

**ESSAYS ON CENTRAL BANK INTERVENTIONS
IN ADVANCED AND EMERGING MARKET ECONOMIES
AN APPLICATION TO JAPAN AND TURKEY**

by

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ABSTRACT

Essays on central Bank Interventions in Advanced and Emerging Market Economies

by

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Despite the move to floating exchange rates after the breakdown of the Bretton Woods system in 1973, Foreign Exchange Intervention (FXI) remains a commonly used tool for influencing exchange rates in most developed economies as well as emerging markets. The objective of this study is threefold which can be seen in my separate essays.

The first objective is to survey the literature on FXI. In my first essay I provide sections on the theoretical channels through which FXI might affect exchange rates, and critically analyze empirical literature on the effectiveness and motivation of intervention in both advanced and emerging markets.

The second objective is to perform a comprehensive empirical study on the FXI in Japan as an example of an advanced economy. In my second essay, I test whether model specification, frequency, and size of intervention produce different impacts of the effectiveness of FXI. I find that model specification yields varying impacts of the effectiveness of FXI. In particular, it is misleading to generalize results obtained from the simple GARCH model because the effectiveness of FXI is highly dependent on the employed model. The explicit distinction between the impact of the frequency and size of intervention provides an accurate measure of the effect of each factor on the exchange rate. This is in contrast to current studies of the Japanese FXI that only rely on the

different patterns intervention in testing its effectiveness. I conclude that the frequency of intervention is more important in affecting the level of the exchange rate while the size of intervention is more influential in affecting its volatility. In my third essay, I estimate the reaction function of the Japanese FXI accounting for different measures of volatility. I find that deviations from medium term, long term and implicit exchange rate targets as well as the volatility of the exchange rate during periods of yen appreciation are considered the key factors motivating JMA to intervene.

The third objective is to test the effectiveness of FXI in Turkey; an emerging economy adopting Inflation Targeting (IT) regime. In my fourth essay, using a multivariate GARCH model, I find that there is always a room for direct FXI to coexist within an IT regime, and to influence the domestic currency to improve competitiveness in the tradable goods markets as long as current inflation rates are within their target bounds. This is in contrast to the previous argument that limits the role of FXI to reducing the volatility instead of defending a particular exchange rate under an IT regime. Using the same model, I find spillover effects of FXI in the sense that change in the TRY/USD as a result of CBT intervention in the FX market leads to change in the TRY/EUR.

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1. Introduction

The foreign exchange (FX) market is the generic term for the worldwide institutions that exist to exchange or trade currencies of different countries. The FX market is one of the most active financial markets in the world in terms of volume, frequency, and intensity of trading. Foreign exchange trades involve trading between central banks, large commercial banks, corporations, currency speculators, and other institutions. The purpose of FX market is to facilitate trade and investment across countries. The average daily turnover in FX markets was reported to be over \$3.2 trillion in April 2007.

During the era of the Bretton Woods system of pegged exchange rates, intervention operations were required whenever rates exceeded parity bands (Dominguez 1998). The collapse of the system in 1973 led to a regime based on exchange rate flexibility, in which the forces of supply and demand in the foreign exchange markets determine the exchange rates. However, intervention policy was left at the freedom of choice of individual central banks. Foreign exchange intervention (FXI) is defined generally as foreign exchange transactions conducted by the monetary authorities with the aim of influencing exchange rates.

Central banks intervene in the FX markets when they perceive markets as disorderedly or dominated by short term disturbances. Although developed economies intervened frequently during the seventies and the eighties, they intervened less frequently during the 90s, Japan, an outstanding exception, has remained very active till March 2004 with varying sizes and frequencies of interventions. FX interventions have

also occurred frequently in emerging economies, as an effective tool to face their unstable economic situations.

This dissertation is about FXI and its effectiveness in advanced and emerging market economies. Chapter two of this study surveys the literature on foreign exchange intervention, and provides sections on the theoretical channels through which intervention might affect exchange rates. It also critically analyzes the empirical literature on the effectiveness and motivation of intervention in advanced and emerging market economies.

There is a clear distinction between the impact of FXI in advanced and emerging market economies. Effectiveness in advanced economies is achieved by influencing the level of the exchange rate at the expense of increasing its volatility. While effectiveness in emerging market economies are generally aiming at reducing the volatility of the exchange rate with insignificant impact on its level. Overall, empirical evidence shows that the effectiveness of interventions in stabilizing the market and influencing the exchange rates depends on different aspects; coordinated, large, infrequent, and reported interventions are the most effective.

Studies relating to the estimation of the central bank reaction function to determine the factors that induce the motivation for the intervention decision by central banks produce similar results in both advanced and emerging market economies. Among these factors (i) achieving exchange rate stability or leaning against the wind policy, so as to correct misalignment from short, medium, or long term targets; (ii) reducing exchange rate volatility to avoid the adverse effects of uncertainty on financial markets, international capital flows and international trade; (iii) prior and coordinated

interventions encourage further intervention in the current day by reducing political costs of convincing monetary authorities to intervene.

Chapter three is an empirical study on the effectiveness of intervention in advanced economies using Japan as a case study. The Japanese Monetary Authorities (JMA) has been very active in intervening in the FX markets in the last two decades. JMA intervened in the JPY/USD exchange market over 340 days and have played a major role in limiting the yen from appreciation against the US dollar by conducting foreign exchange operations that ranged from being very large scaled operations that exceeded 20 billion dollar in a single day to less than one million dollar in another occasion.

In Chapter three, I examine the impact of Japanese FXI transactions on the level and volatility of the JPY/USD exchange rate using different GARCH Models. Earlier studies either use the simple traditional GARCH (1, 1) model as a parsimonious model or impose a certain GARCH specification model without justifying the reason for using these models. According to the model selection exercise, I find that Exponential GARCH, Threshold GARCH and GARCH in Mean models outperform the traditional GARCH (1, 1) model. I obtain different results when estimating the effectiveness of JMA intervention on the level and volatility of the exchange rate using this approach as compared to the traditional GARCH models. I conclude that it is misleading to generalize results obtained from the simple GARCH model because the effectiveness of FXI is highly dependent on the employed model.

I use daily official data of the Japanese foreign exchange intervention during the period January 2 1992 to March 31 2004, dividing my research into three sub-periods and controlling for the asymmetric impact of purchase and sales interventions while testing the

channel through which intervention influenced the exchange rates. I find asymmetric impact of sale and purchase operations throughout the full sample and the three subsamples. In particular, I find that sale operations are effective through the signaling channel, while purchase operations are effective through the portfolio balance channel.

Previous studies on Japanese FXI find that FXI are ineffective during periods of small and frequent interventions, while they are effective during periods of large and infrequent FXI. However they did not provide evidence of whether the cause of effectiveness or ineffectiveness is due to the size or the frequency of intervention. In the second part of this chapter, I explicitly distinguish between the impact of the frequency and size of interventions on the level and volatility of the exchange rate, providing a detailed analysis of the effectiveness of different patterns of the Japanese FXI.

I find that the impact of the frequency of FXI is more important on the level of exchange rate while it is less important on the volatility as compared to the size of intervention. For a given level of frequency, a change from a small to large intervention reduces the rate of appreciation of the exchange rate by 0.014%. However, for a given size of intervention, a change from frequent to infrequent interventions improves the rate of depreciation by 0.093%, providing more evidence of why infrequent large interventions during the second period were more effective as compared to the frequent large interventions in the third period. On the other hand small frequent interventions reduce the volatility while large frequent interventions increase the exchange rate volatility.

Chapter four scrutinizes the JMA reaction function, uncovering the key factors that prompt the JMA to intervene in the JPY/USD market. I propose an intervention

reaction function that emphasizes the different objectives of the central bank for the level and volatility of the exchange rate. I also account for the different patterns of interventions of JMA throughout the period under study, dividing it into three sub-samples; each has its own pattern of intervention.

I estimate the reaction function of the JMA in the JPY/USD exchange rate market for each sub-sample using ordered probit model, after introducing the conditional volatilities measured by the previously better fit GARCH models and the traditional GARCH model in two separate regressions. The volatility of exchange rate estimated using the better fit models have different impacts on the JMA reaction function from those volatilities estimated using traditional GARCH models. This suggests that volatility measurement is a critical issue when considering the determinants of the intervention reaction function.

I find that the main factors prompting JMA interventions during the full sample period when estimating JMA reaction function using volatilities generated by better performing GARCH models are deviations from the monthly exchange rate target and the implicit target, volatility of the exchange rate when the yen is appreciating and the interest rate differential.

For the first period, deviation from the monthly and the yearly exchange rate target, the implicit target, and the interest rate differential. During the second period, intervention operations are affected by deviations of the exchange rate from its monthly and its implicit targets and volatility of exchange rate during periods of yen appreciation. Regarding the third period persistence in intervention and volatility of exchange rate during periods of yen appreciation are the main factors driving JMA to intervene. Overall, JMA is found to smooth out the market by eliminating residual volatility once a clear trend has been established. In

periods of excessive volatility when the trend is unclear, the smoothing operations may be useless.

Chapter five deals with FX effectiveness in emerging market economies. As central banks in these economies are facing conflicting objectives towards currency depreciation for external competitiveness and appreciation brought by inflation targeting; effectiveness of FXI deserves further analysis. The Turkish economy in the post crisis period provides a good example in this context. Turkey is one of those emerging markets that have adopted IT gradually on two phases implicitly then explicitly. The implicit IT regime introduced by the Central Bank of Turkey (CBT) in January 2002 encompasses the core attributes of IT specifically the announcement of a formal target for intervention. The Explicit IT regime is then introduced in January 2006 after achieving successful disinflation, improvements in fiscal conditions and improvements in the banking system, bringing further transparency in the new framework.

Chapter five two main hypotheses regarding the CBT foreign exchange intervention. First, testing whether there is a room for an effective FXI under IT regimes, and whether effectiveness is only limited to reducing volatility as asserted by Domac and Mendoza (2004) or is it possible that FXI can influence the exchange rate as long as inflation targets are achieved; Second, testing whether CBT FXI in the TRY/USD market has any spillover effects or implications on the TRY/EUR market, under both the implicit IT and the explicit IT regimes; while addressing the impact of news on EU membership on the volatility and co-movements of the exchange rates.

In assessing the effectiveness of FXI operations for the CBT in the post crisis period, I use a Multivariate Vech-GARCH model that allows for testing the impact of

FXI on the level and volatility of the TRY/USD exchange rate while accounting for the spillover effects of interventions on the TRY/EUR exchange rates. I find that there is always a room for direct FXI to coexist within an IT regime, and to influence the domestic currency to improve competitiveness in the tradable goods markets as long as current inflation rates are below their target rates or within the uncertainty band, in contrast to previous argument that asserts on the role of FXI in reducing the volatility and against defending a particular exchange rate. I find two types of spillover effects of CBT intervention in the TRY/USD market on the level of the TRY/EUR and its co-movement with the TRY/USD exchange rate, suggesting that the TRY/EUR is not only implied by independent shocks to USD/EUR exchange rate, but also by changes in the TRY/USD due to FXI transmitted to TRY/EUR through the signaling channel of FXI altering agents' expectations of future exchange rates.

