

**The Exchange Rate and Foreign Exchange Reserves:  
Japan and United States, 1974 to 2010**

by

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## Abstract

The exchange rate is very difficult to predict. In 1971, the fixed exchange rate system transferred to a floating exchange rate system after the collapse of the Bretton Woods System. The Bretton Woods system established the principle for commercial and financial transactions among the major industrial countries after World War II. Japan, United States, and Germany are the major three influential countries in international commerce. The Japanese yen, US dollar, and German mark are the major currencies in the exchange rate market. In a floating exchange rate regime, the exchange rate may reflect the financial situation of countries. Central banks might allow one currency price to float freely between upper and lower bound. Central banks can buy or sell foreign exchange against their currency to affect the exchange rate. This is called official intervention. This thesis examines two major currencies, Japanese yen and the US dollars, in an exchange rate model depending on international trade, central bank foreign exchange reserves, and interest rates. Unit root tests for stationarity and Bayesian information criterion (BIC) are used in this thesis. Finally a lagged transformation model tests the short term and long term adjustments.

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# **Chapter I**

## **Introduction**

The exchange rate is the rate one currency can be changed to the other in the foreign exchange market, the price of one country's currency in terms of the other currency. A country can obtain foreign currency income through export in international markets, making estimation of the exchange rate a critical objective of all international investors. Greenspan (2002) remarked that interest rate differentials, productivity gain differentials, and chronic external imbalances explain exchange rates. But none has been found to be consistently useful in forecasting exchange rates.

In the history of global exchange rate market, 1971 is a land mark when the collapse of the Bretton Woods System transferred the fixed exchange rate to a floating exchange rate system. A fixed exchange rate is advantageous to both developed and emerging economies because it acts as a credible constraint on the value of domestic money. Fixed exchange rates can keep inflation under control and offer risk-averse countries, especially emerging ones, a method to avoid undesired inflation. The analysis of exchange rate and foreign exchange reserves in the floating exchange rate is a relevant topic.

Most papers focus on foreign exchange reserves. Some papers argue that official intervention works in the exchange rate market. There are several papers focusing on the volatility of exchange rates and official intervention. This thesis builds a model to link foreign exchange reserves to the exchange rate market. This thesis explains the factors of

two countries, Japan and United States, on the exchange rate in a model depending on international trade, central bank foreign exchange reserves, and interest rates.

There are four chapters in this thesis. Chapter I is Introduction. Chapter II is literature review where some research ideas are described. Chapter III, Chapter IV and Chapter V are about test statistics, empirical results, and a conclusion. Chapter VI is the conclusion of the thesis.

## **Chapter II**

### **Literature Review**

This chapter presents literature related to exchange rate models, and overall usefulness of foreign exchange reserve position from central banks. The volatility of exchange rate movements and the importance of foreign exchange reserves and some economic theory are discussed in this thesis.

Money is an intermediate medium of exchange that facilitates trade. People trade with money in the form of checks, bank deposits, credit cards, cash, and so on. The scarcity of money reflects scarce resources and the need for economic choice. The exchange rate reflects the relative price between two currencies. The exchange rate also shows the influence of the direction and level of international finance. If domestic currency depreciates, foreign investors would like to buy cheaper home stocks and bonds. Relatively high growth rate in money supply leads to inflation and depreciation. Money supply differentials explain long term trends in exchange rate. Short term exchange rate changes are very difficult to predict.

In international economics, demand for foreign exchange has a negative slope and supply has a positive slope if import demand is elastic. Japan and United States are major trade partners in the world. Japanese yen and US dollars are major transaction currencies in the global trade market. The exchange market is clear in case that these two currencies are floating. Some evidence suggests import demand is elastic over long time periods.

When domestic buyers want to buy foreign products, domestic currency is traded for foreign currency on the foreign exchange market. Suppose a US importer purchases manufactured goods from a Japanese firm. The importer earns in dollars while the Japanese counterpart gets income in yen and transfer it to the bank account of the Japanese exporter.

The exchange rate in fact is a relative price between two countries. In foreign exchange rate market, exchange rate is determined by money supply and demand. Here Japanese yen and US dollars can be an example to explain demand and supply of money in foreign exchange rate market. There are participants who need US dollars in exchange rate market. Japanese buy US goods or exports and investments. Others supply the US dollars in foreign exchange rate market. Americans buy Japanese imported goods. Americans invest in Japan. World investors or speculators can profit from expected exchange rate movement, which may influence both demand and supply of money. Various governments impact the exchange rate in the foreign exchange rate market. Foreign exchange rate is determined by the interaction of supply and demand. Let the interaction point is  $E_1$  yen per dollar. See Figure 2.1.

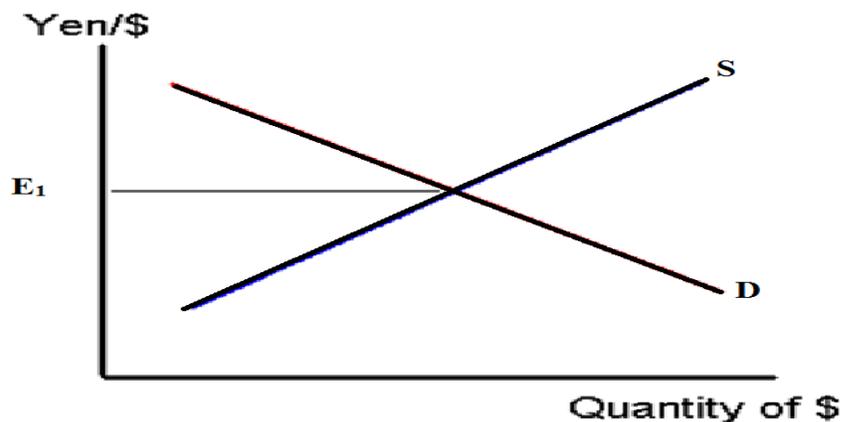


Figure 2.1 Market equilibrium exchange rate

As we move up the vertical axis, the dollar appreciates. The demand for dollars slopes down. If dollars appreciate against the yen, Japanese will buy fewer American products. Because they are more expensive to them, the quantity demand for dollars will fall. The supply curve will slope up because Americans will buy more Japanese goods as the dollar appreciates. Consumers in United States will buy more Japanese goods for a low price. The quantity supplied of dollars will rise.

When exchange rate fluctuates, it is due to a shift in the supply and demand curve. If US economy is growing faster than Japan economy, Americans buy more imported Japanese products. The supply of dollars increases. The dollar depreciates. Here the equilibrium exchange rate moves downward from  $E_1$  yen per dollar to  $E_2$  yen per dollar. The yen appreciates and the dollar depreciates. See Figure 2.2.

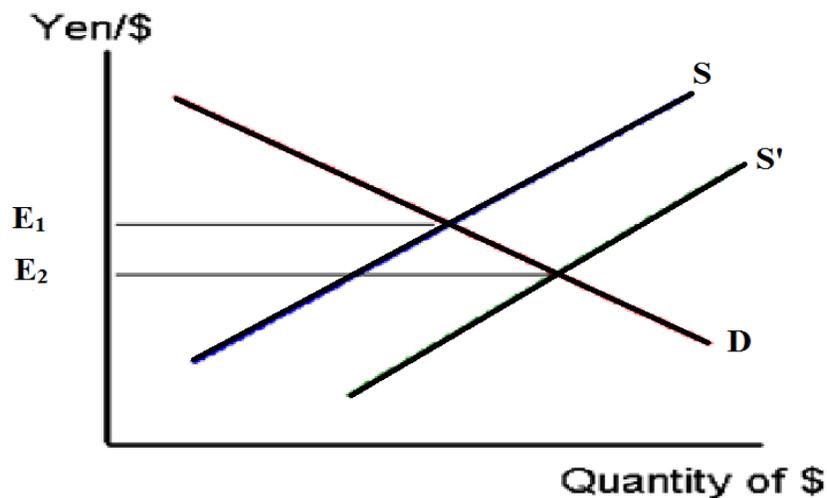


Figure 2.2 Supply curve shift and exchange rate

Speculators can anticipate the movements in yen per dollar exchange rate, and they will start to buy or sell dollars or yens. If speculators expect the dollar to appreciate, they start buying it. The demand for dollars increases. Some productivity shocks will affect the demand of money. An earthquake in Japan, or a flood in United States, will affect exports and imports. An earthquake in Japan forces it to import more food from the U.S, which increases the demand for the dollars, and the US dollars will appreciate. Here the demand curve shifts rightward. The yen per dollar equilibrium move upward from  $E_1$  yen per dollar to  $E_3$  yen per dollar. The yen depreciates. See Figure 2.3.

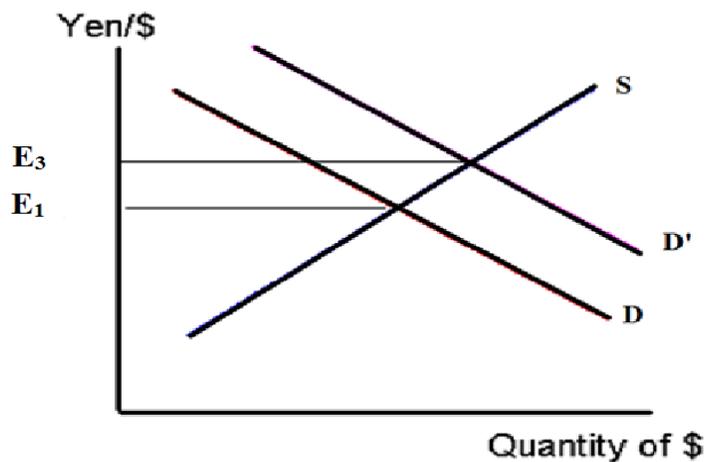


Figure2.3 Demand cure movement and exchange rate.

An unstable foreign exchange market occurs if exports are inelastic. The supply curve has a negative slope. Suppose foreign exports are inelastic and supply slopes downward as the graph A lower yen/\$ rate leads to an increase the quantity of US dollars along the supply curve. The supply of dollars might slope downward during the contact period of the J curve.

The Bretton Woods fixed exchange rate system started from the end of World War II until the oil price hikes in the 1970s. The US dollar was the dominant economy and standard currency. The Bretton Woods system is similar to gold standard in the late 1800s or some other common standard or definition for currencies. The Bretton Woods system was only successful because United States was the only dominant economy. Europe and Japan had been destroyed by World War II. The system depends on conservative US monetary policy to stable prices and reliable currency standard.

Meese and Rogoff (1983b) investigate the bad performance of exchange rate models especially monetary model of exchange rates. They use vector autoregressions (VAR) to identify the factors that influence the exchange rate in both short and long term through the money supplies among US and other foreign currencies, relative outputs, interest rate differentials and trade balance of US and foreign countries. The VAR results show that innovation in exchange rate describe a large portion of the forecast error variance at one month and three month forecast period. Innovations in the rest of variables become more important for the period of one or three years. They suggest that the failure of the exchange rate models is a result of volatility of time varying risk premium, volatility of long run real exchange rates, and bad measurement of inflationary expectations or money demand.

Monetary policy can affect international trade and finance. Inflation occurs when the supply of currency grows faster than the production of money. Inflation can affect the credit market and foreign exchange market. Stable growth in the money supply leads to low or zero inflation. So inflation has little effect on exchange rate market if it is correctly anticipated. Monetary policy has been proposed to control the money supply.

Inflation is predictable with monetary rules. Central Bank or monetary authorities may help the economy adjust to external shocks. But monetary policy has its limits. Large monetary contraction may lead to economic crisis.

Monetary policy affects inflation, the nominal interest rate, and the exchange rate. Central banks actively trade in the exchange rate market in the floating exchange rate system. Monetary policy is not an effective tool for influencing international trade and finance. Steady growth of money supply leads to a steady interest rate and a reliable exchange rate which is the foundation for business, traders, and investors to make better plans.

Business cycles alternate periods of recessions and booms which are a natural part of a dynamic economy. Foreign business cycles may affect domestic economics through export. For example, a recession starts when firms sell inventories. As inventories decline, firms begin to produce more products to build back the same inventories level as before. Foreign firms can start to purchase overflowing inventories from domestic manufacturers. A recession begins when foreign buyers stop buying domestic products or domestic firms cut output.

In an open economy, the exchange rate is both a source of shocks and a mechanism to transmit shocks, and monetary policy choices are dependent on exchange rate dynamics. Central Banks manage the supply of money supply to intervene the business cycle. Increasing the money supply will lower the interest rate and encourage investment. Active monetary policy may not guide the economy from recession to expansion. In theory, monetary policy should establish reliable money supply with zero inflation.

