearing the exchange rate risk.

McKinnon and Schnable (2004) were analysing the invoicing behavior in East Asia. They showed the strong presence of the USD in export and import. They raised South Korea as the main example since the other countries were less industrialized, thus, their currencies less likely entered in international transactions in favour of the dollar. He stated that 86.8% of Korean export was invoinced in U.S. dollar as opposed to the 5.2% in yen in 2002. The shares in import are 80.6% and 12.1% respectively.

Goldberg and Tille (2008) also provided data about the use of Japanese yen in Japan's export and import invoicing. The shares were very low as one could

<sup>&</sup>lt;sup>10</sup> 92.8% of U.S. imports were invoiced in USD in 2003 (Goldberg et al. 2008).

expected with respect to the information above. Only 36.1% of Japanese exports and only 23.5% of imports were invoiced in yen.

My conclusion drawn from the information is that the Japanese importers are not affected by the exchange rate volatility of the yen against the dollar since they use the USD as a vehicle currency in international trade flows, most importantly in the direction of East Asia. The popularity of the U.S. dollar in this region can be explained by the fact that the currencies were pegged to the USD before the 1997 Asian financial crisis. Since the risk premia was high in these countries, the banks prefered to give interest on dollar deposits that also increased the presence of the dollar in these economies (McKinnon 2004). The results and the information suggest that the use of the U.S. dollar as a vehicle currency in international trade can eliminate the exchange rate risk born by Japanese importers.

### 5. Summary and Conclusion

The introduction of the floating exchange rate has triggered a debate among policymakers and economists about the effect of exchange rate volatility on international trade flows. I showed by reviewing the literature of the topic that there is no conclusive result in theoretical and empirical studies about the mechanism.

My thesis examines the quarterly export flows of the United States to four of its major partner countries (Australia, Canada, Japan and United Kingdom) between 1980 and 2009. Contrary to numerous studies made in this area I used a longer sample period and bilateral trade flows. The econometric models applied for obtaining the volatility and the estimation of long-run and short-run effects were also less frequently utilized in preceding papers. A GARCH(1,1) model was estimated for all four currency pairs in order to get the conditional variance of the exchange rates. I carried out unit root test to check the non-stationarity of the variables included in the export equation. To estimate the long-run effect I used multivariate cointegration method and vector error correction model for the analysis of the short-run dynamics.

The results of the cointegration method shows that long-run equilibrium exists between real export, foreign income, real exchange rate and exchange rate volatility. All the four country cases prove this statement. I found evidence for the negative impact of the exchange rate volatility on international trade in the long-run. In three countries (Australia, Canada and United Kingdom) volatility reduces export flows of the U.S. The results of the vector error correction model suggest that the negative impact is also present in the short-run in two countries (Australia and Canada), however the magnitude is minor.

I cannot conclude that the results ease the debate between the two sides since I found evidence for the positive hypothesis in the long-run and short-run as well. In Japan the volatility induces international trade in both time horizon while this statement is true in the United Kingdom in the short-run. Interestingly the magnitude of the effect in Japan is fairly high in both time horizon which necessitated some qualitative explanation.

I provided two possible explanations for the positive effect. First De Grauwe's (1988) arguement states that if the income effect is higher than the substitution effect due to the change in exchange rate risk, volatility can promote international trade flows. Second, the use of the U.S. dollar in foreign countries as vehicle currency in international trade flows can lower or eliminate the risk born by exporters and importers. Examining the invoicing currency choice of the U.S. and Japan I conclude that the Japanese importers are not affected by the volatility since majority of their export and import are invoiced in U.S. dollar due to its widespread usage as vehicle currency in the East Asian countries which are also major trade partners of Japan.

However the results are significant further research needed to investigate the effect in other countries because the empirical research were rather focusing on developed countries. It is also important to examine the effect of exchange rate uncertainty across different sectors since its magnitude and direction might differ. The neglect of this assumption can act to the detriment of efficient trade policies.

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## 7. Appendix

**A)** Estimation of the conditional variances from the GARCH(1,1) models:

$$\begin{aligned} h_{usd,aud,t}^2 &= 0.0000142 + 0.152562\omega_{usd,aud,t-1}^2 + 0.856982h_{usd,aud,t-1}^2 \\ h_{usd,cad,t}^2 &= 0.0000166 + 0.149368\omega_{usd,cad,t-1}^2 + 0.804394h_{usd,cad,t-1}^2 \\ h_{usd,jpy,t}^2 &= 0.114683 + 0.019903\omega_{usd,jpy,t-1}^2 + 0.966590h_{usd,jpy,t-1}^2 \\ h_{usd,gbp,t}^2 &= 0.0000278 + 0.169416\omega_{usd,gbp,t-1}^2 + 0.703984h_{usd,gbp,t-1}^2 \end{aligned}$$

B) Graphs of the conditional variances:



Conditional Variance of the Canadian Dollar



Conditional Variance of Japanese Yen 



## C) Serial Correlation Tests:

Serial correlation (Australia)				Ser	ial correlation	(Canada)
lag	LM statistics	p-value	1	lag	LM statistics	p-value
1	11.47679	0.7791		1	24.22695	0.0847
2	21.01536	0.1779		2	20.62897	0.1932
3	15.04432	0.5214		3	12.49989	0.7089
4	14.58569	0.5552		4	21.55734	0.1581
5	16.37038	0.4274		5	13.79849	0.6137
6	12.82934	0.6852		6	13.45052	0.6396
7	18.67530	0.2859		7	7.694339	0.9574
8	20.51306	0.1980		8	9.341662	0.8987
9	22.34261	0.1325		9	14.60126	0.5540
10	9.485737	0.8921		10	27.08821	0.0405
11	11.08107	0.8045		11	23.42363	0.1029
12	13.89703	0.6064		12	27.88623	0.0326

Serial correlation (Japan)				Serial correlation (UK)			
lag	LM statistics	p-value		lag	LM statistics	p-value	
1	17.90554	0.3295		1	15.72002	0.4727	
2	8.966128	0.9148		2	12.81419	0.6863	
3	14.68611	0.5477		3	17.24499	0.3699	
4	9.942595	0.8696		4	15.15596	0.5132	
5	12.66812	0.6969		5	16.67212	0.4071	
6	8.512129	0.9321		6	18.10593	0.3177	
7	15.93203	0.4577		7	11.12102	0.8020	
8	12.61194	0.7009		8	18.37468	0.3024	
9	11.58291	0.7722		9	9.332981	0.8991	
10	17.83879	0.3334		10	22.50461	0.1276	
11	12.77652	0.6890		11	8.528478	0.9316	
12	23.66049	0.0972		12	21.49258	0.1603	