Each of the following chapters is considered a separate article that has its own references, tables, and figures.

2. Foreign Exchange Intervention Mechanics, Effectiveness and Motivation

2.1 Introduction

During the era of the Bretton Woods system of pegged exchange rates, intervention operations were required whenever rates exceeded parity bands (Dominguez 1998). The collapse of the system in 1973 led to a regime based on exchange rate flexibility, in which the forces of supply and demand in the foreign exchange markets determine the exchange rates. However, central bank foreign exchange intervention (FXI) policy was left at the freedom of choice of individual central banks. FXI is defined generally as foreign exchange transactions conducted by the monetary authorities with the aim of influencing exchange rates.

Earlier studies on FXI focus on three different issues; mechanics, effectiveness and motivation of intervention. Mechanics of intervention refer to the theoretical transmission channels through which FXI affects the exchange rates. FXI affects the exchange rate directly through the monetary channel when this operation is not sterilized by domestic monetary authorities. Sterilized FXI affects the exchange rate indirectly through the portfolio balance channel and the signaling channel. The evidence is mixed for the portfolio balance channel, while most studies find significant impact of intervention through signaling channel. Recent literature has introduced two additional channels; the microstructure (order flow) channel and the noise trading channel.

Empirical studies based on these channels usually use high frequency (daily and intra-daily) data and find support for the functioning of these channels.

The second area of study, the effectiveness of FXI, tests the impact of FXI mainly on the level and the volatility of the exchange rate, with reference to a particular transmission channel, such as the portfolio balance channel, signaling channel, microstructure (order flow) channel, or noise trading channel. The empirical models used to test the effectiveness of intervention adopt three main approaches, the direct approach, the structural approach, and the event-study approach. The direct approach regresses changes in the level and volatility of the exchange rates on the intervention variable and other variables of influence. Some of the studies refer indirectly to the portfolio balance and signaling effect of intervention.

The structural approach allows for the simultaneous determination of the exchange rate and intervention that would lead to inconsistent estimates of coefficients within the simple OLS estimation, mainly used in the direct approach. Thus a system of simultaneous equations is formed and estimated via instrumental variable approach. Some studies use lagged interventions and news about changes in central banks' exchange rate policy as instruments for current interventions, while others employ two-stage least squares method by first estimating the reaction function as a function of lagged deviations of exchange rates from targets and volatilities of exchange rates, then use the fitted values as instruments in regressions that estimate the effect of current interventions on the exchange rate.

The event-study approach suggests a success criterion that enables differentiation between successful events and unsuccessful events of intervention. Studies adopting the

event study approach use a discrete choice model such as the logit or the probit models, employing the size of intervention, coordinated interventions, changes in interest rates as explanatory variables.

The third area of research; the motivation to intervene in FX markets is studied through estimating the central bank's intervention reaction function, in an attempt to determine whether central bank's interventions are predictable. Changes in the exchange rates, deviations of exchange rates from target levels, volatility of the exchange rates, coordinated interventions, and past interventions are possible motives to intervene, and are usually used as explanatory variables in probit and ordered probit models.

Although advanced economies intervened less frequently during the 90s, Japan, an outstanding exception, has remained very active till March 2004 with varying sizes and frequencies of interventions. Thus recent studies on FXI focus mainly on Japanese FXI in the yen/dollar market. FXIs have also been used frequently in emerging economies, as an effective tool to face their unstable economic situations. Because of data limitation, only few studies are available on emerging market economies, and are mainly confined to Turkey, Mexico, Chile, Czech, and Columbia.

There is a clear distinction between the impact of FXI in advanced and emerging market economies. Effectiveness in advanced economies is achieved by influencing the level of the exchange rate at the expense of increasing its volatility. While effectiveness in emerging market economies are generally aiming at reducing the volatility of the exchange rate that arise due to thin FX markets that are dominated by relatively small number of agents. Empirical results on the motivation to intervene in emerging market economies are similar to results from advanced economies. Deviations from exchange

rate targets and higher volatility are the main factors that trigger the central banks in emerging markets to intervene in the FX markets.

This chapter surveys the literature on FXI, provides sections on the theoretical channels through which intervention might affect the exchange rates and critically analyze empirical literature on the effectiveness and motivation of intervention. The organization of this chapter is as follows. Section 2.2 theoretically and empirically describes the mechanics of intervention. Section 2.3 provides empirical evidence of the effectiveness of FXI in advanced and emerging markets. Section 2.4 present empirical studies on the motivation of central bank intervention in advanced and emerging market economies. Section 2.5 concludes.

2.2 Mechanics of Intervention

A foreign exchange market intervention is defined as a sale or a purchase of foreign assets by the domestic monetary authorities which is explicitly aimed at changing the exchange rate of the domestic currency vis-à-vis one or more foreign currencies. The central bank's balance sheet may be used to illustrate the mechanics of FXI.

Table 2.1 shows a simple balance sheet of the central bank. The asset side includes foreign assets and domestic assets. Foreign assets consists of foreign currency bonds, gold and SDR, while domestic assets comprise the domestic government bonds and loans to commercial banks. The two components of the monetary base (MB) –

currency in circulation and reserves of commercial banks - comprise the liability side of the central bank's balance sheet¹.

Central bank FX intervention changes its holding of foreign assets, while central bank open-market operation changes its holdings of domestic assets. When the central bank buys (sells) a domestic or foreign asset from the public, both assets and liabilities increase (decrease). Thus a change in the level of asset holdings by the central bank is accompanied by a change in the money supply.

Traditional economic theory suggests that intervention can affect exchange rates through five different channels – the monetary, the portfolio-balance, the signaling, Micro structure (order flow) and the noise trading channel.

2.2.1 Monetary Channel

The Monetary approach assumes that domestic and foreign assets are perfect substitutes. Therefore, demanders are indifferent to the currencies of denomination as long as the expected return is the same. When the central bank intervenes in the FX market, foreign assets are exchanged for a liability of the central bank. If the central bank buys foreign assets from commercial banks, this transaction increases the foreign assets and increases the reserve position of the commercial banks as shown in Table 2.2. Sarno and Taylor (2001), and Edison (1993) report in their surveys that FX intervention operation *ceteris paribus* leads to changes in the relative supplies of domestic and foreign assets, interest rates, and market expectations, just as conventional changes in monetary policy. Therefore, a central bank FX purchase creates excess supply of domestic assets,

¹ Almekinders (1996).

declining short-term interest rates in domestic money markets, and hence depreciating the domestic currency.

The monetary channel operates if the central bank decides not to offset completely the effect of intervention on the level of domestic bank reserves, and intervention will influence exchange rates through its effect on short-term interest rates. When a central bank buys (sells) domestic bonds in exchange for a foreign currency, it decreases (increases) the amount of its liabilities of monetary authorities, lowering (rising) its domestic money supply. By itself, this transaction would influence exchange rates in the same way as ordinary domestic open market operations; however, most central banks routinely “sterilize” their foreign exchange operations; by an offsetting transaction in domestic assets with the same magnitude as the transaction with foreign assets, by selling (buying) domestic bonds to reverse the effect of the foreign exchange operation on the domestic money supply (Edison, 1993).

This monetary channel is only effective when intervention is not sterilized. In other words the central has to pay the price of loosening the domestic money market. By assumption this FXI operation will result in increase in the domestic money supply. Therefore the central bank can only control exchange rates or interest rates but not both.

Conducting monetary policy that targets short-term interest rates automatically sterilizes intervention. For example, if the central bank purchases foreign assets in a foreign exchange intervention, the monetary base would increase in the absence of sterilization. Other things equal, interest rates and prices would also change. To prevent changes to domestic interest rates and prices, the central bank would sterilize the

intervention by selling an equal value of domestic assets to absorb the liquidity². Table 2.3 shows the net effect on the central bank balance sheet, which would be to increase the relative supply of U.S. government securities versus foreign securities but to leave domestic and foreign money supplies unchanged.

2.2.2 Portfolio-Balance Channel

Because fully sterilized intervention does not affect either prices or interest rates, it does not influence the exchange rate directly. But official intervention might affect the foreign exchange market indirectly through the portfolio balance channel and/or the signaling channel. The effects of intervention through the portfolio balance channel are analyzed within the framework of a portfolio balance model of exchange rate determination. According to this channel, intervention can influence the exchange rate if investors consider foreign and domestic assets to be imperfect substitutes. Investors diversify their holdings among domestic and foreign assets as functions of expected rates of return.

The portfolio balance approach assumes that assets are imperfect substitutes internationally, because investors perceive foreign exchange risk to be attached to foreign currency denominated assets. With imperfect substitutability traders have preferences for distributing their portfolio over different countries assets. They have a desired portfolio share for any particular country's assets. If the supply of one country's assets increases, they will hold a greater proportion of the country's assets only if they are compensated.

² Complete sterilization would also require that the foreign central bank automatically reverse the effect of the intervention on the foreign money market by increasing the supply of foreign currency through open market operations.

This requires a premium to be paid on these assets. In general, the portfolio balance channel has risk premiums that are a function of relative asset supplies. By altering the relative supply of assets denominated in domestic and foreign currencies, central banks may induce investors to demand a higher expected return on the asset, whose outstanding stock has increased, thereby leading to a change in the exchange rate³.

Branson (1983), Branson – Henderson (1985), Bilson – Marston, (1984), Taylor, (1995) and Almekinders (1995), discuss different models of the portfolio balance channel. Edison (1993) expounds a general framework of the portfolio balance model. Net financial wealth (in domestic currency) of the domestic private sector (W) is divided into three components: money (M), domestic bonds (B) and foreign bonds (B^*). Equation set 1 presents the domestic and foreign net wealth function along with the demand functions (W , W^* , M^D , B^D , B^{*D} , M^F , B^F , B^{*F}) respectively, measured in terms of the country's own currency.

Equation set 1:

Domestic Market:	Foreign Market
$W = M_D + B_D + B_D^*$ $M^D = m_D(i, i^* + \hat{S}^e, Y, W),$ $B^D = b_D(i, i^* + \hat{S}^e, Y, W),$ $SB^{*D} = b_D^*(i, i^* + \hat{S}^e, Y, W),$	$W^* = M_F + B_F + B_F^*$ $M^{*F} = m_F(i, i^* + \hat{S}^e, Y^*, W^*),$ $B^{*F} = b_F^*(i, i^* + \hat{S}^e, Y^*, W^*),$ $\frac{1}{S} B^F = b_F(i, i^* + \hat{S}^e, Y^*, W^*),$

³ Rogoff (1984) is among the first to test the importance of the portfolio balance channel. He finds no significant effects of sterilized intervention through this channel. Dominguez and Frankel (1993), however, find evidence in favor of this channel.