The treasury bill rates or government bond rates are treated as risk free rate in economics, especially the long term treasury bill rate. The discount rate in business can be this risk free rate plus suitable risk premium. Treasury bill rates include the inflation expectation in one country. Consider the uncovered exchange rate between United States and Japan. When the treasury bill rate in Japan increases, United States investors will buy Japanese treasury bills more than United States treasury bills. In that case, the exchange rate yen per dollar will rise.

In contrast to increase the Japanese Treasury bill rate, if the United States increases its Treasury bill rate in the market, more Japanese traders purchase US Treasury bill. The dollar will appreciate.

In business, interest rate or discount rate is more relevant than treasury bills rate. The risk premium differs between industries. Treasury bills rate is consider the interest rate without any risk premium. It can be used as simple interest rate to analyze the exchange rate.

Rasmus, Fatum and Michael Hutchison (2005) investigate the effectiveness of intervention in exchange rate market with recently published official daily Bank of Japan intervention data. They explore the effectiveness of official Japanese intervention operations in affecting the exchange rate, especially in a period of interest rate inflexibility. Japan's current zero interest rate environment has no room for monetary policy stimulus to support foreign exchange operations. They use a non parametric sign test for the median to show the directions of exchange rate change following intervention events and a matched sample test to learn whether there is a significant shift in the

exchange rate change between the pre-event and post-event periods. They conclude that intervention can be effective even if there is no supporting interest rate change. That means that even if the Bank of Japan follows a zero interest rate policy it could depreciate the exchange rate but the success rate is not as high as none zero interest policy. According to their event study results, intervention is effective over a period of 2-5 days with an extension of the framework up to two weeks.

Bonser-Neal (1996) discusses whether official intervention of central banks can stabilize foreign exchange rates. She argues that there are mainly three reasons causing volatile exchange rates: changes in market fundamentals, the degree of confidence with market expectations, and speculative exchange rate movements unrelated to market fundamentals. She builds a GARCH model to estimate the volatility related to central bank intervention. She uses implied volatility of foreign exchange currency option prices which is forward looking. She uses US macroeconomic data and other foreign variables to ensure the volatility changes attributed to intervention do not affect some other macroeconomic cause of volatility. The estimated model is

$$\begin{aligned} \% \Delta(\text{yen/dollar volatility}) = & \beta_0 + \beta_1 \text{ Fed Intervention} \\ & + \beta_2 \text{ Bank of Japan intervention} + \beta_3 \text{ Macro \& other variables} + \text{error} \end{aligned}$$

The results provide little support for the view that central bank intervention decreases the volatility of exchange rate. From early 1985 till 1991, central bank intervention has little effect on volatility and in some cases increased exchange rate volatility. Central Banks can reduce exchange rate volatility if they resolve market uncertainty about future fundamentals and policies.

Government central banks can buy and sell currencies in order to influence or manage exchange rates. A depreciated or devalued currency implies more expensive imports and cheaper export than before. In a flexible exchange rate system, official international reserve can allow a central bank to purchase domestic currency which is a liability for central banks. This action can stabilize domestic currency.

Supply and demand is the most important tool in economics. Prices of products in the market are determined by goods and service traded in markets. According to Adam Smith, price is the invisible hand in the market. Money between buyers and sellers changes hands at promised prices in market transactions. International transactions can occur when the buyer and seller are from different countries. The international transaction involves exchange rate when the buyer's currency is convert to seller's currency.

Imports are foreign products that domestic consumers can get without producing. Exports are goods one country has to produce but cannot consume currently. One country pays for import goods with the foreign currency it collects from export goods or service. When goods are exported, the foreign importer must trade domestic currency for foreign currency to pay for the exporter.

Amaya (1998) notes that Japan is one of the leading countries in world trade and investment. Japan has very high relative savings rates to other countries. On the contrary, United States has very low savings rates and foreign investment. The main reason is that the shin-jinrui (young wealthy) in Japan spend more and save less, while baby boomers in United States save money for retirement. Suppose there is no arbitrage in foreign

exchange rate market in both countries. In that case, foreign capital is supposed to move to Japan. The exchange rate between these two countries will change. When foreign countries increase investment in Japan, the dollar depreciates.

Each country chooses its inflation rate through political and economic process. So if inflation rates are different from each other across countries, exchange rates will adjust. Government or monetary authorities can change the supply of money.

Sarno, Taylor, and Frankel (2003) describe some economic models about the exchange rate market. They offer exchange rate models using the latest econometric techniques, which cover the main theories that explain the determination of exchange rates and utilizes recent empirical data on exchange rate behavior. Their book is the introduction of methodology to research in the exchange rate which is the economic foundation on foreign exchange rate market.

Official intervention in the foreign currency exchange market happens when the financial authorizes buy or sell foreign exchange against their native currency to affect the exchange rate. When Bretton Woods adjustable peg exchange rate system collapsed in the early 1970s, the economics profession favored pure float exchange rate system with zero intervention. As the result of the realization of the speed which capital could move among developed countries, an increasing number of economists and foreign exchange market participants during the early 1980s appeared to favor intervention. The main argument promoted a case for exchange rate system intervention is called the “mistaken rate” issue: under a floating exchange rate system, an inefficient foreign exchange market tends to generate the wrong rate which implies abnormal returns rather

than correct returns reflecting the economic fundamentals. Official intervention is a useful tool to induce an appropriate rate, which is to say that the exchange rate moves toward what the monetary authorities believe to be the correct rate.

Bayoumi and Eichengreen (1998) discussed the exchange rate volatility and intervention with implications of the theory of optimum currency areas. They linked the theory of optimum currency areas to the exchange rates of industrial countries. Those countries with more stable rates suffer the greatest reduction in the transaction value of domestic currency when their exchange rates changes because they have very small size and dependence on trade. Countries with more variable exchange rates face more asymmetric shocks than those with less volatile rates. Asymmetric shocks increase the volatility of the exchange rate through magnifying exchange market pressure. Official intervention could reduce the variability of exchange rate.

Kathryn Dominguez (1992) provides evidence that United States, Germany, Japan central banks influence the value of a currency is interpreted as a signal of a change in monetary policy. If central banks buy dollars in the foreign exchange market, central banks attempt to support the dollar. In the long run, the value of dollars will rise due to tight monetary policy. Fed Reserve will reduce the growth in the supply of dollars which would lead to dollar appreciation. Participants in the market may view central bank's activities as credible signal. The Fed, the German Bundesbank, and the Bank of Japan publicized their plan to sell dollars through coordinated intervention following the Plaza Agreement of September 1985. Participants in the foreign exchange market believed that Fed agreed in principle to increase the growth of the U.S money supply. They expected dollar depreciation in the future. They started to sell dollars. The Plaza Agreement

influenced the market expectation. German Bundesbank and Bank of Japan tried to resist continued dollar depreciation with the Louvre Agreement in June 1987, but Fed did not join in the buying of dollars at once. Market participants did not give central bank efforts credibility and the dollar depreciation continued.

Schwartz (2000) discusses foreign exchange intervention as a policy tool. Schwartz discusses central bank official intervention in the past and target zones for a bilateral exchange rate that central banks will defend by intervening. Schwartz also explained the exchange rate from national and international view points and observations on the case of Bank of Japan. The conclusion of the paper shows that intervention by monetary authorities has little effect on the exchange rate. The thesis presents the same result as Schwartz discusses in the paper, that official intervention has little effect in the foreign exchange rate market.

McKinnon (1999) asserts that Japan was in a liquidity trap with short term interest rate and the monetary base over expanded in the late 1990s. Japan's dilemma is the result of market expectations from 1971 that yen is likely to be higher in the long run. The Bank of Japan cannot by itself affect the exchange rate no matter its intervention is sterilized or not. The upward pressure on yen reflects mercantile pressure from the United States. The appreciation pressure on the yen is associated with trade disputes between Japan and United States. The current unwillingness of Japanese financial institutions adds to the shock of dollar claims that invests the US current account deficit. Only Japan and United States joint program of long run yen stabilization will bring yen to international levels. The expectation of inflation in the United States has led to lower the interest rate in United States which has pushed Japanese interest rate four percentage points lower by the

expectation of the appreciation of the yen. McKinnon contends that Bank of Japan by itself can do little to escape from the liquidity trap. Monetary base may contract to keep exchange rate steady. So the recommendation of raising monetary base would make adjustment more difficult than before.

## Chapter III

### Data Description and Variable Definitions

This chapter describes the data sources in the thesis, and reports statistical results. The dataset comprises quarterly time series spanning from January 1974 to December 2010 for United States and Japan. All the data are from International Monetary Fund International Statistics resource CD. The database resource CD starts from 1945 to 2010, published in June 2011. In 1971, the Bretton Woods system collapsed. Japanese yen was permitted to float above its fluctuation ceiling 357.30 yen per dollar on August 28<sup>th</sup>, 1971. On February 14<sup>th</sup>, 1973, the theoretical official rate was set at 277.20 yen per dollar based on Japanese yen stable gold content. At the same time, the effective exchange rate is set to float upward and no margins were maintained in exchange rate transaction. In this thesis, the research period started from the first quarter in 1974 to the last quarter in 2010 which is the floating exchange rate period. The exchange rate system changed from fixed exchange rate system to floating exchange rate system. The dataset shows the time series economic data in the floating exchange rate system.

The exchange rate is Japanese yen per dollars. Exports and imports are in domestic currency for each country. United States foreign exchange reserve, Japan foreign exchange reserve, are in millions units of currency. There are 156 observations for each variable.

The dependent variable is exchange rate (EXR) from International Monetary Fund International Statistics Database. The dependent variable measures the relative price of

two currencies in foreign exchange market. It is also regarded as the value of one country's currency in terms of the other currency. The exchange rate in this model is the nominal exchange rate, yen per dollar. The dependent variable measured as Japanese yen per dollar that means one US dollar can get the number of yen according to the exchange rate in the foreign exchange market.

There are eight independent variables in this thesis. According to the characteristics of the variables, there are four major groups of independent variables.

The first group is export value for Japan and United States. Export is the income of one country if the country sells domestic products to foreign countries. Export in international financial statistical database is counted in domestic currency. When a country sells more products to the other, it will earn more money from the foreign country. If Japan increases its export to the United States, the demand of yen will increase. The demand of Japanese yen should shift rightward. The same thing happens if United States buyers demand more Japanese products.

The changes of export will affect the equilibrium exchange rate in both countries. If the United States increases export to Japan, the United States exporter will earn more Japanese yen. The demand for yen should increase. If the United States decreases export to Japan, the United States exporter will obtain less Japanese yen. The demand for yen will decline. Exports are calculated in their own domestic currency for both countries in quarterly time series data based on the international trade balance sheet. Export data can be treated as income of one country from international trade through selling products to the other countries. Export is also the foreign currency income for United States and

Japan under goods and service account in international trade. Japanese export is described as JPEXP which is the variable name in the model and United States export is described as USEXP.

The second group is import value for United States and Japan which is the foreign consumption for each country. Import in international financial database is freight on board. American consumers purchase Japanese products and Japanese consumers purchase American products. In the early 1900s, there was an international trade theory called proportions theory of two Swedish economists, Eli Hechscher and Bertil Ohlin. This theory is called Heckscher- Ohlin theory. Heckscher-Ohlin theory states that a country should specialize in production and exports with the factors that are most abundant. Leontief (1953) notes the empirical problems with H-O model, known as Leontief paradox that United States tended to export labor intensive goods despite have a capital abundance. He found out that the US's exports less capital intensive than import. Samuelson (2001) emphasized gains from trade of intermediate goods are considerable in the international trade. Japan and United States are two developed countries. The technology of these two countries is the same across the countries. Japanese buyers can import more agricultural products which are the main export products in the United States. American consumers would like to buy more digital products from Japanese manufacturers, which are the well-known products in the world. Imports activities will affect the supply and demand of money to affect the exchange rate. If American buyers purchase Japanese products, the supply of US dollars declines. The exchange rate between Japan and United States rises. If Japanese consumers buy American export

products, the supply of Japanese yen decline. The yen appreciates. USIMP reflects the import value of United States quarterly. JPIMP shows the import value of Japan quarterly.

The third group of independent variables is interest rates. The interest rate is the nominal interest rate. The interest rate reflects the monetary policy. When one country changes the supply of currencies, the interest rate will change. If Federal Reserve increases the supply of US dollars in the market, the interest rate declines. If Bank of Japan decrease the supply of Japanese yen in the market, the interest rate of Japanese yen decline. Here in the model the interest is lending rate for both countries, the lending rate bank offered on loan to prime customers such as corporations, financial institution. The lending rate is the interest rate in most economic or financial models with the consideration of inflation. In the International Financial Statistics database, there are lending rates for United States. For Japan, the lending rate data comes from Bank of Japan time series database. In this case, United States lending rate and Japan lending rate are chosen.

The fourth group is foreign exchange reserve. Foreign exchange reserve is the foreign money or bonds held by central banks and monetary authorities which are accounted in US dollars for these two countries. The Central Bank can intervene to influence the exchange rate through changing foreign exchange reserve. Foreign exchange reserve is the effective instrument when central bank clears the excess demand or excess supply through purchasing or selling foreign currencies. The foreign exchange reserve in this database for Japan and United States is in US dollars because US dollars are the most popular currency in international commerce.

The two available instruments are monetary policy and direct intervention in foreign exchange market. Dominguez and Frankel (1993) argue that monetary policy and official intervention are not effective tools separately. These two instruments are combined. Official intervention is not stable to intervene in the foreign exchange rate market. Interventions can also have a signal effect which means that they can provide information for monetary policy in the future. Here foreign exchange reserves show the liability of central bank which can reflect the official intervention in the foreign exchange market.

In this model, USFOREV shows United States foreign exchange reserve and JFOREV stands for Japanese foreign exchange reserve. Japan is by far the larger participant in the foreign exchange market. The Bank of Japan can still influence the exchange rate market by its foreign exchange reserve. United States is one of the free economic countries without much government intervention in the exchange market. When the Bank of Japan increases its foreign exchange reserve, the dollar appreciates.

## Chapter IV

### The Model

This chapter presents a general model of independent variables that affects the exchange rate between Japan and United States. The exchange rate is posited to be a function of 1) Japanese export and United States export 2) Japanese import and United States import 3) Japanese foreign exchange reserve and United States foreign exchange reserve. 4) the Japanese treasury bill rate and the United States treasury bill rate. The exchange rate can be expressed as a function of eight variables,

$$e = f(X_{JP}, X_{US}, M_{JP}, M_{US}, R_{JP}, R_{US}) \quad (1)$$

where  $e = EXR$ ,  $X_{JP} = JPEXP$ ,  $X_{US} = USEXP$ ,  $M_{JP} = JPIMP$ ,  $M_{US} = USIMP$ ,  $R_{JP} = JPFOREV$ ,  $R_{US} = USFOREV$ .

The equilibrium exchange rate is the intersection point when the demand curve of yen and supply curve of US dollars intersect. The market equilibrium exchange rate can be endogenous variable in the demand and supply system.

The equilibrium exchange rate is determined by the supply and demand of two currencies. The equilibrium exchange rate is defined when the supply of Japanese yen equals the demand of Japanese yen. The demand for yen is determined by United States imports, Japanese exports, United States foreign exchange reserve. The supply curve function is described:

$$Q_D = Q_D(e, X_{JP}, M_{us}, R_{us}) \quad (2)$$

The coefficients of implicit demand function are all positive in theory which means that Japanese export, US import and US foreign exchange reserve have positive relationship with the supply of the US dollars. If US imports decline, the supply curve of US dollars shifts leftward. The equilibrium exchange rate decreases. Japan can earn US dollars if export goods and services to United States. When Japan increases export to the United States, Japan can earn more US dollars. The rising supply of US dollars will shift the supply curve rightwards. The equilibrium exchange rate declines. When United States Federal Reserve would like to intervene in the foreign exchange market, they will increase foreign exchange reserve. When the United States Federal Reserve increases foreign exchange reserves, the supply curve of US dollars moves right. That will result in a decrease in the equilibrium exchange rate. So in this thesis, a positive sign marks the positive relationship among exchange rate and independent variables in the demand function.

The supply curve of Japanese yen is determined by United States exports, Japanese imports, and Japanese foreign exchange reserve. The demand function is specified as:

$$Q_S = Q_S(e, X_{US}, M_{JP}, R_{JP}) \quad (3)$$

The coefficients in the implicit supply function are positive which show that the positive relationship between US exports, Japanese imports, and Japanese foreign exchange reserve. If United States exports more products to Japan, the supply of Japanese yen decreases and shifts the supply curve leftward. The market equilibrium exchange rate declines. If Japan increases imports, the supply curve of Japanese yen shifts leftward. The market equilibrium exchange rate rises. When Bank of Japan increases foreign exchange

reserve to influence and stabilize the exchange rate market, the demand curve of Japanese yen move to the right hand side. If firms in United States increase export foods and service to earn Japanese yen in international market, there will be more US dollars in the US market. Increase in United States export will shift supply curve leftward. The equilibrium exchange rate will rise. The positive signs in supply function below show the positive relationship among exchange rate and independent variables.

The solution of supply curve and demand curve functions together is the market equilibrium exchange rate. In this thesis, the supply and demand functions transform to log transformed linear regression functions. Log transformed linear regression coefficients are point estimates of elasticity. The aim is to interpret theory in terms of the estimated elasticities  $c_1 = \frac{\partial \ln e}{\partial X}$ ,  $c_2 = \frac{\partial \ln e}{\partial M}$ ,  $c_3 = \frac{\partial \ln e}{\partial R}$ , which are the coefficients in the market equilibrium exchange rate equation. The implicit demand and implicit supply function can be solved in the following equation. Equation supply (2) and demand function (3) together, solve for  $e_{mkt}$ :

$$e_{mkt} (\text{¥/}\$) = c_0 + c_1 X + c_2 M + c_3 R + u \quad (4)$$

Here,  $e_{mkt} = \ln e$ ,  $X = \ln X_{JP} - \ln X_{US}$ ,  $M = \ln M_{JP} - \ln M_{US}$ ,  $R = \ln R_{JP} - \ln R_{US}$ .

Market equilibrium exchange rate is a log transformed regression model. The log transformed ratio is the same as the difference between two variables. After log transformed this model, the dependent variables on the right hand become the difference of log transformed variables.

In market equilibrium exchange rate equation, X, M, R, are the difference of log transformed variable. It can be treated as ratio of log transformed independent variables from the demand function and supply function. The market equilibrium exchange rate equation is defined as  $\ln e$ . The negative signs of  $\ln X_{US}$ ,  $\ln M_{US}$ ,  $\ln R_{US}$  reflects the negative relationship among  $\ln e$  and independent variables. In market equilibrium exchange rate equation, the changing of independent variables and the moving of dependent variable is in the same direction.

Interest rates change when the monetary authorities or central banks increase or decrease the supply of money. The interest rates are exogenous variables in the equilibrium exchange rate equation. The interest rate is a percentage, not log transformed. The interest rate can reflect the monetary policy in both two countries. Interest rate difference, exogenous variable in the equation, is similar to log transformed independent variables. In this model, interest rate difference (I) ,  $I = \Delta i = i_{JP} - i_{US}$ , which is the difference between Japanese lending rate and United States lending rate, reflects the interest rate effect or monetary policy effect. The market equilibrium exchange rate model function becomes:

$$\ln e = c_0 - c_1 X + c_2 M + c_3 R + c_4 I + u \quad (5)$$

The coefficients in the market equilibrium exchange rate equation show the relationship between each independent variable and dependent variable. The coefficients of export difference (X) can be negative. If Japanese consumers purchase US export products, the demand of quantity of US dollars in the foreign exchange rate market decreases. The demand of quantity of US dollars declines which means that participants

in the market sell yens to get dollars. The equilibrium market exchange rate declines. The coefficient of import difference (M) can be positive. If the supply of dollars increases in the foreign exchange rate market, there are more participants buying dollars to get yens. The market equilibrium exchange rate rises. The coefficient of foreign exchange reserve difference (R) can be positive. If Bank of Japan would like to buy yens in the market, the demand of quantity of dollars rises. The market equilibrium exchange rate increases. There is positive relationship among M and R market equilibrium exchange rate. The coefficient of interest rate difference (I) can be negative. The increase of interest rate in one country will depreciate the domestic currency against others. There is negative relationship between interest rate difference and market equilibrium exchange rate.

The first step for this new model is unit root test to test for stationarity. Stationarity is a tool in time series. Raw data may be transformed to a stationary process. This thesis utilizes the augmented Dickey–Fuller test (ADF test). The ADF test is an augmented version of the Dickey-Fuller test. The results of ADF test is in Appendices Table 1. An ARCH model is built to test the residual heteroskedasticity.

The second step for this new model is log transformed linear regression. Durbin-Watson test is done after the regression model. The test statistics results show the model has a high  $R^2$  and residual correlation by the Durbin-Watson test. The model is built on difference stationary variables  $I(1)$  and stationary variables  $I(0)$ . See Table 3. ARCH model is also built here to test for the residual heteroskedasticity.

Finally lagged transformed model is built in this thesis. Lagged transformed model shows that the contemporaneous effect and lagged effect in the model. In the long run,

the variables in the thesis show the strong relationship among dependent variable and independent variables. The lagged transformed model is compared with other significant model in in this thesis.

There are a lot of statistical software packages to deal with time series data. In this thesis, SAS 9.2 is used to do the ADF test. Mohamed (2003) describes the ADF test of quarterly data time series model in SAS 9.2.

The raw data in this thesis is quarterly data, sequential equal time increments. The dependent variables and independent variables are both non stationary random walk process as integrated order 1. Regressing the dependent and independent variables will generate a spurious regression. The time plot of variables moving during the time period shows the relationship between dependent variable exchange rate and each independent variable in the model (See Appendix Figure 6). Granger and Newbold (1974) introduced the spurious regression that produces apparently significant statistics results between series that contain trends and are otherwise random. If both mean and variance are constant over time, then the series follows a stationary process. Otherwise, the series is described as a non stationary process, but may be a random walk with unit root.

To transform a non stationary to stationary series subtract each variable in the series from its predecessor. Differencing a series produces other sets of observations as the first differenced values, the second differenced values, and so on.

x level	$X_t$
$x$ 1 <sup>st</sup> differenced value ( $\Delta x_t$ )	$X_t - X_{t-1}$

Suppose there is a very simple and model:

$$y_t = \alpha + \beta x_t + \varepsilon_t \quad (6)$$

If a series is stationary without differencing, it can be designed as I(0), or integrated of order 0. A series is stationary with first differences is designed as I(1), or integrated of order 1. Stationarity is important for its influence in behavior. For example, if there is a shock in this simple model, the shock will die away soon for a stationary process. That means a shock in period t will produce a smaller effect in period t+1, a much smaller effect in period t+2, and so on. Every independent variable needs to test stationarity before Ordinary Least Square (OLS) regression analysis. The data is quarterly and stationarity test will include at least five lagged periods. The quarterly data may have seasonality problems. For example, the first quarterly data in one year may affect the next first quarterly data in the next year. The seasonality problem often appears in agricultural products. The spring and fall may have quite different results of agricultural products.

Here Jenkins, Reinsel (1994) and Choi (1992) provide method to decide how many lags should include in the model. They uses SCAN method. In this thesis, both methods are use to decide the numbers of lags in the unit root test.

Given a stationary or non-stationary time series  $\{x_t : 1 \leq t \leq n\}$  by using mean corrected form  $y_t = x_t - \mu$  with autoregressive order of p+d and with a true moving-average order of q. SCAN method can be used to analyze eigenvalues of the ARMA process.

For autoregressive test order  $h = p_{\min}, \dots, p_{\max}$  and moving- average test order  $j = q_{\min}, \dots, q_{\max}$ . Moving average test order  $l = q_{\min}, \dots, q_{\max}$  performs the following step.

1. Let  $Y_{h,t} = (x_t, x_{t-1}, \dots, x_{t-h})'$ . Computing the following  $(h+1) \times (h+1)$  matrix

$$\beta(h, l+1) = (\sum_t (Y_{h,t} - 1 Y_{h,t-1} - 1)')^{-1} (\sum_t (Y_{h,t} - 1 Y_{h,t-1} - 1)) \quad (7)$$

$$\beta^*(h, l+1) = (\sum_t Y_{h,t} Y'_{h,t})^{-1} (\sum_t Y_{h,t} Y'_{h,t-l-1}) \quad (8)$$

$$A^*(h, l) = \beta^*(h, l+1) \beta^*(m, l+1) \quad (9)$$

, where t ranges from h + l + 2 to n.

2. Find the smallest eigenvalue,  $\lambda^*(h, l)$ ,  $A^*(h, l)$  and its corresponding normalized eigen-vector  $\Phi_{h,l} = (1, -\Phi_1^{(h,l)}, -\Phi_2^{(h,l)}, \dots, -\Phi_h^{(h,l)})$ . The squared typical correlation estimate is  $\lambda^*(h, l)$ .
3. With the  $\Phi_{h,l}$  as AR (h) coefficients, obtain the residuals for t= h+l +1 to n, by following the formula:

$$w_t^{(h,l)} = y_t - \Phi_1^{(h,l)} y_{t-1} - \Phi_2^{(h,l)} y_{t-2} - \dots - \Phi_h^{(h,l)} y_{t-m}. \quad (10)$$

4. From the autocorrelations of the residuals,  $r_k(w)$ , the standard error of the squared correlation estimate by

$$\text{var}(\lambda^*(h, l) / 2) \approx \frac{d(h,l)}{(n-h-1)} \quad (11)$$

, where  $d(h, l) = (1 + 2\sum_{i=1}^{l-1} r_k(w^{(h,l)}))$ .