Where i and i^* denote the domestic and foreign interest rates respectively; S denotes the spot exchange rate (domestic currency for unit of foreign currency), $\hat{S}^e$ denotes the expected rate of depreciation of the domestic currency, and x_k denotes the partial derivative of $X(\cdot)$ with respect to k for $X = M, B$ and B^* .

Equation set 2 shows that the supplies of money (M^S), domestic bonds (B^S) and foreign bonds (B^{*S}) are predetermined and that the domestic economy is in equilibrium.

Equation set 2:

Domestic Market	Foreign Market
$M^D = \bar{M},$ $B^D + B^F = \bar{B},$	$M^{*F} = \bar{M}^*,$ $B^{*D} + B^{*F} = \bar{B}^*,$

Equation 3 shows the equilibrium condition of domestic bond market which explains the mechanism through which the supplies of bonds affects the exchange rate as follows:

Equation 3:
$$\bar{B} = b_D(i, i^* + \hat{S}^e, Y, W) + S b_F(i, i^* + \hat{S}^e, Y^*, W^*),$$

When the central bank intervenes to depreciate the domestic currency following a sterilized intervention, it purchases foreign bonds from private investors and sells them domestic bonds, raising the supply of domestic bonds, which requires a rise in the quantity demanded to maintain equilibrium. Since domestic monetary base is not affected by sterilized intervention, then interest rates do not change, and only exchange rate must change. However, the private investors will require a higher expected return (risk premium) on domestic assets relative to foreign assets to willingly hold the increased

supply of domestic bonds and lower their holdings of foreign bonds. To restore equilibrium, depreciation, in terms of a rise in S , results in a rise in W which increases the demand for domestic assets, and reduces the demand for foreign assets.

The studies related to the portfolio balance channel are controversial, are mainly using the estimated risk premium obtained from the inverted asset demand functions to test the joint hypothesis on the degree of asset substitutability and on the expectation formation. In their seminal paper, Dominguez and Frankel (1993a, 1993b) present empirical evidence for some effectiveness of official interventions through the portfolio balance channel for the 1980s. However they also reported that the magnitude of the FXI effectiveness was small and economically insignificant effects despite their statistical significance. Dominguez and Frankel stated that as long as the interest rate differential does not fully absorb the impact of FXI on risk premiums. Thus, FXI matters even when they are economically small. On the other side, Sarno and Taylor 2001 attribute that the portfolio balance channel is likely to have become less relevant over time to two main factors. The rapid integration of global financial markets over the past decade, which has made financial assets of different countries better substitutes, and second, the enormous increase in the size of foreign exchange market volumes.

2.2.3 The Signaling (Expectations) Channel

Edison (1993), Dominguez (1998), Sarno and Taylor (2001) list a third channel of transmitting central bank FX intervention to exchange rate. The signaling channel does not require the assets to be considered imperfect substitutes, it is operative when the central bank reveals inside information that are only known to the central bank about

future fundamentals as signals to the public. If market participants believe that the central bank is right, they will correct their expectations about future fundamentals and revise their expectations of future spot exchange rate causing changes to the current exchange rate by trading with the new information. This channel assumes that monetary authorities have superior information about future fundamentals to market participants and that they are willing to reveal it to the public (Sarno – Taylor, 2001).

However, even if the central bank may not have superior information to the public in all fundamental issues that contribute to the exchange rate determination, the signaling effect would still be successful. If the central bank believes that the exchange rate is misaligned above (below) from its value warranted by fundamentals, then buying (selling) foreign exchange signaling that the exchange rate should fall (rise), causing the private agents to adjust their exchange rate expectations, bringing changes in the current exchange rate. Mussa (1981) attributed this effect to private agents belief that the central bank is surely having superior information in the field of future monetary policy and that the central bank is credible. Thus, FX intervention provides very credible information about future monetary policy because the monetary authorities stake their capital in support of that policy. Therefore, FX intervention may signal information regarding changes in future monetary policy.

In this sense, the mere announcement of future monetary policy or other verbal interventions in order to affect exchange rate expectations do not represent credible statements. If, for example, a central bank wants to depreciate the domestic currency, it will buy foreign bonds, signaling with it future monetary ease, i.e. fall in interest rates. Because such an intervention as a signal of future monetary policy is credible – the

central bank would otherwise suffer losses if it failed to validate its signals – the market traders will change their expectations of future interest rates.

Dominguez (1998) provides a model of the signaling channel in which the exchange rates are regarded as forward looking processes that are exceptionally efficient with respect to public information. So the current spot rate is determined by those exogenous variables that are well known to the public and therefore included in the current set of public information. The current spot rate can be represented as

$$s_t = (1 - \delta) \sum_{k=0}^{\infty} \delta^k E_t(z_{t+k} | \Omega_t)$$

Where s_t is the current spot rate (domestic currency per unit of foreign currency) in log form, δ is the discount factor, z_t is the vector of exogenous driving variables, and Ω_t is the public set of information at time t . If intervention operations (I_t) provide relevant information to the public, then they will add to their market's information set ($\Omega_t + I_t$) and influence the spot rate.

Dominguez (1998) describes that the expected influence of an operation via the signaling channel depends on (i) the nature of the intervention signal (credible or non-credible), (ii) the state of the market (efficient or inefficient), and the perceived objective of the central bank (to influence the level or the volatility of the exchange rate). In this framework, the only scenario under which an intervention will reduce exchange rate volatility is when intervention signals are credible, the foreign exchange market is efficient, and the perceived central bank objective is to lower volatility.

Arguments against the signaling effect are based on the secrecy puzzle of intervention and whether intervention is considered an independent tool of the monetary authorities. Edison (1993), Sarno and Taylor (2001) in their survey of FX intervention

inquire why the central banks FX intervention are often operated in secrecy fashion, if they want to signal future monetary policy by intervention. Sarno and Taylor (2001) also assert that in order for central banks to maintain credibility in the future, sterilized intervention must be accompanied by corresponding subsequent changes in the money supply, implying that official intervention does not represent an instrument independent of monetary policy.

Empirical research provides mixing results in favor of the signaling channel regarding its effect on the level and volatility of the exchange rate. Eijffinger and Verhagen (1997) suggest that interventions may convey signals about the central banks short-term exchange rate target, reflecting the central bank's assessment of the possible future paths of fundamentals. Dominguez (1998) finds that intervention need not be publicly known in order to influence volatility. Secret interventions were generally found to increase volatility. This result provides evidence in support of hypothesis that the more ambiguous the signals, the more likely they are to increase volatility.

2.2.4 The Microstructure (Order Flow) Channel

Recent literature introduces a new channel using the microstructure approach to foreign exchange market (Lyons and Evans, 2006), Dominguez (2003), (Lyons, 1997, 2001), (Peiers, 1997). Information based microstructure theory views the trading process for financial assets as a strategic game involving players who adjust order flows and prices based on asymmetric information regarding the underlying assets true value. Empirical studies on information asymmetry are based on high frequency data. According to Lyons (1997), speculative or informed traders can privately distinguish

between own-customer orders that are liquidity-based and those that reflect superior information regarding the fundamental determinants of the spot exchange rate. Hence informed agents are optimally qualified to take advantage of short-term profit opportunities. “Liquidity” or uninformed traders are driven by customer needs for financing international trade and corporate transactions. Their strategies are to minimize losses when dealing with informed traders.

The microstructure approach to exchange rate asserts that new and dispersed bits of information on economic fundamentals are impounded in order flow and consequently, the latter may have persistent price effects. Private information, institutions (trading mechanisms) and different motives of players in the market are relevant features that can affect market prices (i.e. exchange rates) but cannot be at the same time explained in the traditional macroeconomic framework of exchange rate determination.

Order flow thus carries relevant information about market pressures, fundamentals or market expectations that are often not public. There is asymmetric information; some agents (typically large players) in the market are better informed than others are because they observe more order flow.

Peiers (1997) explains how the channel works as follows. When the central bank intervenes secretly and without an official announcement in the foreign exchange market through a private commercial bank, the latter gains an information advantage by receiving a market order from the central bank, and hence a short term profit opportunity. Thus, it adjusts its order flows and prices. Other banks in the market learn from the order flows that there is an informed agent in the market (i.e. a trader that knows relevant information regarding fundamental determinants of exchange rate) and, in order to

minimize losses, will adjust their positions accordingly. Once intervention news is fully revealed, commercial banks will return to their pre-intervention trading strategies.

Lyons (2001) and Evans Lyons (2001) focus on the role of FX dealers who as market makers stand ready to buy and sell foreign exchange. These dealers typically do not hold sizable open positions in a foreign currency, especially overnight. They will try to distribute it among other dealers and eventually among their commercial customers. Since different currencies are not perfect substitutes in the dealer's portfolio, this inventory adjustment process resembles a portfolio balance mechanism at the micro level. Evans and Lyons claim evidence of both temporary (dealer to dealer) and permanent (dealer to customer) portfolio balance effects. However, the permanent component of this model is at odds with the macro literature. The microstructure model measures only currency flows in the FX market. It does not account for the fact that the sterilization process leaves the total amount of bank reserves for each currency unchanged, while changing the relative stock of interest bearing assets.

Dominguez (2006) interprets the microstructure channel based on the model developed by Bacchetta and van Wincoop (2003) of exchange rate determination. Based on differences in information or interpretation of information, trader heterogeneity might lead to short run price and volatility effects in the reaction to information revelation. Information based trades (including interventions that provide informative signals) and non-informative trades can both move exchange rates in the short run depending on aggregate market ability to differentiate noise from fundamentals. If market participants receive information or signals about future fundamentals, but this information is not common knowledge (either because people receive different bits of information or

because they interpret the information differently), then there is a common average signal among traders (assuming there are large numbers of market participants) but due to heterogeneity across traders, they will expect their own expectation next period to differ from that of others. This sort of information heterogeneity leads both to magnification and to endogenous persistence of the impact of non-fundamentals trade on the exchange rate.

This channel implies that, under the assumption of asymmetric information between informed and uninformed traders and when intervening “secretly” (at least to some extent), the central bank does not have to buy or sell large volumes of currency if it aims to influence the spot exchange rate. At the same time, the effect of intervention is not short lasting. On the other hand, even if the secret intervention strategy, aiming to maintain the traders in some kind of uncertainty about fundamentals, can temporarily weaken the exchange rate misalignment, it is still a kind of “fooling” the market and provides no durable solution to the very problem of market expectations. Thus, again, this channel may serve only to signal the “right” value of exchange rate to the market participants.

Dominguez (2003) finds supporting evidence of the microstructure channel, in which central bank interventions influence intra-daily foreign exchange returns and volatility. Her study suggests that policy makers should time intervention operations to take place when trading volume is high, and when other central banks are also in the market in order to achieve the largest intra-daily influence on exchange rate returns.