The test statistics uses in the method as an identification criterion is

$$C(h, l) = (n-h-1) \ln(1 - \lambda^*(h, l) / d(h, l)) \quad (12)$$

which is chi square  $\chi^2$  distribution if  $h = p + d$  and  $l \geq q$  or if  $h \geq p + d$  and  $l = q$ . If  $h > p$  and  $l < q$ , there is more than one zero correlation between  $Y_{h,t}$  and  $Y_{h,t-l-1}$ . Since  $\lambda^*(h, l)$  is the smallest correlations for each (h, l), the percentiles of  $c(h, l)$  are less than those of  $\chi^2$ . For  $h < p$  and  $l < q$ , no conclusions about the distribution of  $c(h, l)$  are made.

Bayesian information criterion (BIC) is a statistical method to provide the standard to select the best model. The Bayesian information criterion (BIC) is an asymptotic result derived under the assumptions that the data distribution is the one of the exponential families. Here is the equation as follows:

$$\text{BIC} = -2\ln(L) + k\ln(n) \quad (13)$$

Here in the equation above,  $n$  is the size of the sample.  $k$  is the number of free parameters to be estimated in the model.  $L$  is the maximum value of the likelihood function for the estimated model. Under the assumption that the model errors or disturbances are normally distributed, BIC equation becomes as follows,

$$\text{BIC} = n\ln\left(\frac{\text{RSS}}{n}\right) + k\ln(n) \quad (14)$$

The residual sum of square (RSS) is the residual sum of squares from the estimated model. Here in the thesis, RSS comes from the Augmented Dickey Fuller (ADF) test on the selected lags in ADF test model.

Given any two estimated models, the model with the lower value of BIC is the one to be preferred. The BIC is an increasing function of RSS and also an rising function of  $k$ , the number of free parameters to be estimated in the model. That means, unexplained variation in the dependent variable and the number of explanatory variables increase the value of the BIC.

In the thesis, the numerical values of the dependent variable which are the differences of the variables in the model are identical for all the estimates being compared. The BIC can be used to compare estimated models only when the numerical values of the dependent variable are identical for all the estimates being compared.

In the thesis, the extended sample autocorrelation function (ESACF) provides the method to identify the orders of a stationary and non-stationary ARMA process based on iterated least square estimates of the autoregressive parameters. Tsay and Tiao (1984) provide the technique of the ESACF method. Choi (1992) provides the useful descriptions of the algorithms.

Here in the thesis, given stationary or non-stationary time series  $\{z_t : 1 \leq t \leq n\}$  with mean corrected form  $\check{z}_t = z_t - \mu_z$  with autoregressive order  $p + d$  and with moving average order of  $q$ . In this thesis, the ESACF method is used to estimate the unknown order  $p + d$  and  $q$  through analyzing the autocorrelation functions with filtered series of the form:

$$w_t^{(m,j)} = \Phi_{(m,j)}(\beta) \check{z}_t = \check{z}_t - \sum_{i=1}^m \Phi_i^{(m,j)} \check{z}_{t-i} \quad (15)$$

where  $\beta$  is the backshift operator,  $m = p_{\min}, \dots, p_{\max}$  are autoregressive test orders, where  $j = q_{\min} + 1, \dots, q_{\max} + 1$  are moving average test orders, and where  $\Phi_i^{(m,j)}$  are autoregressive estimators under the assumption that the series is an ARMA  $(m, j)$  process.

The SCAN method and ESACF method provide the autoregressive orders and BIC test statistics result. The BIC results define the autoregressive orders for Augmented Dickey-Fuller (ADF) test. The number of the lagged differences in the thesis model can derive from the lowest BIC test statistics results. The autoregressive orders of the log transformed exchange rate ADF autoregressive order is one. The autoregressive orders of log transformed export difference in the ADF model are five. The autoregressive orders of the log transformed import difference in the ADF model are five. The autoregressive orders of the log transformed foreign exchange reserve difference in the ADF model are four. The autoregressive orders of the log transformed interest rate difference in the ADF model are thirteen.

The stationarity test will take the Augmented Dickey-Fuller (ADF) technique (Dickey and Fuller, 1981) which actually is auto-regression model in the following regression equation (Dickey and Fuller, 1981). The ADF test formula is as follows,

$$\Delta x_{j,t} = \sum_{k=1}^t \beta_{j,k} x_{j,t-k} + k_i x_{j,t-1} + \varepsilon_{k,t} \quad (16)$$

where  $\Delta x_{j,t}$  is the 1<sup>st</sup> differenced value of  $x_t$ ,  $k_i x_{j,t-1}$  is the 1<sup>st</sup> lagged value of  $x_t$ ,

$\sum_{k=1}^t \beta_{j,k} \Delta x_{j,t-k}$  are the 1<sup>st</sup>, 2<sup>nd</sup>, 3<sup>rd</sup>, 4<sup>th</sup>, & t<sup>th</sup> lagged value of the 1<sup>st</sup> differenced value of  $x$ , and  $\varepsilon_{k,t}$  is the error term.

The model hypothesis tests are: The Model is

$H_0$ : Non stationary

$H_1$ : Stationary

There is no trend in the ADF test. The graph of log transformed data shows that there is no significant trend for the dependent variable and independent variable. See Appendices Figure1. Scatter plot matrices of variables moving during the period in the model. In the thesis, the same methodology and technique is used for the ADF test. In the thesis, the dependent variable is  $y$  in the previous simple model. All the four independent variables substitute for  $x$  in above model.

The ADF test models in this thesis can use the same equation as equation (16) with the same method.  $k_i$  ( $i=1,2,3,4,5, \dots, n$ ) shows the coefficient of lag term which is one lag before the current term. The coefficient of one lag term  $k_i$  before current term is the mark in ADF test. Four ADF test models of independent variables in this thesis will be:

$$\Delta X_{j,t} = k_1 X_{t-1} + \sum_{k=1}^n \beta_{j,k} \Delta X_{j,t-k} + \varepsilon_{k,t} \quad (17)$$

$$\Delta M_{j,t} = k_2 Y_{t-1} + \sum_{k=1}^n \beta_{j,k} \Delta Y_{j,t-k} + \varepsilon_{k,t} \quad (18)$$

$$\Delta R_{j,t} = k_3 R_{t-1} + \sum_{k=1}^n \beta_{j,k} \Delta R_{j,t-k} + \varepsilon_{k,t} \quad (19)$$

$$\Delta I_{j,t} = k_4 I_{t-1} + \sum_{k=1}^n \beta_{j,k} \Delta I_{j,t-k} + \varepsilon_{k,t} \quad (20)$$

There are totally seven T test statistics values in each equation. The second coefficients  $k_1, k_2, k_3, k_4$ , which are the coefficient of first lag of independent variables

are the most important in the test. The T test statistics results of first lag value of independent variables are compared with the critical value in Augmented Dickey-Fuller test. The dataset in this thesis is quarterly series so stationary tests have to be conducted at level up to 5 lagged periods. The sixth independent variable in the ADF test is fourth lagged of the first difference which can show four quarters or one year ago the same quarter. When critical value is larger than test statistics results, the model fails to reject ADF hypothesis test. When the test statistics results are larger than critical values, the model rejects the null hypothesis. The ADF test statistics test results table is in Table 2.

The test statistics critical value with constant for 5% confidence interval is -2.79, for 1% confidence interval is -3.96, and for 10% interval is -2.57. The test statistics critical value with constant and time trend for 5% level is -3.41, for 1% level is -3.96 and for 10% level is -3.12. The test statistic value for X, M, R, I with constant are -0.68, -1.67, -3.80, -2.31. Here 5% level is chosen as confidence interval. The test statistical value of X, -0.68, is larger than -2.79 at level 5% which fails to reject the null hypothesis of unit root or non stationarity. Export difference (X) follows a non-stationary process. The test statistical value of import difference is -1.67 which is larger than -2.79 at level 5%. This result fails to reject the null hypothesis of non-stationarity of import difference (M) so there are no unit roots in import difference and export difference series. Import and export difference (X, M) follows non stationary process. The results of foreign exchange reserve difference (R) and interest rate difference rejects the null hypothesis. The test statistical value of foreign exchange reserve difference is -3.80 which is smaller than critical value, -2.79, at level 5%. The result rejects the null hypothesis of non stationarity. The test statistical value of interest rate difference (I) is -2.31 which is larger than critical value, -

2.79, at level 5%. The result fails to reject the null hypothesis of non stationarity. The conclusion is that foreign exchange reserve difference (R) follows stationary process at 5% level. In this case, there are unit roots for foreign exchange reserve difference. The export difference, the import difference and the interest rate difference follow non stationary process.

The test statistics critical value with constant and time trend for 5% confidence interval is -3.41, for 1% confidence interval is -3.96, and for 10% interval is -3.12. The test statistic value for X, M, R, I with constant are -3.22, -1.94, -3.73, -2.21. Here 5% level is chosen as confidence interval. The test statistical value of X, -3.22, is larger than -3.12 at level 10% which rejects the null hypothesis of unit root or non stationarity. Export difference (X) follows a stationary process. The test statistical value of import difference is -1.94 which is larger than -3.41 at level 5%. This result fails to reject the null hypothesis of non-stationarity of import difference (M) so there are no unit roots in import difference and export difference series. Import and export difference (I, M) follows non stationary process. The results of foreign exchange reserve difference (R) and export difference rejects the null hypothesis. The test statistical value of foreign exchange reserve difference is -3.73 which is smaller than critical value, -3.41, at level 5%. The result rejects the null hypothesis of non stationarity. The test statistical value of interest rate difference (I) is -2.21 which is larger than critical value, -3.41, at level 5%. The result fails to reject the null hypothesis of non-stationarity. The conclusion is that foreign exchange reserve difference (R) follows a stationary process at 5% level. The export difference (X) follows a stationary process at 10% level. In this case, there are

unit roots for foreign exchange reserve difference at 5% level. The import difference and the interest rate difference follow non stationary process.

The test statistics critical value with constant, lags of the difference and time trend for 5% confidence interval is -3.41, for 1% confidence interval is -3.96, and for 10% interval is -3.12. The test statistic value for X, M, R, I with constant are -2.97, -3.00, -3.84, -4.36. Here 5% level is chosen as confidence interval. The test statistical value of X, -2.97, is larger than -3.41 at level 10% which fails to reject the null hypothesis of unit root or non stationarity. Export difference (X) follows a stationary process. The test statistical value of import difference is -3.00 which is larger than -3.41 at level 5%. This result fails to reject the null hypothesis of non-stationarity of import difference (M) so there are no unit roots in import difference and export difference series. Import and export difference (X, M) follows non stationary process. The results of foreign exchange reserve difference (R) and export difference rejects the null hypothesis. The test statistical value of foreign exchange reserve difference is -3.84 which is smaller than critical value, -3.41, at level 5%. The result rejects the null hypothesis of non stationarity. The test statistical value of interest rate difference (I) is -4.36 which is larger than critical value, -3.41, at level 5%. The result fails to reject the null hypothesis of non stationarity. The conclusion is that foreign exchange reserve difference (R) follows a stationary process at 5% level. The interest rate difference (I) follows a stationary process at 1% level. In this case, there are unit roots for foreign exchange reserve difference at 5% level. The import difference and the interest rate difference follow non stationary process.

The dependent variable, exchange rate is also a time series variable. There may be a unit root in exchange rate  $\ln e$  series. Under the same hypothesis as independent variables, another ADF test is to test stationarity of dependent variable.

$$\Delta \ln e_{t,j} = \alpha_5 \ln e_{t-1} + \sum_{k=1}^n \beta_{j,k} \Delta \ln e_{j,t-k} + \varepsilon_{k,t} \quad (21)$$

The test statistics value with constant is -0.99 which is also greater than critical value -2.79 at level 5%. The test statistics value with constant and time trend is -2.12 which is larger than critical value at any level. The BIC help the ADF to pick eleven lags. The test statistics result with constant, time trend and lags is -2.76. The market equilibrium exchange rate is following a non-stationary process so there is no unit root in market equilibrium exchange rate. The test statistics result table in Table 2.

The residual plots of ADF test show that in some periods these independent variables are riskier than others because the variance in some periods is larger than others. In this case, the expected values of error terms are greater than others. There may be heteroskedasticity in the error variance. The independent variables in this thesis have very large error variance. The residual plot of shows the amplitude of the returns varies over time which is described as “volatility clustering”. See Appendix Figure 11, Figure 12, Figure 13, Figure 14, and Figure 15.