2.2.5 The Noise Trading Channel

Hung (1991, 1997) introduced a new transmission channel – based on the microstructure approach of the FX market – through which the central bank may use well designed intervention strategies to induce noise traders to buy or sell a currency in such a way that generates a longer-lasting effect from the temporary effect of sterilized intervention. The main assumptions underlying the noise trading channel are the prevalence of noise trading in the FX market (at least part of the time), and that the exchange rate is determined by the flow market equilibrium on a minute by minute basis.

Noise traders are chartists who pursue former movements in the determination of the exchange rates, relying on some kind of feedback rule (buying when the price is going up, and selling when the price is going down). Their actions are induced by views and market reactions partially incoherent with economic fundamentals. If FX market is dominated by noise traders, the odds of speculative bubbles and long-term misalignment soar.

In order for the noise trading channel to work successfully, the central bank must conduct secret intervention operations and is well-versed with the noise traders' reaction functions. When the central bank regards the domestic currency as overvalued, the central bank secretly intervenes by selling domestic currency to resolve this misalignment. The immediate transitory and short-lasting effect may induce the noise traders to perceive that the prevailing trend has broken and to incorporate this new information of the downward pressure on domestic currency into their trend analysis. Because chartists are highly influenced by recent changes, they revise their forecast of exchange rate by assigning more weight to the novel movements in the exchange rate. Chartists may perceive the

impact of intervention as an alarming signal of a change in the market direction. Thus, Chartists may reverse their behavior and sell domestic currency, thereby supporting the central bank goal to depreciate the value of the domestic currency.

This kind of intervention, by enhancing the exchange rate volatility and thus promoting a sense of two-way risk in the market, seems to be at the first sight a contradiction of one of the main motives for intervention, i.e. to lower the exchange rate volatility. However, only in this way can the traders be maintained, in the uncertainty about the future exchange rate development. In addition, this channel offers a satisfactory explanation why monetary authorities often intervene in a thin market, why they intervene secretly and why they hope (and sometimes manage) to reach a longer-lasting effect on the exchange rate.

2.3 Effectiveness of Intervention

The purpose of this section is to survey the literature on effectiveness of FX intervention in advanced and emerging market economies. The effectiveness of FXI, tests its impact mainly on the level and the volatility of the exchange rate, with reference to a particular transmission channel. The empirical models used to test the effectiveness of intervention on the level of the exchange rate adopt three main approaches, the direct approach, the structural approach, and the event-study approach. Studies on the direct approach regress changes in the level and volatility of the exchange rates on the intervention variable and other variables of influence. Some of the studies refer indirectly to the portfolio balance, signaling microstructure channel of intervention.

Studies on the impact of FXI on the volatility of the exchange rates are mainly operated using two different measures of volatility: ex-post volatility generated from GARCH framework or ex-ante implied volatility derived from market-determined option prices. The GARCH framework allows estimating the effects of intervention on both the level of the exchange rate in the mean equation and on the conditional volatility in the variance equation. If the options are efficiently priced, then the volatility implied by the option price provides an unbiased estimate of the market's forecast of volatility. Further, because the implied volatilities are calculated from options that expire in the future, they measure longer term exchange rate volatility.

The structural approach allows for the simultaneous determination of the exchange rate and intervention that would lead to inconsistent estimates of coefficients within the simple OLS estimation, mainly used in the direct approach. Thus a system of simultaneous equations is formed and estimated via instrumental variable approach. Some studies use lagged interventions and news about changes in central banks' exchange rate policy as instruments for current interventions, while others employ two-stage least squares method by first estimating the reaction function as a function of lagged deviations of exchange rates from targets and volatilities of exchange rates, then use the fitted values as instruments in regressions that estimate the effect of current interventions on the exchange rate.

The event-study approach suggests a success criterion that enables differentiation between successful events and unsuccessful events of intervention and denotes 1 for successful and 0 for unsuccessful events. Studies adopting the event study approach use a

discrete choice model such as the logit or the probit models, employing the size of intervention, coordinated interventions, changes in interest rates as explanatory variables.

There is a vast literature that focuses on the effectiveness of FXI. However, results are widely conflicting. Results depend heavily on the model's assumptions, types of intervention, different exchange rates, and different time periods. Dominguez and Frenkel (1993), Edison (1993), Sarno and Taylor (2001) and Neely (2005) provide a detailed survey of the literature. In this section, I focus on recent studies, highlighting new directions of research. This section is divided into two subsections to distinguish the impact of FXI in advanced from emerging market economies.

2.3.1 Empirical evidence from advanced economies: Effectiveness

The following studies reflect common conclusions regarding the effectiveness of FXI on the level and the volatility of the exchange rates in advanced economies. FXI tends to be effective when intervention operations are coordinated, large and infrequent (Ito (2003) and Fatum and Hutchinson (2003)). While FXI may be effective on the level of the exchange rate, this is achieved at the expense of higher volatility of the exchange rate which is to the contrary of the aim of central bank interventions to counter disorderly market conditions (Bonser-Neal and Tanner (1996), Ballie and Osterberg (1997), Dominguez (1998), Frenkel et al (2003), Hillerband and Schnabl (2000), Dominguez (2003)). Other studies find insignificant impact of the FXI on the volatility of the exchange rate (Galate et al (2005), and Neely (2006)).

Since the late 1980s, the direct approach has been the most followed approach in studying the effectiveness of FXI on both the level and volatility of exchange rate. Ito

(2003) examines the short term intervention effects on the level of the exchange rate during the period 1991 to 2001, noting changes in the strategy used by the Japanese monetary authorities over the period. The author concludes that intervention operations conducted in the second half of the 1990s often appeared to produce the intended effect on the exchange rate. This result suggests that large infrequent interventions are more effective than small frequent intervention operations. In addition, joint interventions were found to be 20-50 times more effective than the Japanese unilateral interventions.

Bonser-Neal and Tanner (1996) examines intervention operations in the G3 countries (US, Germany, and Japan) in the dollar/mark and the dollar/yen exchange rates during the period 1985-1991. They find positive correlation between official US intervention and implied volatility derived from options contracts on exchange-rate futures.

Ballie and Osterberg (1997) investigate the effectiveness of intervention operations in the dollar/mark and the dollar/yen exchange rates using the GARCH process over the period 1985-1990. They find evidence that FED intervention did not influence the mark/dollar and the yen/dollar exchange rates and intervention is associated with increases in the volatility of the exchange rates.

Dominguez (1998) studies the effects of the G3 intervention policies on the volatility of the exchange rate during the period 1977-1994 using both GARCH generated and implied volatilities. Dominguez finds that intervention effects on the volatility are situation specific. Her regressions suggest that secret interventions are associated with high volatility while reported interventions reduce the volatility.

Frenkel et al (2003) studied the effects of Japanese Foreign Exchange Market Interventions on the Yen/US Dollar Exchange Rate Volatility during the period 1993-2000 using daily data. They found that the interventions of the Bank of Japan (BoJ) increased the volatility of the yen/U.S. dollar exchange rate and that those interventions not reported in the financial press, were positively correlated with exchange rate volatility measured as absolute exchange rate return.

Hillebrand and Schnabl (2006) studied the effects of Japanese FXI using GARCH estimation and change point detection, throughout the period 1991-2002. They show that the success of interventions varies over time. Measured on the total sample between 1991 and 2002, interventions had the desired effect on the exchange rate at the cost of higher volatility.

The direct approach also encompasses the impact of FXI using multi-variate GARCH frameworks. Multivariate estimation techniques help to estimate the correlation between cross currency movements and foreign currency interventions, and the spillover effects of FXI when the level and volatility of one exchange rate changes due central bank intervention in another FX market.

Beine (2003) investigates the effects of central bank interventions on the ex-post correlation and covariance of exchange rates. Using a multivariate GARCH model with time varying conditional covariances, he estimates the effects of central bank interventions on both the variances and covariances between the yen and the deutsche mark (the Euro) in terms of the U.S. dollar. Such an analysis suggests that coordinated interventions by different country Central Banks not only tend to increase the volatility of exchange rates but also explain a significant amount of the covariance between the major

currencies. In other words, the Bank of Japan's intervention into the Japanese Yen (JPY) against the US dollar (USD) will have implications on the value of Euro. So a study of an intervention to the Euro against USD must take into account the interactions in cross currencies.

Chortareas, Jiang and Nankervis (2006) perform rolling estimations of a multivariate GARCH model, on the yen/dollar exchange rate during the period 200-2004. They find that Bank of Japan interventions in the yen/dollar market decrease the volatility of the exchange rate in contrast to previous research, however it increase the volatility of the euro/yen exchange rate suggesting spillover effects of Bank of Japan intervention policy.

The structural approach of effectiveness of FXI pioneered by Galati et al (2005) uses instrumental variable (IV) approach to test the impact of FXI on the mean and higher moments of the exchange rate. Galate et al (2005) examined the foreign exchange intervention in the dollar/yen exchange market during the periods 1993-1996, and 1997-2000 using daily intervention data. They use expected moments of the expected distribution of future exchange rates as a way to describe market expectations to estimate probability density functions (PDFs) from option data. They find that intervention had no statistically significant systematic effect on the mean of dollar/yen expectations. They detect no evidence that intervention systematically altered market participants' bias between a stronger and a weaker dollar with respect to the forward rate. Contrary to most findings of the literature, they failed to find evidence that intervention was associated on average with higher exchange rate variability.

Recent literature adopts the event study approach to study the effectiveness of intervention. Humpage (1999) studied the U.S. intervention during the period 1987-1990 using daily data on the DEM/USD and the JPY/USD exchange rates using an event study. Results from a logit model suggest that coordinated intervention has a higher probability of success than unilateral intervention. The probability of success also increases with the dollar amount of an intervention.

Ramaswamy and Samiei (2000) use an event study method employing daily data for JPY/USD during the period 1995-99 to estimate a simple forward looking model of the exchange rate and show that foreign exchange interventions have, on the whole, had small but persistent effects on the yen-dollar rate, and coordinated interventions have a higher probability of success and move the yen-dollar rate by a larger margin than unilateral interventions.

Fatum and Hutchison (2003) examined the Effectiveness of Official Daily Foreign Exchange Market Intervention Operations in Japan for the period April 1, 1991 to December 31, 2000 using daily data of the USD/JPY exchange rate. They conclude that evidence of short-term effectiveness is present, and that effectiveness is boosted by the size of the intervention episode and by coordination with the Federal Reserve.

Dominguez (2003) used an event study to analyze the influence of interventions on the volatility of the dollar/mark and dollar yen exchange rates using high frequency intra daily exchange rate and intervention data over the period 1990 through 2002. Dominguez referring to the microstructure channel of FXI finds that the FED intervention operations significantly influence the returns and the volatility of the dollar/mark and dollar/yen exchange rates. Dominguez finds evidence that the timing of intervention

operations matters – interventions that occur during heavy trading volume, interventions tied to macroeconomic announcements and coordinated interventions with other central banks are the most effective interventions. In addition, Dominguez finds that volatility of exchange rates is substantially higher during intervention periods than non-intervention periods.

Neely (2005) uses an intra-daily data of the DEM/USD and JPY/USD exchange rates during the period 1987-1990 to identify the effects of U.S. central bank intervention using Structural VAR models. He proposes an identification criterion for the cross-effects of intervention with the level and volatility of exchange rates using the likely timing of intervention, macroeconomic announcements as instruments and the nonlinear structure of the intervention reaction function. Proper identification of the effects of intervention indicates that it is moderately effective in changing the levels of exchange rates but has no significant effect on volatility.

2.3.2 Empirical evidence from emerging markets: Effectiveness

Unlike advanced economies, empirical literature on emerging market countries is still relatively few due to data limitations. However, we can benefit from recent work to at least provide a broad sense of intervention's effectiveness in these countries. In contrast to advanced markets, where FXI was effective in influencing the level of the exchange rate at the expense of higher volatility, FXI in emerging markets are less effective in influencing the level, and is capable of reducing the volatility. Policy objectives such as to accumulate FX reserves and to achieve inflation targeting reduce the effectiveness of FXI on the level of the exchange rate in emerging markets.

Most of the empirical studies on the effectiveness of intervention lie under the direct approach because of the limitations on high frequency data. Only few studies on Czech economy provide evidence of the microstructure channel. Similar to advanced economies, the effectiveness of intervention is highly sample-dependent with conclusions varying significantly across countries. In particular, the effectiveness of intervention appeared to be dependent on the monetary policy framework pursued and whether the intervention is publicly announced or not.

Tapia and Tokman (2004) studied the effectiveness of intervention in Chile using daily and intra daily data from 1998 to 2003. Their analysis indicated that the effectiveness of intervention operations varied throughout the sample in line with the changing policy framework of the central bank. They find that although actual intervention appeared to have a small and generally insignificant effect on contemporaneous exchange rate movements, public announcements of potential interventions had significant effects on the level and trend of the exchange rate.

Similarly, Guimarães and Karacadag (2004) analyze the effects of intervention on the level and volatility of the exchange rate in Mexico and Turkey, two emerging countries that have floating exchange rate regimes during 1996-2003, and March 2001-October 2003 respectively. They find mixed evidence on the effectiveness of intervention. In Mexico, foreign exchange sales have a small impact on the exchange rate level and raise short-term volatility, while in Turkey; intervention does not appear to affect the exchange rate level but reduces its short term volatility. In both cases, the findings are consistent with officially stated policy objectives, which aim to minimize the effect of intervention on the exchange rate. In Mexico, the bulk of intervention

undertaken during the sample period was aimed at accumulating reserves rather than influencing the underlying exchange rate trend. In Turkey's case, the apparent ineffectiveness of intervention in influencing the level of the exchange rate may reflect the nature of intervention policies there. In particular, the vast majority of official interventions were conducted in the context of pre-announced foreign exchange auctions, where the timing and amounts were largely predetermined and known by market participants. Hence, the potential impact of interventions may have operated through the signaling channel well in advance of actual interventions themselves.

Domac and Mendoza (2004) investigate whether central bank FXI have any impact on the level and volatility of the exchange rate in Mexico and Turkey since the adoption of the floating regime. They find asymmetric effects of the impact of sale and purchase interventions, concluding that central bank foreign exchange sales (but not purchases) were generally effective in influencing the exchange rate in both countries. In particular, a net sale of US\$100 million appreciated the exchange rate by 0.08% on average in Mexico and 0.2% in Turkey.

Galate et al (2005) use official statistics on Central bank intervention by the Czech National Bank in conjunction with options market data, to study the impact of intervention during 2001-02. They find that central bank intervention had some weekly statistically impact on the spot rate and the risk reversal but this impact was small.

Akinci et al (2005) studies the effectiveness of foreign exchange interventions of the Central Bank of Turkey (CBT) in the post crisis period from 2001 to 2003. They find that neither purchase nor sale interventions are effective in changing the appreciation/depreciation trend of the Turkish Lira. A result that is very much in line with

the official announcement of the CBT, which is explicitly announces that it has no intention to alter the level or the trend of the exchange rate.

Kamil (2008) examines the effectiveness of Colombian Central Bank's intervention in stemming domestic currency appreciation under an inflation targeting regime. The results indicate that the FXI is effective during 2004-2006, when the currency purchases were undertaken during the period of monetary easing. During 2007, on the other hand, intervention was ineffective in reversing or slowing down domestic currency appreciation, as large scale intervention became incompatible with meeting the inflation target in an overheating economy.

Pinar et al (2008) examines the impact of FXI of the CBT in a multivariate GARCH framework during the period 2002-2005, suggesting that unannounced direct intervention being more effective in stabilizing the Turkish Lira market as compared to announced auctions interventions.

Scalia (2008) provides an empirical test of the effectiveness of FXI in the Czech Republic under a floating exchange rate. Referring to the microstructure model, Scalia estimates a two-equation system on the change of the exchange, and the order flow measured at hourly intervals on the CZK/EUR in the second half of 2002. He finds a significant impact of the order flow on the exchange rate.

With respect to the impact of intervention on exchange rate volatility, the evidence is generally more positive. Domaç and Mendoza (2002) found in the context of Mexico and Turkey that intervention reduced exchange rate volatility in both countries.

Pattanaik and Sahoo (2002) also concluded that intervention operations of the Reserve Bank of India had been effective in containing volatility of the rupee, although the degree of influence did not appear to be very strong.

For the Philippines, Abenoja's (2003) study using daily intervention data from 1992 to 2003 indicated that although intervention reduced volatility contemporaneously, persistent operations actually increased volatility. This might suggest that successive interventions lead to greater market uncertainty.

For Mexico and Turkey, and in contrast to Domaç and Mendoza (2004), Guimarães and Karacadag (2004) find that significant positive impact of intervention on exchange rate volatility in Mexico, and a negative one on Turkey. Akinci et al (2005) find that large and isolated purchase interventions are effective in decreasing the volatility of the exchange rate in Turkey.

2.4 Motivation to Intervene

The third area of research; the motivation to intervene in FX markets is studied through estimating the central bank's intervention reaction function, in an attempt to determine whether central bank's interventions are predictable. Changes in the exchange rates, exchange rates deviations from target levels, volatility of the exchange rates, coordinated interventions, and past interventions are possible motives to intervene, and are usually used as explanatory variables, reflecting possible motives for intervention.

Due to the possible simultaneity problem in determining the relation between the exchange rate and intervention, as exchange rate changes may trigger intervention and interventions may influence exchange rates, some studies use instrumental variable

approach to address this problem. In general, most of the studies find strong evidence for the “lean against the wind” policy in FXI by central banks, i.e. to prevent the exchange rate from appreciating by intervening to depreciate the currency, and vice versa. Results vary according to different factors; the frequency of intervention data, proxies used intervention variables when intervention data are not reported, the definition of target exchange rates (using short term, medium term and long term moving averages, PPP equilibrium levels, implicit and explicit targets) and the estimation method.

Recent studies are using binary choice models such as the probit and logit models, and friction models such as the ordered probit models to estimate the probability of intervention. Econometric modeling of the daily intervention series poses some practical challenges owing to the unique nature of the series. As the intervention series have the feature of zero inflated process. Thus the dependent variable, the intervention series, is discontinuous and so modeling it using standard regression techniques is inappropriate. The conventional OLS estimation of the reaction function would lead to biased coefficients.

Friction models involve specifying three separate distributional assumptions for the intervention series, corresponding to the three different states of intervention outcome. This approach considers the intervention series to have three types of events; buying intervention, selling intervention, and zero intervention. The central bank is assumed to react to market conditions and constraints (as defined by the explanatory variables), but only after an intervention threshold is reached. In other words, the central bank will not intervene to influence the exchange rate unless the perceived necessity to enter the market exceeds a certain level. The thresholds may differ for positive and

negative interventions (buying or selling of foreign currency) and these may be estimated. The thresholds must be exceeded before the central bank acts to buy or sell foreign currency. These thresholds can be seen as the political cost.

Studies relating to the estimation of the central bank reaction function to determine the factors that induce the motivation for the intervention decision by central banks produce similar results in both advanced and emerging market economies. Among these factors (i) achieving exchange rate stability and correcting for overshooting to smooth transitions when economic conditions are changing; (ii) reducing exchange rate volatility to avoid the adverse effects of uncertainty on financial markets, international capital flows and international trade; (iii) leaning against the wind policy, so as to correct misalignment from short, medium, long term targets; and (iv) past interventions suggesting declining political costs of intervention.

2.4.1 Empirical evidence from advanced economies: Motivation

The motivation to intervene in FX markets is studied through estimating the central bank's intervention reaction function in an attempt to determine whether central bank's interventions are predictable. Empirical studies suggest that changes in the exchange rates, exchange rates deviations from target levels, volatility of the exchange rates, coordinated interventions, and past interventions are possible motives to intervene, and are usually used as explanatory variables in probit, logit, and friction models.

Ballie and Osterberg (1997) adopt a binary choice dependent variable method, a probit analysis, and find that the probability of intervention is determined by the

magnitude of deviation of the nominal exchange rate from a target level and by the current volatility of the exchange rates.

Galati and Melick (1999) and Galati et al (2005) in their estimation of the reaction function for Japanese FXI in the dollar/yen exchange market during the periods 1993-1996, and 1997-2000 find that Japanese monetary authorities appeared to intervene mainly in response to deviations of the exchange rate from some implicit target levels, and to a rise in market uncertainty.

Ramaswamy and Samiei (2000) use daily data for JPY/USD during the period 1995-99 to estimate the reaction function of the Japanese monetary authorities using a probit model. Results indicate that both an excessive appreciation and depreciation of the yen provoke interventions, and that interventions occur in clusters—if there is one today, there will likely be another the following day.

Ito 2002 in his effort to estimate the Japanese central bank reaction function finds that Japanese interventions are prompted by rapid changes in the yen/dollar rate and the deviation from the long-run mean. The interventions in the second half were less predictable than the first half.

Kim and Sheen (2002) estimate the reaction function of intervention by the Reserve Bank of Australia on foreign exchange markets from 1993 to 1997. They find that Australian FXI is determined by exchange rate trend correction, exchange rate volatility smoothing and profitability considerations. Using probit and friction models, they show that these factors were significant influences on intervention behavior. They find that above average measures of deviations from trend and of volatility muted the response of the Reserve Bank.

Another approach adopted by Ito and Yabu (2004) develop and estimate an intervention reaction function for the Japanese authorities involving a “political cost” which must be taken into account by the authorities when deciding whether or not to enter the market. They find that interventions often came in reaction to large exchange rate movements on the previous days, and that deviations from a long-term moving average also tends to lead to a decision to intervene.

Frenkel et al. (2005) examines the motivation for the Japanese intervention policy. They find that Japanese authorities regularly responded to deviations of the JPY/USD from short term and long term exchange rate target.