The variables in the model are non stationary process. The residual is non stationary. The standard ordinary least square regression result does not hold. The standard ordinary least square regression gives spurious results. The exchange rate and import difference are following a difference stationary which is also called I (1). The foreign exchange reserve difference, export difference and interest rate difference are following stationary process, which are called I(0).

The ordinary least square (OLS) regression can give best linear unbiased estimation (BLUE) when all the variables in the model are stationary. In the thesis, exchange rate, export difference, import difference are difference stationary, I (1). Foreign exchange reserve difference and interest rate difference are stationary, I (0). The model can use exchange rate difference ( $\Delta e$ ), difference of export difference ( $\Delta X$ ), difference of import difference ( $\Delta M$ ), foreign exchange reserve difference (R), and interest rate difference (I).

$$\Delta e = f(\Delta X, \Delta M, R, I) \quad (22)$$

$$\Delta e = -0.021^* + 0.055\Delta X + 0.27\Delta M^{**} + 0.00083R - 0.0038I^{**} + \varepsilon_t \quad (23)$$

(0.013)   (0.059)   (0.081)   (0.0033)   (0.0019)

The regression result shows that import difference has the strongest positive effect in the model. The coefficient of the difference of the foreign exchange reserve difference is very small. If there is one percent change in foreign exchange reserve, exchange rate difference will only move 0.083 percent. Trade variables have strong linear relationship with dependent variable. If there is an increase in import difference about 1 percent, exchange rate will increase 27 percent. The sign of interest rate difference should be positive in the model. The unexpected inflation will have negative effect on exchange rate. If there is one percent increase in interest rate, the exchange rate will decrease 0.38 percent which shows very tiny effect on exchange rate.

The residuals of each variable in the model may have the autocorrelation. The most common test for autocorrelation is Durbin-Watson test. The assumption of Durbin-Watson test is that the noise or disturb terms are stationary and normally distributed with mean zero.

$$H_0: \rho = 0$$

$H_a: \rho \neq 0$

The residual correlation in the regression is  $\rho$ . The null hypothesis is that the errors or noise terms are uncorrelated. The alternative hypothesis is that error terms have correlation following AR(1) process. To test  $H_0$  against  $H_a$ , get the least square estimator  $\beta$  and residuals  $e_1, e_2, e_3, \dots, e_n$ . The test statistics is as follows:

$$d = \frac{\sum_{t=2}^n (e_t - e_{t-1})^2}{\sum_{t=1}^n e_t^2} \quad (24)$$

where  $e_i = y_i - \hat{y}_i$  and  $y_i$  is the observed values of the response variable for individual  $i$ .  $\hat{y}_i$  is the predicted values of the response variable for individual  $i$ .  $d$  decrease as the serial correlations increase. Upper and lower critical values,  $d_U$  and  $d_L$  have been tabulated for different value of  $k$  which is the number of explanatory variables in the model and  $n$ .

Durbin Watson test result in the model is 2.16. The critical value for the lower is 1.68, and the critical value of the upper is 1.80. In the model,  $d = 2.16$  is larger than the upper critical value, 1.80. The test statistics result fails to reject the null hypothesis. So there is no serial correlation in the model.

The residuals may have heteroskedasticiy in the model. The ARCH model can be used to test heteroskedasticity. The ARCH model which is autoregressive conditional heteroskedasticity is designed to deal with this heteroskedasticity.

The model in this thesis explain ARCH(1) model for dependent variable  $\ln e$  and independent variables  $X, M, R, I$ . The model explains “ $y$ ” which represents means of  $\ln e$ ,  $X, M, R, I$ , mean equation using AR(1) model.

$$y_t = c + \phi y_{t-1} + u_t \quad (25)$$

$$\text{Var}(u_t | \Omega_{t-1}) = h_t \quad (26)$$

$\text{Var}(u_t | \Omega_{t-1})$  is the conditional variance of  $u_t$ , where  $\Omega_{t-1}$  is the information set available at  $t - 1$ .

The model explains the conditional variance:

$$h_t = \omega + \alpha_1 u_{t-1}^2 + \dots + \alpha_q u_{t-q}^2 \quad (27)$$

These two equations (25) and (26) can consist of AR (1)-ARCH(Q) model which is AR(1) Mean and ARCH(Q) Variance equations.

So ARCH (1) model is as follows:

$$h_t = \omega + \alpha_1 u_{t-1}^2 \quad (28)$$

The ARCH (1) model in this thesis is test the heteroskedasticity of the residuals in every ADF test model. The error term can be expressed in this thesis by the past values of lagged residuals:

$$\varepsilon_t^2 = a_0 + a_1 \varepsilon_{k,t-1}^2 \quad (29)$$

The hypothesis test of ARCH model is as follows:

$$H_0: a_0 = a_1 = 0$$

$$H_1: a_0 \neq 0 \text{ or } a_1 \neq 0$$

Here in the thesis T test and F test statistics test the ARCH effect of the residual. In the thesis, ARCH (1) model is built to test the heteroskedasticity. The lag order for ARCH model is one. The F test critical value of the model is 3.90. F test statistics result is 0.54 which is greater than critical value ( $F_{1,150} = 3.90$ ). The test result fails to reject the null hypothesis of no ARCH effect. The T test results of variance one lag before is -0.73 which is larger than critical value 1.65. The test result fails to reject the null hypothesis of no ARCH effect. There are no ARCH effects of the residual in the model. See Table 3.

## Chapter V

### Empirical Results

The regression model in this thesis is based on the factors that affect the exchange rate market. The Durbin-Watson test result is 2.16, which is larger than the upper critical value of 1.80. There is no serial correlation if the Durbin-Watson test result is between 1.80 and 2.20. Here, in the thesis, the Durbin-Watson test result of the OLS regression is in the interval. The test statistics result fails to reject the null hypothesis of no serial correlation in the residuals. So error terms have no serial correlation. There is no stationarity of  $e$ ,  $X$  and  $M$ , which means that these three variables in this regression model are not following a stationary process. The exchange rate, the export difference, and import difference are following a difference stationary process. The regression model with all stationary variables, which are three difference variables and two level variables, is based on a stationary variable. The regression model is:

$$\Delta e = -0.021^* + 0.055\Delta X + 0.27\Delta M^{**} + 0.00083R - 0.0038I^{**} + \varepsilon_t \quad (30)$$

(0.013)    (0.059)    (0.081)    (0.0033)    (0.0019)

The statistics result shows that  $R^2$  is 84%. There is a very significant linear relationship according to the goodness and fitness test. The explanatory variables in the model can explain 84% of the dependent variable, which is the exchange rate difference. The test statistics result shows that two of the coefficients of independent variables are very significant. Only the difference of the export difference, which is the difference of Japanese export and US export difference, and the difference of the foreign exchange reserve are less significant than other variables. The results show that foreign exchange reserve is not the effective method to intervene the foreign exchange market. The t test

result of the intercept provides the evidence to reject the null hypothesis of zero intercept. The small intercept of the regression model show that there are not much unexplained information in the model. The linear regression results are very significant in test statistics.

This thesis use Bayesian information criterion (BIC) to derive the number of the lags of the first difference of variables in ADF test model to test stationarity of variables in the model. The technique in SAS programming to run ADF test provides “best fit” mathematic equation. The dependent variable is the first difference of every variable in the thesis model and independent variables are the number of previous lagged value of the first difference defined by BIC method in the model. Here every variable in the model includes the dependent variable,  $e$ , independent variables such as  $X$ ,  $M$ ,  $R$ , and  $I$ . The test results prove non-stationary process for exchange rate, import difference and export difference. The test statistics provide a path to fail to reject the null hypothesis for 5% level -3.41. The test statistics values of export difference and import difference are -2.97, -3.00 which are larger than critical value of 5% level, so export difference ( $X$ ) and import difference ( $M$ ) are following non-stationary process. The test statistical value of foreign reserve difference ( $R$ ) and interest rate difference ( $I$ ) are -3.84,-4.36 which are larger than critical value -3.41 at level 5%, so foreign exchange reserve difference and interest rate difference are stationary process for rejection of the null hypothesis. There are unit roots of foreign exchange reserve difference and interest rate difference in ADF test model.

There is linear relationship among trade variables and dependent variable, exchange rate. Export and import are two main effective variables in foreign exchange rate market for the higher coefficients than other independent variables. Japan and United States can

get counterpart currencies from exports and imports. If one country imports or exports products in international commerce, the market equilibrium will move upward or downward for the changes of money supply and demand. The exchange rate will appreciate or depreciate. The rise of US imports and Japanese exports will increase the demand of the quantity of Japanese yens in the foreign exchange rate market. When one percent of import changes in the market, 27% change in the market equilibrium exchange rate. If the US exports and Japanese imports rise, the supply of quantity of Japanese yens will increase the supply of quantity of US dollars. The rising one unit of export in the market, the market equilibrium exchange rate increases by 5.5%. Comparing with export difference, import difference plays a more important role on market equilibrium exchange rate.

The foreign exchange reserve is not an effective tool to stabilize the exchange rate. Compared with monetary policy, official intervention is less effective than monetary policy on the exchange rate. That is the reason why some European countries set the upper and lower band for the exchange rate. Now the Central bank of European Union set the upper and lower band of the euro. Central banks sell their domestic currencies when the currency is appreciate or overvalued and buy their currencies when the currency is undervalued. One percent increases in foreign exchange reserve, the market equilibrium exchange rate might only move upward 0.083%. In fact, there is no significant effect. This result is consistent with the opinion that official intervention will not affect a floating exchange rate.

Interest rate difference has negative relationship with the dependent variable, market equilibrium exchange rate. When one country increases its discount rate, the stronger

currency will bring lower exchange rate for indirect exchange rate. In this model, when Japanese economics becomes stronger and better than before what it was, the exchange rate yen per dollar depreciates. Stronger yen lower the exchange rate yen per dollar.

Interest rate can be changed when central banks increase or decrease money supply in the financial market. In the long term, monetary policy is not an effective tool in exchange rate market. If the countries are under uncovered exchange rate system, the increase in domestic interest rate will decrease the exchange rate. When interest rate is increasing, more and more foreign capital moves to the country. The exchange rate will decrease. In floating exchange rate market, the domestic will appreciate. These shocks in exchange rate market will not hold for a long time. In the long run, the exchange rate will reach its own equilibrium which reflects countries' economic fundamentals. The coefficient of interest rate difference is 0.38% which means that one percent change in the interest rate difference will change the market equilibrium exchange rate 0.38%. That is why some economists agreed that interest rate movement or monetary policy will not change the exchange rate that much. The exogenous variable, interest rate difference, is not significant in the result.

Lagged transformation function is a transfer function with the effects of the independent variables processes transferred onto an AR(1) process of the endogenous variable, the dependent variable in the model, which is  $e_t$  in the thesis. The second order LTM is

$$\Delta e_t = f(\Delta e_{t-1}, \Delta X_t, \Delta X_{t-1}, \Delta M_t, \Delta M_{t-1}, R_t, R_{t-1}, I_t, I_{t-1}) \quad (31)$$

Estimated results are

$$\Delta e_t = -0.022^* - 0.20\Delta e_{t-1}^{**} + 0.11\Delta X_t - 0.12\Delta X_{t-1}^{**} + 0.36\Delta M_t^{***} - 0.094\Delta M_{t-1}$$

(0.013)      (0.10)      (0.067)      (0.059)      (0.086)      (0.088)

$$\begin{array}{cccc}
-0.0011R_t + 0.0021\Delta R_{t-1} - 0.0082I_t^* + 0.0042I_{t-1} + \varepsilon_t & & & (32) \\
(0.0072) & (0.0071) & (0.0048) & (0.0049)
\end{array}$$

The lagged transformation function combines the contemporaneous independent effect from  $\Delta X_t$ ,  $\Delta M_t$ ,  $R_t$ ,  $I_t$  and the lagged effects of  $\Delta X_{t-1}$ ,  $\Delta M_{t-1}$ ,  $R_{t-1}$ ,  $I_{t-1}$ . The total effect  $\Delta X_t$  on  $\Delta e_t$  over two periods is -0.01. The total effect  $\Delta M_t$  on  $\Delta e_t$  over two periods is 0.27. The total effect  $R_t$  on  $\Delta e_t$  over two periods is 0.0010. The total effect  $I_t$  on  $\Delta e_t$  over two periods is -0.0040.

The residual in the lagged transformed model should be white noise given the difference variables. Durbin-Watson test is only applicable to the first order autoregressive systems. Durbin-h test is applicable when there are endogenous lagged variables in the model.