Hall and Kim (2008) use friction model to estimate the reaction function of Bank of Japan’s interventions for the period 1991-2004. Hall and Kim introduced overnight offshore market returns and overnight yen movements as additional explanatory variables to the reaction function. They find that prior to June 1995 there were significant responses to previous day’s intra daily yen returns and volatility. Post 1995, interventions responded to overnight offshore market returns. During the 2002-2004 period, Bank of Japan responded only to lagged intra daily volatility and to an overall measure of market uncertainty.

2.4.2 Empirical evidence from emerging markets: Motivation

In the second area of studies, regarding estimating the central bank FX reaction function, studies are limited for emerging markets. Empirical results on the motivation to intervene in emerging market economies are similar to results from advanced economies.

Deviations from exchange rate targets and higher volatility are the main factors that trigger the central banks in emerging markets to intervene in the FX markets.

Akinci et al (2005) find that the main motivation of behind the CBT interventions is the excessive volatility of the exchange rate. Galati et al (2005) estimate a reaction function for the intervention of the Czech National Bank. They find that Czech authorities appeared to intervene mainly in response to an acceleration of the speed of Koruna appreciation.

Hovarth (2006) uses daily data of FXI in the Czech Republic for the period 1998-2002. He constructs a simple indicator of Inflation targeting consistency based on deviation from its targets and output gap, and then estimates the determinants of FXI activity employing the measures of exchange rate misalignment, volatility an inflation targeting consistency. He finds FXI is determined by the degree of the exchange rate misalignment and lagged interventions. Hovarth also finds that inflation targeting regime is a binding constraint of intervention activity

Gersl and Holub (2006), and Gersl (2006) estimate Czech National Bank intervention reaction function. Results suggest that the CNB intervened systematically to correct the deviation of the exchange rate from the target value and was triggered by higher volatility.

Ozlu and Prokhorov (2007) conjecture that the CBT intervenes differently depending on whether a single measure of market disorder exceeds a threshold value or not. They find that during the managed float period, there is no support for a threshold in the Bank's reaction function, during the free float period; they find evidence of a threshold in volatility, which is in line with the Bank's policy.

Herrera and Ozbay (2008) examine the CBT intervention in foreign exchange markets using a dynamic censored regression model (Tobit analysis). They find persistence in interventions, which suggests the presence of political costs and a signal of future monetary policy. In addition excessive exchange rate volatility and interest rate differentials are important factors in determining the central bank intervention.

2.5 Conclusion

This paper surveys the theoretical and empirical literature on foreign exchange (FX) intervention in both industrialized and emerging economies. Sections on the theoretical channels through which intervention might affect exchange rates distinguish between the macro-structure transmission channels (the portfolio balance and the signaling channels) from the micro-structure transmission channels (order flow and noise trading channels).

Empirical results suggest that FX intervention is used as an independent monetary policy tool to influence exchange rates by monetary authorities in both industrialized and emerging markets to achieve short term goals (temporary) however it cannot substitute other monetary policy instruments in dealing with underlying fundamental inconsistencies in macro policy over the long term.

There is a clear distinction between the impact of FXI in advanced and emerging market economies. Effectiveness in advanced economies is achieved by influencing the level of the exchange rate at the expense of increasing its volatility. While effectiveness in emerging market economies are generally aiming at reducing the volatility of the exchange rate with insignificant impact on its level. Overall, empirical evidence shows

that the effectiveness of interventions in stabilizing the market and influencing the exchange rates depends on different aspects; coordinated, large, infrequent, and reported interventions are the most effective. (i) Coordinated intervention is more effective than the individual intervention; the coordinated signals offered by the intervention are views as more credible as compared to unilateral intervention. (ii) Size of intervention, the larger the amount of interventions, the greater the possibility of success; (iii) Frequency of intervention, frequent interventions are effective in reducing the volatility of the exchange rate but may be counterproductive on its level; (iv) reported interventions are regarded as a credible source of information about the future monetary policy while secret interventions have little effect on exchange rate and rather increase its volatility.

Studies relating to the estimation of the central bank reaction function to determine the factors that induce the motivation for the intervention decision by central banks produce similar results in both advanced and emerging market economies. Among these factors (i) achieving exchange rate stability or leaning against the wind policy, so as to correct misalignment from short, medium, long term targets; (ii) reducing exchange rate volatility to avoid the adverse effects of uncertainty on financial markets, international capital flows and international trade; (iii) past and coordinated interventions encourage further intervention in the following day by reducing political costs of convincing monetary authorities to intervene.

Table 2.1: Central Bank Balance Sheet

Assets	Liabilities
Foreign Assets (FA)	Monetary Base
Domestic Assets (DA)	Total currency in circulation
	Reserves of commercial banks

Table 2.2: Non-sterilized intervention:

Assets		Liabilities	
Foreign Assets (FA)	+	Monetary Base	
Domestic Assets (DA)		Total currency in circulation	0
		Reserves of commercial banks	+

Table 2.3: Sterilized intervention:

Assets		Liabilities	
Foreign Assets (FA)	+	Monetary Base	
Domestic Assets (DA)	-	Total currency in circulation	0
		Reserves of commercial banks	0

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3. Testing the efficacy of Japanese foreign exchange intervention in the JPY/USD exchange market.

3.1 Introduction

Despite the move to floating exchange rates after the breakdown of the Bretton Woods exchange rate system in the early 1970s, Foreign Exchange Intervention (FXI) remains a commonly used tool for influencing exchange rates in most developed economies. During the last two decades of the twentieth century the FED and the Bundsbank immensely operated on unilateral and coordinated interventions to counter disorderedly exchange market conditions. The Japanese monetary authorities (JMA) joined the race seriously during the 1990s while the US and European monetary authorities have stepped back. JMA intervened in the JPY/USD exchange market over 340 days and have played a major role in limiting the yen from appreciation against the US dollar by conducting foreign exchange operations that ranged from being very large scaled operations that exceeded 20 billion USD in a single day to less than one million dollar in another occasion.

This paper studies the efficacy of the Japanese FXI in the JPY/USD market during the period January 2 1992 – March 31 2004 in influencing the level of the exchange rate and reducing its volatility. Prior empirical literature on the efficacy of FXI has relied heavily on the use of GARCH models. This is done by introducing the FXI as an independent variable in the GARCH models, thus providing an appropriate testing of

the effectiveness of FXI on both the level and volatility of the exchange rates within the same model.

Earlier studies either use the simple traditional GARCH (1, 1) model as a parsimonious model or impose a certain GARCH specification model without justifying the reason for using these models; such as the use of GARCH (1, 1) in Ballie and Osterberg (1997), Dominguez (1998), Hillebrand and Schnabl (2002), and Ito (2002 & 2004) and the use of EGARCH model in Kim and Sheen 2002 and ACT-GARCH model in Guimaraes and Karacadag (2004).

This study investigates different specifications of the GARCH models chosen based on their in-sample properties and their relative out-of-sample predictive ability using standard statistical measures. The purpose of this exercise is twofold. First, to test whether better fitting GARCH specifications, yield similar results to those of the simple GARCH (1, 1) model. Thus, one can generalize the outcomes of simple GARCH or a better fit model is more applicable on a case by case basis. Second, the best fit model for the full sample will be used in the frequency and size tests in the second part of the paper.

I employ the GARCH-in-Mean, the Threshold GARCH and the Exponential GARCH models as compared to the simple GARCH (1, 1) and GARCH (p, q) models. The GARCH-in-Mean allows the conditional variance to be a determinant in the mean process. The TGARCH and the EGARCH models have the advantage of permitting investigation of the potentially asymmetric nature of the response to past shocks. I find that the GARCH in Mean, TGARCH and EGARCH models outperform the simple GARCH models in explaining the level and volatility of the JPY/USD exchange rate. In

turn, this illustrates that the efficacy of FXI is model-specific and one should not generalize outcomes of the simple GARCH models.

Furthermore, intervention policies vary with the occasions, economic conditions and also the administrative goals. Certainly, one drawback of the literature of intervention is the implicit assumption that central banks' objective functions are stable across episodes of intervention. Only few empirical works have studied the behavior of Japanese foreign exchange intervention over the full period accounting for the change in intervention patterns. In this study, I use daily official data of the Japanese foreign exchange intervention during the period January 2 1992 to March 31 2004, dividing my research into three sub-periods to account for different intervention patterns and address all the previously mentioned issues for each period.

In my GARCH estimation, I incorporate two ideas that are mainly overlooked in recent research. First, I control for the asymmetric impact of purchase and sale interventions for both the Japanese and US monetary authorities on the level and volatility of the JPY/USD exchange rate. In prior research, FXI is usually introduced as single variable that is either the absolute value of intervention, or a variable that takes positive (negative) values for purchase (sale) operations, which does not reflect the accurate impact of separate purchase and sale interventions. I find asymmetric impact of sale and purchase operations throughout the full sample and the three subsamples.

Second, in the macroeconomic literature, FXI has various channels of influences, such as the portfolio balance and signaling channels (see Mussa, 1981 or Lewis, 1995). The former channel covers the direct impact of the actual volume of official purchases and sales on the exchange rate. The latter channel uses dummy variables to interpret

intervention as information released in the market and therefore works indirectly through moving the expectations of market agents. I test the hypothesis that what may influence the level and volatility of the exchange rate is the presence of the monetary authority in the market (Signaling Channel) regardless of the magnitude of the actual intervention operation (Portfolio Balance Channel). This is done by employing two different expressions of the intervention variable implemented in two separate models; the Portfolio Balance model and the Signaling model. Significance of the estimates of intervention variables across the two models conveys the channel through which the intervention was more effective in influencing the exchange rate and its volatility. I find that sale operations are effective through the signaling channel, while purchase operations are effective through the portfolio balance channel.

Previous studies on Japanese FXI divide the entire period of intervention into two main sub-periods, the pre-Sakakibara period, and the Sakakibara period. Sakakibara is the Director General of the International Finance Bureau. The pre-Sakakibara period is characterized by small and frequent FXI, while the Sakakibara period is characterized by large infrequent FXI. Ito and Yabu (2004) and Fatum and Hutchinson (2004) find that FXI are ineffective or even counterproductive during periods of small and frequent interventions, while they are effective during periods of large and infrequent FXI. However they did not provide evidence of whether the cause of effectiveness or ineffectiveness is due to the size or the frequency of intervention.

The second part of this paper explicitly distinguishes between the impact of the frequency and size of interventions on the level and volatility of the exchange rate, providing a detailed analysis of the effectiveness of different patterns of the Japanese

FXI. I employ the entire period of intervention which is characterized by three different patterns of interventions; frequent small, infrequent large and frequent large sized interventions using the best fitting EGARCH model for the full sample period. I introduce two models to generalize my conclusion; the Frequency-Size model and the Regime Change model. In the Frequency-Size model, I introduce the frequency and the size of intervention as independent variables affecting the level and volatility of the exchange rate. The Frequency-Size model captures the different impacts of small-frequent, large-frequent, small-infrequent and large-infrequent interventions on the level of the exchange rate as occurred throughout the full sample. The Regime-change model accounts for the different institutional changes due to changes in the JMA intervention policy throughout the full sample by introducing two dummy variables S_2 and S_3 that represent the second and third subsamples.

Both models confirm the effectiveness of purchase interventions on the level of the exchange rate. According to the Frequency-Size model, the impact of the frequency of FXI is more powerful on the level of exchange rate as compared to the size of intervention. For a given level of frequency, a change from a small to large intervention reduces the rate of appreciation of the exchange rate by 0.014%. However, for a given size of intervention, a change from frequent to infrequent interventions improves the rate of depreciation by 0.093%. A result that is confirmed by the Regime-Change model where large and infrequent purchase interventions occurring in the second subsample are the most effective in depreciating the exchange rate.

On the volatility side, the Regime Change model shows small and frequent interventions reduce the volatility while large sized interventions increases the exchange rate volatility.

The organization of the paper is as follows. After a brief literature review, section III provides Data and section IV presents stylized facts. Section V introduces the methodology. Section VI shows empirical results by assessing the efficacy of foreign exchange intervention in Japan. Section VII concludes.

3.2 Literature Review

A large amount of literature is devoted to study the effectiveness of foreign exchange intervention in developed countries currencies, focusing on the US dollar, the German mark, and the Japanese yen. The models used to study the effectiveness of intervention produced widely conflicting results and depend heavily on their assumptions and methodologies in trying to capture all the relevant features of an economy, particularly the behavior of financial markets. Dominguez and Frenkel (1993), Edison (1993), and Sarno and Taylor (2001) provide a detailed survey of the literature. The studies on intervention can be divided into two main areas. The first one assesses the impact of foreign exchange intervention on the level and volatility of the exchange rate. The second one estimates the central bank reaction function, looking for the factors that prompt the monetary authorities to intervene. In this section I focus on those studies that were related to the Yen/dollar exchange rate.

Among the studies belonging to the first one is Bonser-Neal and Tanner (1996), and Dominguez (1998) studied the dollar/mark and the dollar/yen exchange rate. They

find positive correlation between official US intervention and implied volatility derived from options contracts on exchange-rate futures. Their finding that intervention increases exchange rate volatility is similar to investigations of dollar-yen volatility that relied on news reports of Japanese intervention. Dominguez (1997 and 2002) analyzed the influence of interventions on exchange rate volatility using intra daily and daily exchange rate and intervention data over the period 1990 through 2002. Dominguez found evidence of both intra-daily and daily effects, but little evidence that interventions increase longer-term volatility of the USD/DEM and JPY/USD exchange rates.

Ito (2003) examines the short term intervention effects on the level of the exchange rate during the period 1991 to 2001, noting changes in the strategy used by the Japanese monetary authorities over the period. The author concludes that intervention operations conducted in the second half of the 1990s often appeared to produce the intended effect on the exchange rate.

Fatum and Hutchison (2003) examined the Effectiveness of Official Daily Foreign Exchange Market Intervention Operations in Japan for the period April 1, 1991 to December 31, 2000 using daily data of the USD/JPY exchange rate. They conclude that evidence of short-term effectiveness is present, and that effectiveness is boosted by the size of the intervention episode and by coordination with the Federal Reserve.

Frenkel et al (2003) studied the effects of Japanese Foreign Exchange Market Interventions on the Yen/US Dollar Exchange Rate Volatility during the period 1993-2000 using daily data. They found that the interventions of the Bank of Japan (BoJ) increased the volatility of the yen/U.S. dollar exchange rate and that those interventions

not reported in the financial press, were positively correlated with exchange rate volatility measured as absolute exchange rate return.

Hillebrand, and Schnabl, (2003) studied the effects of Japanese foreign exchange intervention using GARCH estimation and change point detection, throughout the period 1991-2002. They show that the success of interventions varies over time. Measured on the total sample between 1991 and 2002, interventions had the desired effect on the exchange rate at the cost of higher volatility. From 1991 to 1998 interventions were unsuccessful and coincided with increased exchange rate volatility. However, Intervention in 1999 yielded the intended effect while volatility is lower, providing evidence for successful intervention in Japan's liquidity trap.

Galati et al (2005) examined the foreign exchange intervention in the dollar/yen exchange market during the periods 1993-1996, and 1997-2000 using daily intervention data. They estimate probability density functions (PDFs) from option data to describe market expectations. They find that, between 1993 and 1996, JMA tended to respond mainly to deviations of the exchange rate from some implicit target levels and to a rise in market uncertainty. Between 1997 and 2000, the Bank of Japan mainly reacted in response to higher uncertainty. On the other hand, the Federal Reserve mainly intervened in cooperation with the Bank of Japan. They find that intervention had no statistically significant systematic effect on the mean of dollar/yen expectations. They detect no evidence that intervention systematically altered market participants' bias between a stronger and a weaker dollar with respect to the forward rate. Contrary to most findings of the literature, they failed to find evidence that intervention was associated on average with higher exchange rate variability.

Neely, Christopher J. (2005) use intra-daily data of the DEM/USD and JPY/USD exchange rates during the period 1987-1990 to identifying the effects of U.S. central bank intervention using Structural VAR models. He proposes to identify the cross-effects of intervention with the level and volatility of exchange rates using the likely timing of intervention, macroeconomic announcements as instruments and the nonlinear structure of the intervention reaction function. Proper identification of the effects of intervention indicates that it is moderately effective in changing the levels of exchange rates but has no significant effect on volatility.

3.3 Stylized Facts

Japan fixed its exchange rate at 360 yen per US dollar in the 22 years period starting from 1949 to 1971. It was during this period that Japan witnessed economic growth. Overall real economic growth has been called a "miracle": a 10% average in the 1960s. The Japanese yen has been appreciating since December 1971. During the phase 1971-85, yen appreciation took place without any fluctuating in the trend. Growth rates averaged a 5% in the 1970s and a 4% in the 1980s. After the plaza Accord in 1985, the Japanese currency appreciated repeatedly from 1985-1995 creating the bubble in Japanese land and equity values from 1987-1990 and then with the inevitable collapse of the bubble, threw Japan into a deflationary slump in the 1990s.

In such a situation Japanese industries invested abroad to capture the offshore markets. This in turn depressed the domestic industrial growth and employment. Domestic investments dipped and all these led to the deflation in the Japanese economy. Growth slowed markedly in the late 1990s; largely due to the Bank of Japan's failure to

cut interest rates quickly enough to counter after-effects of over-investment during the late 1980s. Japan entered a liquidity trap.

To rescue the economy, Japan incurred huge budget deficits to finance large public works programs. By 1998, Japan's public works projects still could not stimulate demand enough to end the economy's stagnation. The Japanese government undertook "structural reform" policies intended to press speculative excesses from the stock and real estate markets. Unfortunately, these policies led Japan into deflation on numerous occasions between 1999 and 2004. The interest rates set by the Bank of Japan has greatly influenced the exchange rate of Yen. In the face of a rise in the interest rate the investors would want higher returns from Yen assets. This will further push up the Yen currency. This will have a negative impact on the export side although the import bills will fall. In these times, Japan is operating with zero interest rate policy and this has made it the largest investors in foreign securities.

At this juncture the Japanese government intervened rapidly in the foreign exchange market to curb Yen appreciation in order to support the export sector. Japan also intervened by selling dollars at times when the yen was depreciating too rapidly. Figure 3.1 shows the frequency of intervention as the number of intervention days per year during the full period April 1 1991 to March 31 2004. It is clear from Figure 3.1 that the Japanese intervention transactions were implemented in small sized, high frequencies during years 1992, 1993, 1994, 1995, and in large sized, low frequencies during years 1996, 1997, 1998, 1999, 2000, and 2001, and large sized, high frequencies during years 2003, and 2004. These differences in frequencies are caused in part by the change of administrative personnel of the Vice president of Finance for International Affairs. I

excluded year 1991 from my study, since it reflects a low frequency intervention period in which there were only 4 days of interventions and it was followed by high frequency intervention period.

The Japanese and the US intervention data series used in the empirical study measure consolidated daily official transactions in billions of dollars at the market values. Overall, since January 2, 1992 till March 31, 2004, Japanese monetary authorities intervened on 340 days against the U.S. dollar over a sample size of 3195 observations; of which 311 days involved official purchases of dollars and 29 days involved official sales of dollars. The higher tendency towards purchasing US dollars reflects the attempt of the Japanese authorities to counter or slow the appreciation of the yen. During that period, the United States joined Japan in a coordinated intervention effort in 21 occasions, most of which were dollar purchases.

My model is estimated over the full period and three sub-periods that lie within the full period of intervention, to allow for different intervention policies and economic conditions. The sub-periods used in the empirical tests throughout the paper were chosen on the basis of changes in intervention regimes reflected by changes in amount, frequency, and persistence of intervention as well as in the degree of coordination with the United States as suggested by Ito (2002) and Chaboud & Humpage (2005) and Rasmus & Fatum (2007).

The first period, January 2nd 1992 to June 20, 1995 was characterized by frequent, persistent and relatively small interventions. The intervention size and frequencies greatly changed before and after June 21, 1995, when DR. Sakakibara became Director General of the International Finance Bureau of ministry of Finance. Japan intervened on 162 days

over a period of 904 days, of which 139 times to buy US dollars and on 23 times to sell US dollars. The U.S. intervened 17 times -3 sales and 14 purchase of USD- of the 21 joint operations with Japanese monetary authorities over the first period.

The second period begins on June 21 1995 to December 31 2002, marks a shift in the strategy to large infrequent interventions. During which the Japanese ministry of Finance undertook 51 interventions, 45 times to buy USD and 6 times to sell USD over a period of 1965 days. The United States occurred in 4 occasions, 3 times to buy USD and one time to sell USD. The third sub-sample begins January 2 2003 and ends March 31 2004, the Japanese authorities were only purchasing US dollars on 127 days out of 326 days and there were no US interventions.

Figure 3.2 depicts the behavior of the JPY/USD exchange rate round the Japanese and the US foreign exchange intervention operations. Figure 3.3 presents the plots of JPY/USD exchange rate returns and volatilities (defined as squared returns) over time showing the high volatility clustering.

Furthermore, I present four statistics which are calculated using the observations in the full sample: Skewness, Kurtosis, Jarque-Bera and Augmented Dickey Fuller (ADF). The return series of the JPY/USD exchange rate has negative mean and skewness⁴ representing the prevailing yen appreciation pressure against the dollar. The values for kurtosis are high (close to three) in all cases. So, the distributions are peaked relative to normal. The Jarque-Bera test rejects normality at the 5% level for all distributions. So, the samples have all financial characteristics: volatility clustering and leptokurtosis. Furthermore, in terms of stationarity, the results from the ADF tests

⁴ Negative skewness implies that the distribution has a long left tail.

indicate that the series is $I(1)$, and therefore, time-series models can be used to examine the behavior of volatility over time.