When there is one or more lagged dependent variables in the model, the Durbin-Watson test statistics will be biased toward 2 which mean that even if the test result is 2 there may be serial correlation. This test for serial correlation when there is a lagged independent variable in the equation based on h test.

Suppose there is an estimated model with OLS:

$$Y_t = \alpha + \gamma X_t + \beta Y_{t-1} + \varepsilon_t \quad (33)$$

The Durbin h statistics is defined as:

$$h = \hat{\rho} \sqrt{\frac{T}{1 - T[\text{Var}(\hat{\beta})]}} \quad (34)$$

where T is the number of observations, where  $\hat{\rho}$  is the estimated correlation coefficient of the residuals, that is the autocorrelation coefficient of the residuals, and where The  $\text{Var}(\hat{\beta})$  is the variance of the coefficient on the lagged dependent variable.

Solve for  $\hat{\rho}$ , substitute, and write the h statistics as:

$$h = \left(1 - \frac{DW}{2}\right) \sqrt{\frac{T}{1 - T[Var(\hat{\beta})]}} \quad (35)$$

Durbin has shown that the h statistics is approximately normally distributed with a unit variance, hence the test for first order serial correlation can be done with the standard normal distribution. It should be noted, however, that if  $T[Var(\hat{\beta})]$  is greater than one, then the ratio with the square root becomes negative and this test cannot be applied. So the test is normal distribution Z test and the null hypothesis is that  $\rho = 0$ .

If the Durbin h test result is within the interval (-1.96, 1.96), there is no serial correlation in the residual. Durbin h test result of the lagged transformation function is -0.75 which in the interval. The test result fails to reject the null hypothesis. There is no serial correlation in the residual.

The total effect of export difference  $\Delta X_t = 0.11 - 0.12 = -0.01$ . The total effect of import difference  $\Delta M_t = 0.36 - 0.094 = 0.35$ . The total effect of foreign exchange reserve difference  $\Delta R_t = -0.0011 + 0.0021 = 0.0010$ . The total effect of interest rate difference  $I_t = -0.0082 + 0.0042 = -0.0040$ .

The standard deviation of the total effect model with rules of error propagation is derived by the following equation. Assume  $\gamma$  is the coefficient of the total effect model

$$\begin{aligned} \gamma = \alpha \pm \beta &\quad \Rightarrow \quad \sigma_\gamma = (\sigma_\alpha^2 + \sigma_\beta^2)^{.5} \\ \gamma = \alpha\beta \text{ or } \gamma = \alpha/\beta &\quad \Rightarrow \quad \sigma_\gamma = \gamma((\sigma_\alpha/\alpha)^2 + (\sigma_\beta/\beta)^2)^{.5} \end{aligned} \quad (36)$$

The standard deviation for each variable in the equation (32) and equation (36) can be derived from standard error times the squared root of the number of the observations.

The standard error of the variables in the total effect model can be calculated by using equation (36).

The standard error (SE) of the export difference  $\Delta X_t$  in the total effect model is 0.089. The standard error (SE) of the import difference  $\Delta M_t$  in the total effect model is 0.12. The standard error (SE) of the foreign exchange reserve difference  $R_t$  in the total effect model is 0.010. The standard error (SE) of the interest rate difference  $I_t$  in the total effect model is 0.0069.

The total effect model is as follows:

$$\Delta e_t = -0.022^* - 0.01\Delta X_t + 0.27\Delta M_t^{**} + 0.0010R_t - 0.0040I_t + e_t \quad (37)$$

$$(0.013) \quad (0.089) \quad (0.12) \quad (0.010) \quad (0.0069)$$

The total effect model provides the strong evidence in the economic theory. The total effect model shows that the coefficient of foreign exchange reserve ratio is 0.0010 which is approximately zero. In the difference total effect model, the result shows that the foreign exchange reserve has no effect in foreign exchange rate market. The activity of central banks or monetary authorities which try to adjust the foreign exchange reserve will not influence the exchange rate in the long run. The export difference and import difference are the two main factors in the market equilibrium exchange rate equation. The movement of exports and imports will affect the market equilibrium exchange rate in the long run. Interest rate is the exogenous variable in the model. Interest rate shows the negative effect on the market equilibrium exchange rate. If there is inflation in Japan, yen will depreciate in the exchange rate market. Inflation will increase the nominal interest rate. The intercept in the total effect is still insignificant that the result fails to reject the

null hypothesis of no intercept. The total effect model can explain all the differenced variables in the model.

## **Chapter VI**

### **Conclusion**

This thesis analyzes the exchange rate between Japan and United States. The model reflects the influence of exports, foreign exchange reserves, and interest rates on the exchange rate. These independent variables have direct or indirect effects on exchange rate. The exchange rate is very volatile and difficult to determine. This thesis builds the general outline of an empirical floating exchange rate model.

The thesis addresses the main factors in the exchange rate market. Export and import are main two economic factors influencing the exchange rate. The import difference is the most effective factor of all variables in the model. Export provides the foreign income in international trade for goods and services. The United States as a buyer and Japan as a buyer purchase from each other. The supply and demand of foreign exchange moves the market equilibrium exchange rate upward or downward due to the import and export activities. The coefficient of export shows the positive effect in the exchange rate model. In theory the coefficient should be negative. In the total effect model, the negative coefficient shows the negative relationship between export difference and exchange rate. When Japanese firms sell products to buyers in United States, Japanese firms earn US dollars in exchange rate market.

Central banks would like to stabilize the exchange rate. They increase or decrease the money supply of their own currency. This is an indirect tool to affect exchange rate because the money supply will bring inflation to economic systems. There are many

papers on the issue of whether monetary policy has little effect on exchange rate. In the present results, the coefficient of the foreign exchange reserve is zero.

The negative coefficient of interest rate difference means that the increase in the interest rate difference will decrease in the market equilibrium exchange rate. The increase in the interest rate will lead to a reduction in the demand for money. Domestic money supply increases will lead to a fall in the equilibrium interest rate. The monetary policy shock should cause a depreciation of the domestic currency. The interest rate is the exogenous variable in the market equilibrium exchange rate equation. The thesis subtracts the interest difference as the monetary policy variable in the model. The low coefficient of interest rate difference in the model shows that monetary policy is not the method to control the volatility of exchange rate.

Central banks can buy or sell domestic currency or government bonds to stabilize the exchange rate. The volatility of exchange rate is risky to export or import in international trade. The appreciation of exchange rate will let export firms lose sales. On the contrary, the depreciation of exchange rate will make export companies obtain more sales.

Some economists argue that floating exchange rate system is better than fixed exchange rate. The flexible exchange rate system can automatically adjust and enable countries to dampen the impact of shocks and foreign business cycle. It will also reduce the crisis of balance of payment. When appreciation or depreciation occurs, central bank and monetary authorities intervene to manage the float. In the model, the coefficient is very low which shows that foreign exchange reserves are not an effective tool to control the exchange rate.

Finally the analysis in this thesis model proves the total effect of the model in the long run. Independent variables such as exchange rate, export difference, and import difference are individually non stationary. Foreign exchange reserve difference and the interest rate difference are stationary. The model is based on difference stationary variables which are exchange rate, export difference, and import difference. Level stationary variables are foreign exchange reserves and interest rate difference. The coefficient in the lagged transformation function shows adjustment to the equilibrium in the long run.

The coefficient of the foreign exchange reserve difference in lagged transformation function model is negative. The coefficient of the foreign exchange reserve difference in the total effect model is positive, the same as the result in the regression model. The very low coefficient of the foreign exchange reserve difference is insignificant. This shows that foreign exchange reserves in the exchange rate market fail to influence the exchange rate in the present sample.

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## Appendix

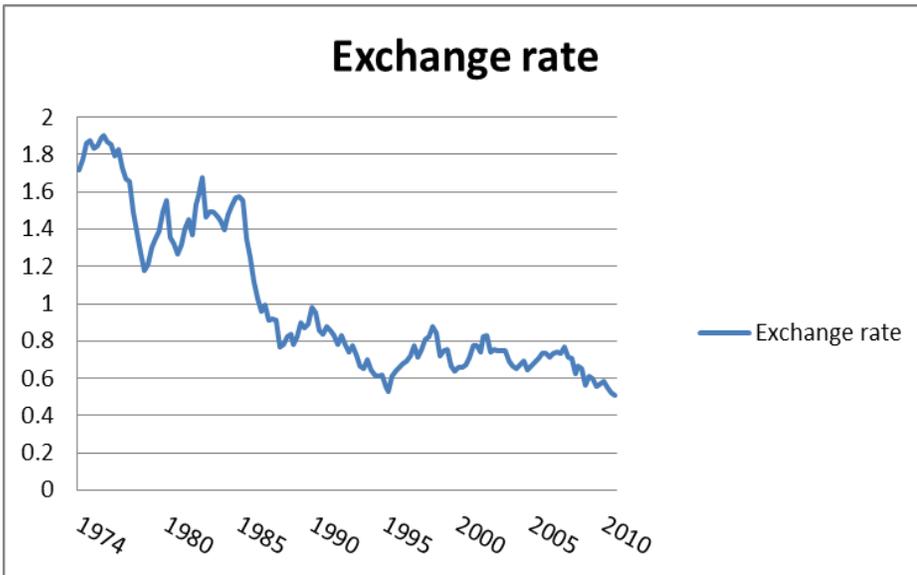


Figure 1. Exchange rate time plot from 1974 to 2010

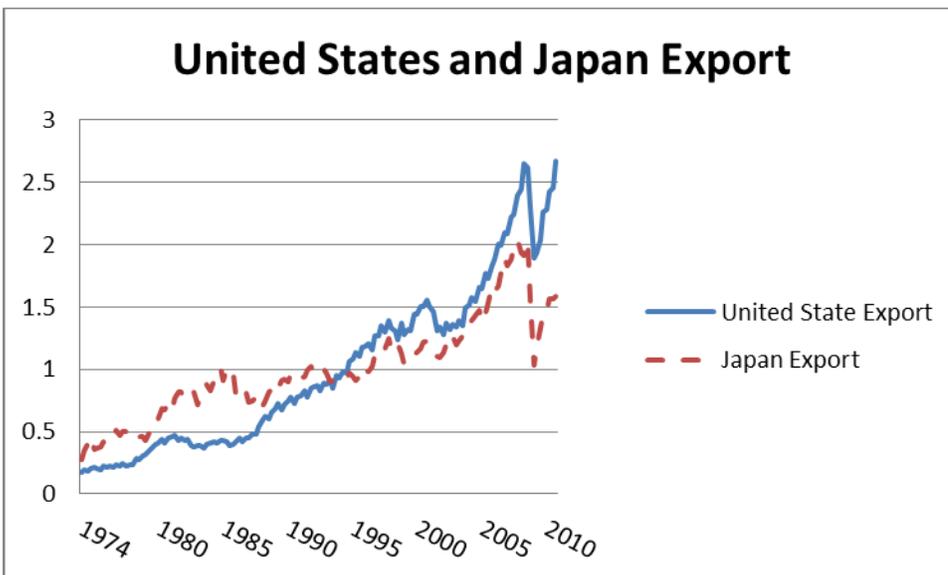


Figure 2. Export time plot from 1974 to 2010

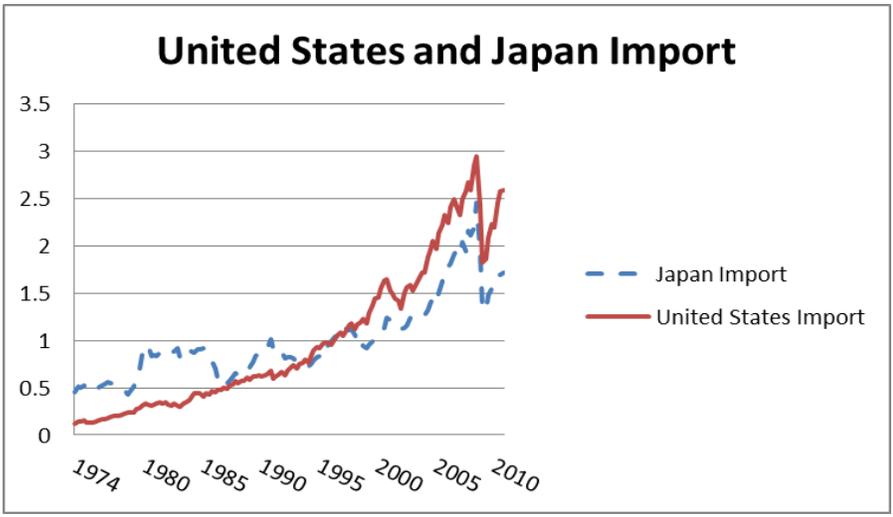


Figure 3. Import time plot from 1974 to 2010

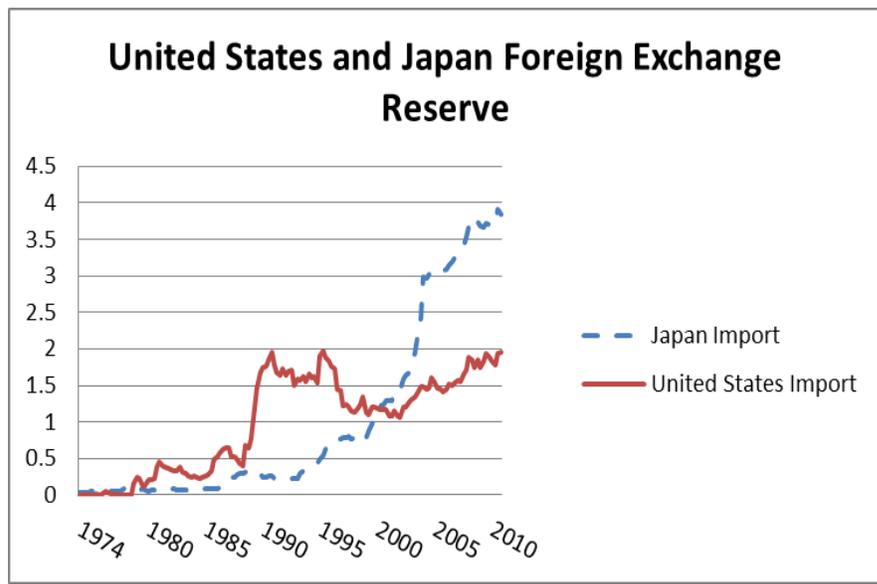


Figure 4. Foreign Exchange time plot from 1974 to 2010

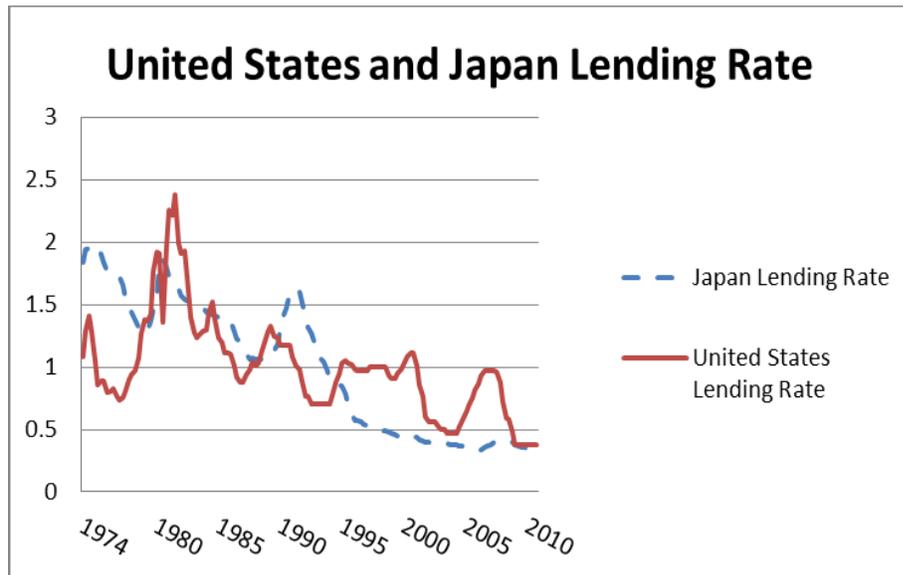


Figure 5. Lending rate time plot from 1974 to 2010

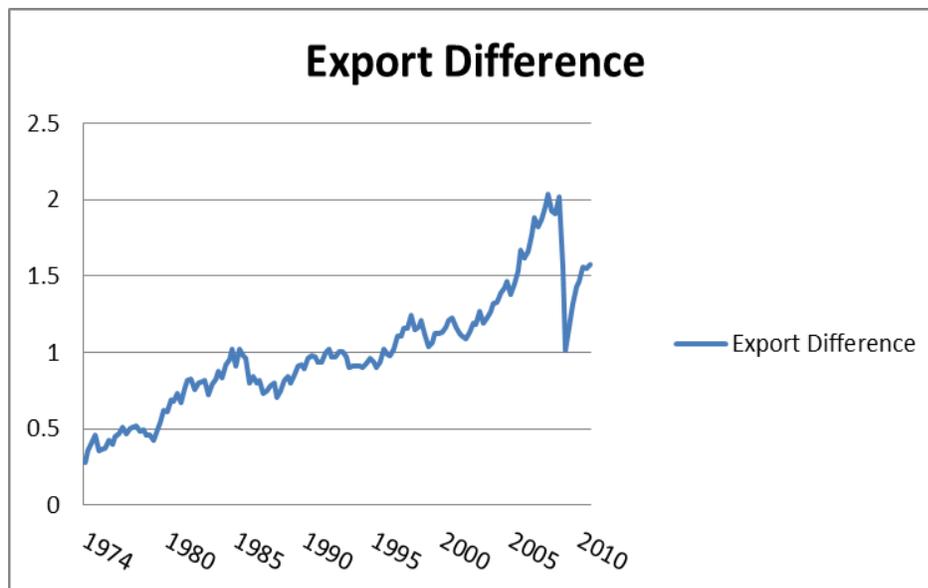


Figure 6. Export difference time plot from 1974 to 2010

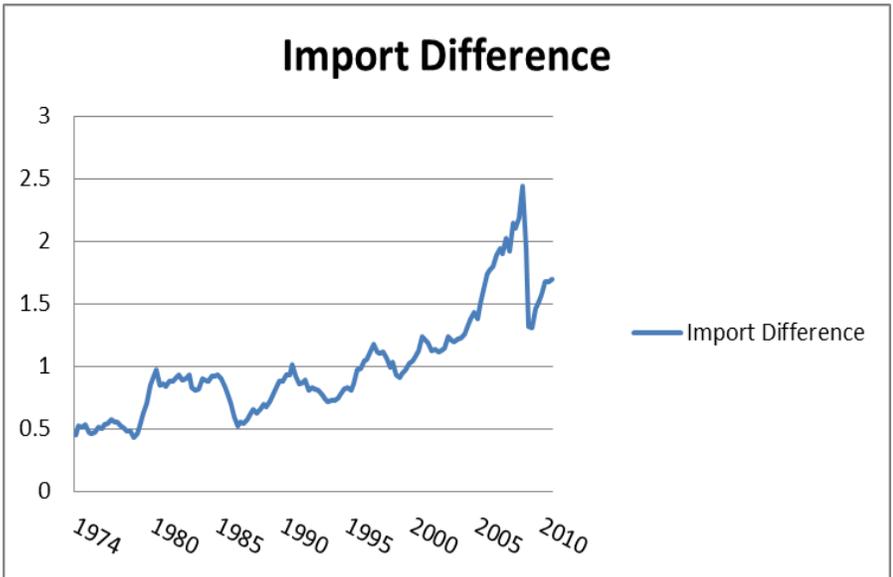


Figure 7. Import difference time plot from 1974 to 2010

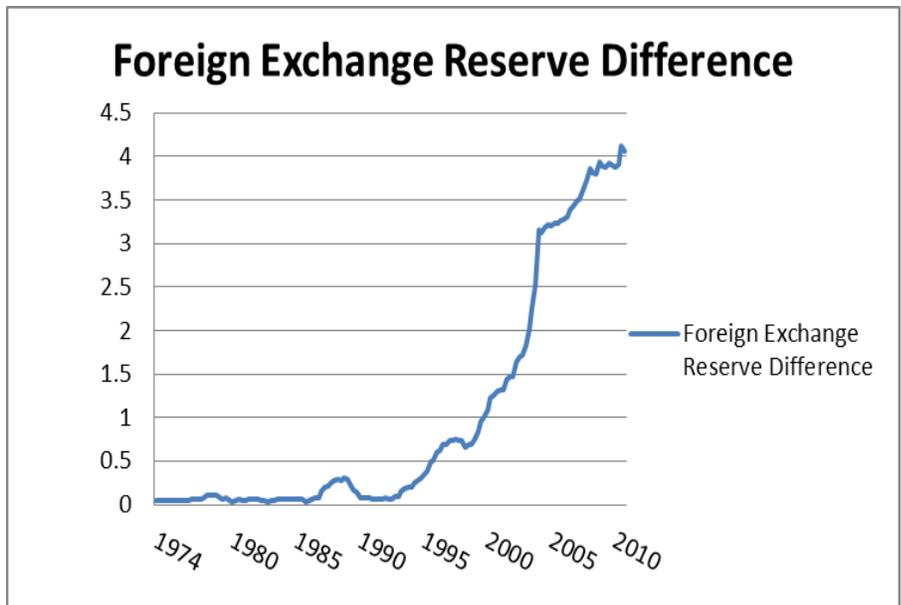


Figure 8. Foreign Exchange Reserve difference time plot from 1974 to 2010

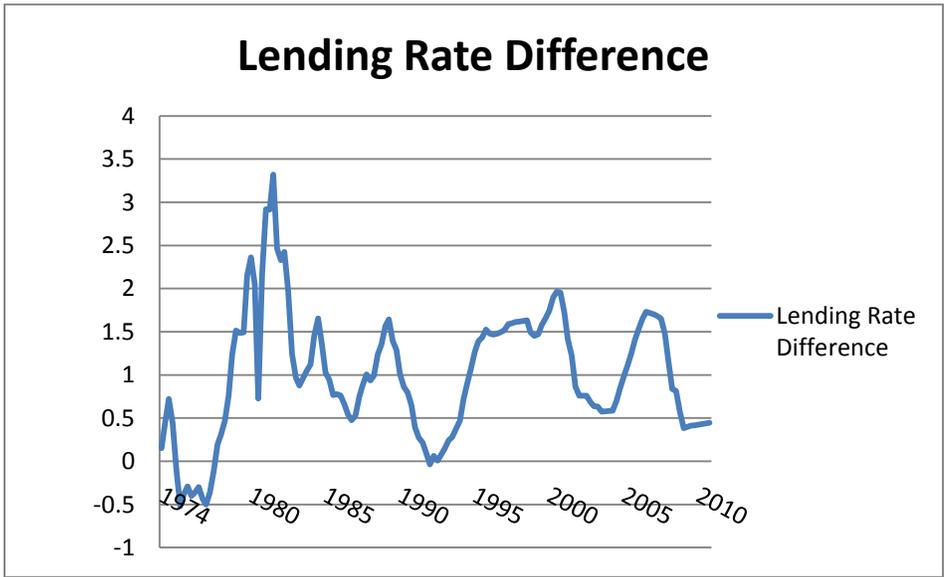


Figure 9. Lending rate Difference time plot from 1974 to 2010

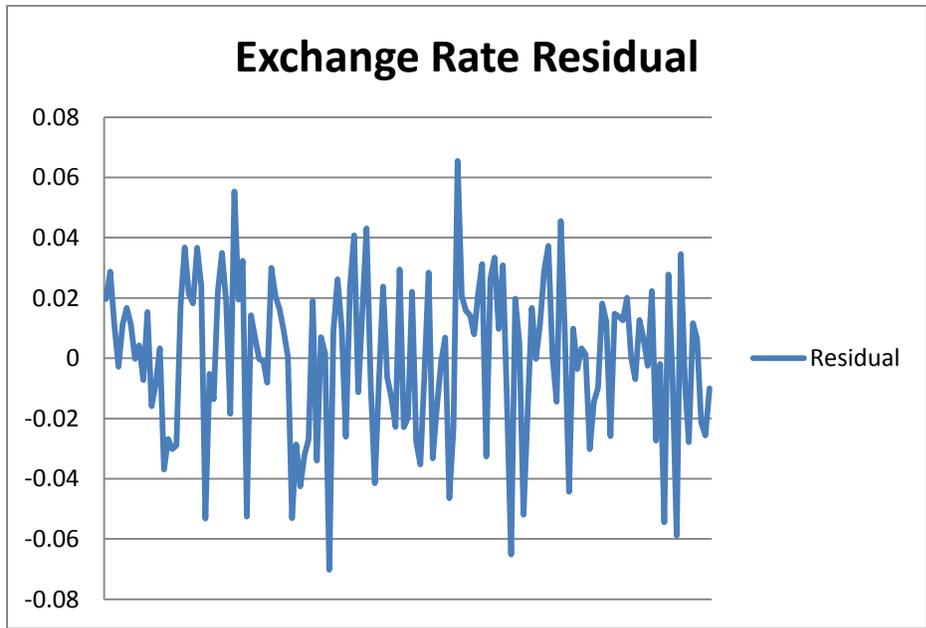


Figure 11. Market equilibrium exchange rate residual plot

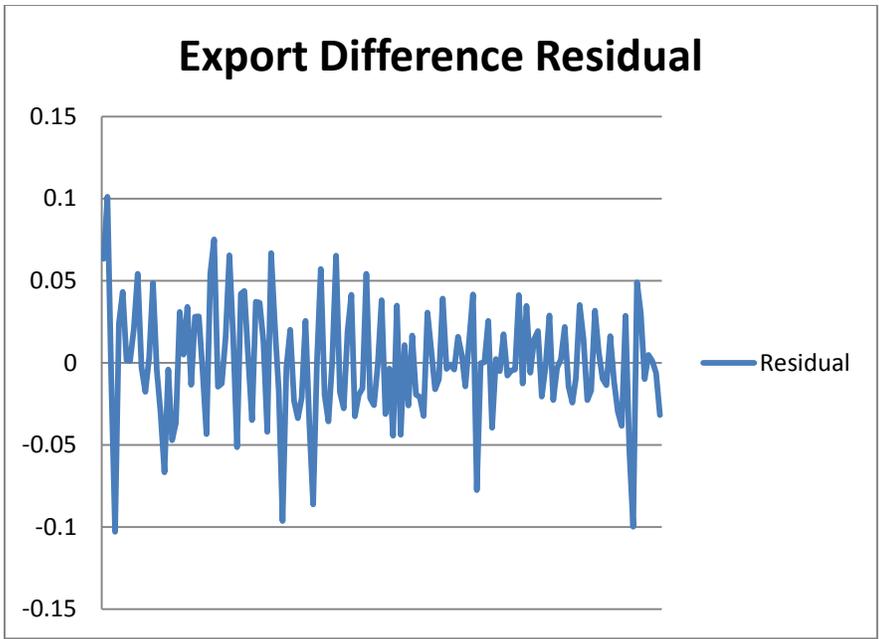


Figure 12. Export difference residual plot

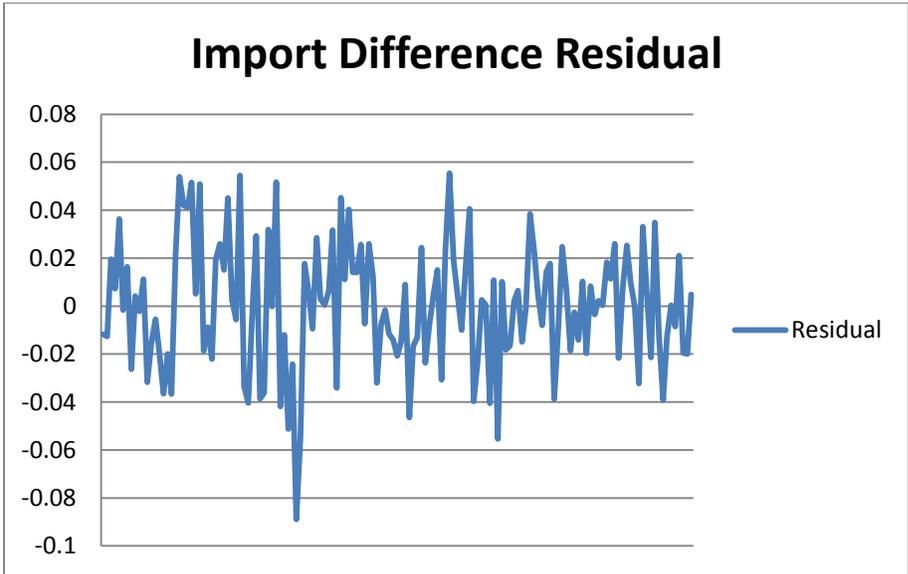


Figure 13. Import difference residual plot

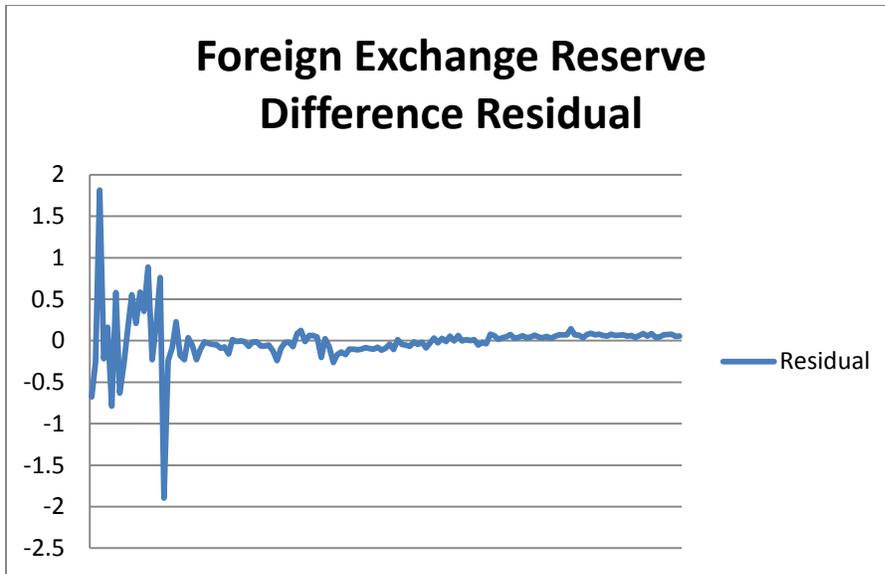


Figure 14. Foreign reserve difference residual plot

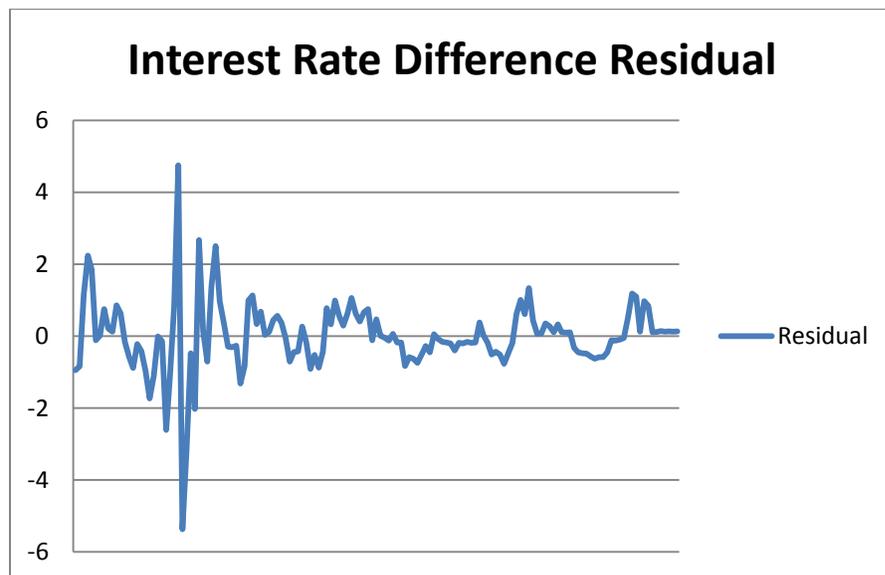


Figure 15. Interest rate difference residual plot

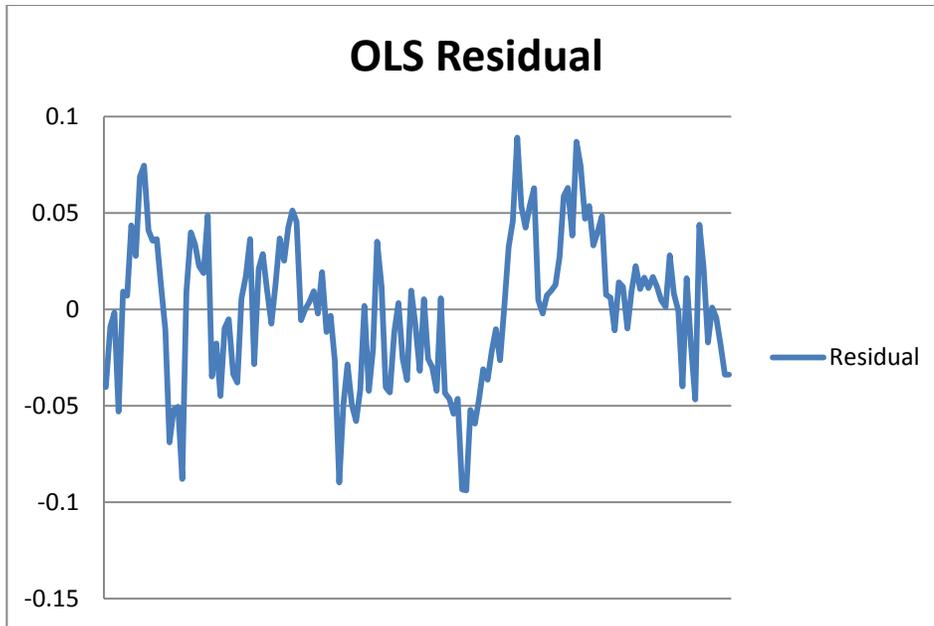


Figure 16. Ordinary Least Square(OLS) residual plot

**Table1. SCAN ESACF Result Table**

Variable	SCAN		BIC	ESACF		BIC
	p + d	q		p+d	q	
Exchange rate (e)	1	3	-5.58	4	2	-5.53
	4	0	-5.58	1	3	-5.58
	3	2	-5.49	2	3	-5.55
	1	0	-5.60	3	3	-5.53
				5	2	-5.50
Export Difference (X)	p+d	q		p+d	q	
	5	0	-5.51	3	4	-5.45
	4	3	-5.40	4	4	-5.43
			5	4	-5.52	
Import Difference (M)	p + d	q		p + d	Q	
	3	0	-5.57	1	0	-5.59
	1	4	-5.56	3	1	-5.53
Foreign exchange reserve (R)	p + d	q		p + d	q	
	2	0	-1.41	3	2	-1.37
	4	0	-1.43			

Interest rate	p + d	q		p + d	q	
(I)	2	0	-0.11	5	4	-0.011
	3	4	0.0060	1	5	-0.016
	1	5	-0.016	2	5	-0.014
				3	5	0.014

**Table 2. Augmented Dickey- Fuller Test Results**

Variable	ADF <sub>c</sub>	ADF <sub>c,t</sub>	ADF <sub>c, t, lag</sub>
Exchange rate (e)	-0.99	-2.12	-2.76
Export difference(X)	-0.68	-3.22*	-2.97
Import Difference (M)	-1.67	-1.94	-3.0
Foreign Exchange Reserve (R)	-3.80***	-3.73**	-3.84**
Interest Rate ( I)	-2.31	-2.21	-4.36***

Note: In the thesis, ADF tests for each variable are single mean, constant with time trend. SAS output provides the test statistical results with trend and constant. Critical values with constant and time trend are 10% level -3.12, 5% level -3.41, 1% level -3.96. Critical values with constant only are 10% -2.57, 5% level -2.86, 1% level -3.43.

**Table3. Ordinary Least Square (OLS) Result**

Intercept	-0.021 (0.013)
$\Delta X$	0.055 (0.059)
$\Delta M$	0.27** (0.081)
R	0.00083 (0.0033)
I	-0.0017** (0.00081)
$R^2$	0.85
ARCH (1)	ARCH <sub>F</sub> test: 0.53 ARCH <sub>t</sub> test: -0.73
Durbin Watson test	2.16

\* Significant at the 10% level

\*\* Significant at the 5% level

\*\*\*Significant at the level 1% level

**Table 4. Lagged transformation Model (LTM) Result**

Variable	Coefficient
Intercept	-0.022* (0.013)
$\Delta e_{t-1}$	-0.20** (0.10)
$\Delta X_t$	0.11 (0.067)
$\Delta X_{t-1}$	-0.12 (0.059)
$\Delta M_t$	0.36*** (0.086)
$\Delta M_{t-1}$	-0.94 (0.088)
$R_t$	-0.0010 (0.0072)
$R_{t-1}$	0.0021 (0.0071)
$I_{t-1}$	-0.0082 (0.0048)
$I_{t-1}$	0.0042 (0.0049)
$R^2$	0.81
Durbin h test	-0.75
ARCH	ARCH <sub>F</sub> 0.32 ARCH <sub>T</sub> -0.57

\* Significant at the 10% level

\*\* Significant at the 5% level

\*\*\*Significant at the level 1% level

**Table 5. Total Effect Table**

Variable	Coefficient
Intercept	-0.022 (0.013)
X	0.010 (0.089)
M	0.27** (0.12)
R	0.0010 (0.01)
I	-0.0040 (0.0069)

\* Significant at the 10% level

\*\* Significant at the 5% level

\*\*\*Significant at the level 1% level