3.4 Data

The Japanese monetary authorities (JMA) recently published historical data on foreign exchange intervention, permitting increasing research on the most active intervention policy among industrial nations in the past decade. The Japanese Ministry of Finance started to release to the public in July 2001 historical data, with currency pair details, at a daily frequency going back to April 1991. According to the official Ministry of Finance data, Japan undertook frequent and massive foreign exchange market interventions between 1991 and early 2004, most of the time in a manner consistent with promoting a yen depreciation or limiting a yen appreciation. The foreign exchange intervention data are published in billions of yen, which is then converted into millions of dollars. Table 3.1 summarizes the intervention data statistics during the full period from January 2 1992 to March 31 2001.

The data on the JPY/USD exchange rate are daily NY closing spot exchange rates obtained from the Global Financial Data. I analyze the log returns of the exchange rate series. Table 3.2 presents various descriptive statistics for the JPY/USD exchange rate over the full period from January 2, 1992 to March 31, 2004. The negative mean and skewness reflect the prevailing yen appreciation pressure against the dollar. The kurtosis is significantly above 3 representing a leptokurtic distribution of yen/dollar exchange rate returns, which does not constitute a problem in our estimation because the GARCH

specification identified by Bollerslev (1986) takes a time dependent variable as a possible reason for leptokurtic into account.

The data employed in this study comprise 3195 daily observations of the JPY/USD exchange rate covering the period 1/2/1992 – 3/31/2004. Table 3.2 gives the descriptive statistics for daily JPY/USD exchange rate and returns. Daily returns are computed as logarithmic price relatives: $ds_t = \ln(\frac{S_t}{S_{t-1}})$; where S_t is the daily JPY/USD exchange rate.

3.5 Methodology

3.5.1 Testing the efficacy of intervention on the level and volatility of the exchange rates using different GARCH specifications.

GARCH models have recently been used to measure the impact of the foreign exchange intervention on both the level and volatility of the exchange rate using exogenous intervention data in both the conditional mean and variance equations. In this section, I test the impact of the Japanese and US foreign exchange intervention on the level and volatility of the JPY/USD exchange rate and provide a comparative analysis between using different GARCH models⁵. Two important characteristics within financial time series, the fat tails and volatility clustering can be captured by the GARCH family

⁵ GARCH models have found extensive application in the literature estimating the volatility of financial time series. GARCH models are used in order to capture the changing variance of the financial time series. Reviews can be found in Engle (1982), Bollerslev et al. (1986 & 1992), Diebold and Lopez (1995), and Poon and Granger (2003).

models.⁶ Volatility clustering implies that the error exhibits time-varying heteroskedasticity (unconditional standard deviations are not constant). Therefore, to model the non-constant volatility parameter, I consider various GARCH models, including the simple GARCH model as a benchmark model, as well as GARCH in Mean, the Threshold GARCH and the EGARCH model.

Bollerslev (1986) proposed a GARCH (p, q) random process, which can represent a greater degree of inertia in its conditional volatility or risk. Previous studies like Ballie and Osterberg (1997), Dominguez (1998), Hillebrand and Schnabl (2002), Frenkel et al (2003), and Ito (2002 & 2004) followed the literature (Connolly, 1989; Baillie and DeGennaro, 1990; Bera and Higgins, 1993; Bollerslev et al., 1992; among others), and considered a simple GARCH model to be parsimonious and give significant results. Only few who used other specifications of the GARCH model like Kim and Sheen (2002), Beine, Quere, and Lecourt (2002), Guimaraes and Karacadag (2004) who used EGARCH(1,1), FIGARCH, and ACT-GARCH respectively to study the impact of Central Bank intervention on the level and the volatility of the exchange rate. Even these studies imposed their choice of the GARCH type model without any justification. This section shows that simple GARCH model performs poorly as compared to other GARCH models based on model selection criteria leading to different results for the impact of intervention on the level and volatility of the exchange rate.

I estimate GARCH, GARCH-in-Mean, Threshold GARCH (TGARCH) and Exponential GARCH (EGARCH) models with normal and t-student distributions for the

⁶ Fat tails indicate that distributions are exhibiting extreme kurtosis (leptokurtic distribution). A series with some periods of low volatility and some periods of high volatility is said to exhibit volatility clustering. Volatility clustering can be thought of clustering of the variance of the error term over time: if the regression error has a small variance in one period, its variance tends to be small in the next period, too

exchange rate returns with different lags. GARCH-in-mean model suggests that an increase in the variance results in a higher expected return. EGARCH and TGARCH models have the advantage of permitting investigation of the potentially asymmetric nature of the response to past shocks⁷.

In testing the different impacts of foreign exchange intervention on the level and volatility of the exchange rate, I employ two different expressions of the intervention variable in two distinct models to infer the channel through which intervention was successful. The choice of the intervention variable involves either the use of variables expressed in terms of the volume of intervention or of dummy variables to capture the presence of the central bank in the market. Using volumes of intervention refers to the Portfolio-balance channel while working with the dummy variables usually refers to the signaling channel according to Mussa (1981) and Lewis (1995).

More specifically, Model 1 (the Portfolio model) uses actual volume of intervention in billions of US dollars. Therefore, coefficients of intervention variables in Model 1 refer to the impact of the size of separate purchase or sale intervention transactions on the level and volatility of the exchange rate. However, Model 2 (the signaling model) uses a dummy indicator for separate purchase and sale foreign exchange intervention, representing the presence of the monetary authorities in the market that day.

Differences in the significance of the estimates of intervention variables across the two models convey the channel through which successful intervention was transmitted to the level and volatility of the exchange rate. According to the theoretical explanation of the portfolio channel, as long as foreign and domestic assets are perfect

⁷ See appendix for a detailed discussion about the used GARCH models.

substitutes, intervention that modifies the relative outstanding supply of domestic assets will involve a change in relative returns, leading to a change in the value of the exchange rate. The main drawback of such explanation is that the usual size of central bank intervention is very small relative to the average daily turnover in the major exchange rate markets, so that impact is likely to be very limited. A significant estimate of the volume of intervention means intervention transactions have to be incurred in large volumes in order to be effective especially during periods where actions of the monetary authorities are perceived predictable by trading agents (as seen in the third period). However, if the estimate of the indicator of intervention is significant, this means that the actions of the monetary authorities are unpredictable and regardless of the volume of intervention transaction, their intervention will be effective.

Equation 1 provides the process of the exchange rate for models 1 and 2, as a broad-spectrum GARCH set of equations which allows actual volumes or indicators of intervention to have an exogenous effect on the mean and the variance of the exchange rate returns. The GARCH (p, q) model is given by:

$$\begin{aligned}
 ds_t &= \mu + a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{sell,t} + a_5 DOW_t + a_6 Nikkei_t \\
 &+ a_7 (i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t \\
 \text{Eq. 1} \quad \varepsilon_t | \Omega_{t-1} &\sim N(0, h_t) \\
 h_t &= \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-i} + b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{sell,t}
 \end{aligned}$$

where

ds_t is the logarithmic return of the JPY/USD spot exchange rate over the 24 hour period from the closing of the foreign exchange market on day t-1 until day t's closing?

$INV_{Buy,t}$ denotes Japan foreign exchange volume of purchases in billions of US dollars for model 1, and denotes a dummy variable that takes the value one if the JMA purchased dollars on that day and zero otherwise for model 2,

$INV_{Sell,t}$ denotes Japan foreign exchange volume of sales in billions of US dollars for model 1, and denotes a dummy variable that takes the value one if the JMA sold dollars on that day and zero otherwise for model 2,

$INVUS_{Buy,t}$ denotes US foreign exchange volume of purchases in billions of US dollars for model 1, and denotes a dummy variable that takes the value one if the USMA purchased dollars on that day and zero otherwise for model 2,

$INVUS_{Sell,t}$ denotes US foreign exchange volume of sales in billions of US dollars for model 1, and denotes a dummy variable that takes the value one if the USMA sold dollars on that day and zero otherwise for model 2,

Dow_t denotes the returns on the Dow Jones Industrial average index,

$Nikkei_t$ denotes the returns on the Japanese Nikkei 500 stock index

$i_t - i_t^*$ denotes the interest rate differential, which is the spread between the Japanese inter-bank overnight interest rate and the US Federal funds rate.

ε_t is the residual of the mean equation,

h_t is the conditional variance of the exchange rate.

d_t is a dummy variable that takes the value of one if $\varepsilon_t > 1$, and zero otherwise.

In addition to the previously mentioned model specification criteria to select the best performing model, this model explicitly tests the asymmetric impact of purchase and sale intervention operations, while detecting the transmission scheme of intervention. My model is specifically different from Hillebrand and Schnabl (2006) by introducing separate Japanese and US purchase and sale interventions, allowing for testing the impact of coordinated intervention, and introducing the interest rate differential to control for changes in domestic and foreign monetary policy.

The first line in equation 1 characterizes the mean of the stochastic process which generates the exchange rate return series. If $\mu > 0$ ($\mu < 0$) this denotes a constant rate of appreciation (depreciation) of the US dollar against the yen. The exchange rate is assumed to be influenced by current official foreign exchange interventions $INV_{Buy,t}$ ($INV_{Sell,t}$) defined as volumes or indicators of purchases (sales) of US dollars by JMA and

the US monetary authorities. The Fed and BOJ intervention operations need not be lagged one period because the exchange rate data are New York market close data. Therefore, the Fed intervention for day “ t ” is predetermined. Also, Japan is 14 hours ahead of New York so its day “ t ” intervention will also be predetermined.

Purchase interventions by the JMA are effective if $a_1 > 0$, implying that current purchases of US dollar by the JMA lead to a higher exchange value of US dollar in terms of Yen (that is an appreciation of the dollar, and depreciation of the yen). Similarly, JMA sale interventions are effective if $a_3 < 0$ implying that current sales of USD by the JMA lead to a lower exchange value of US dollar in terms of Yen (that is a depreciation of the dollar, and appreciation of the yen). The US interventions are deemed to be effective when $a_2 > 0$ and $a_4 < 0$. The total effect of the current joint intervention is measured by $a_1 + a_2$ and $a_3 + a_4$, for foreign exchange purchase and sale transactions respectively.

I include the daily returns of Japanese and US stock markets – Nikkei 500 and DOW Jones Industrial – as control variables to reflect the impact of economic or political events on the foreign exchange market.⁸ Exchange rates are expected to react differently to stock prices. Ajayi and Mougoue (1996) support the hypothesis that an increase in stock prices causes domestic currency depreciation. A rising stock market is an indicator for an expanding economy, which goes together with higher inflation expectations. Foreign investors perceive higher inflation negatively. Their demand for currency drops and it depreciates, i.e. I expect to see $a_5 > 0$, and $a_6 < 0$. Another hypothesis states that the currency will depreciate if the stock market declines. In market with high capital mobility, it is capital flows, and not the trade flows that determine the daily demand for

⁸ Following Bonser Neal and Tanner (1996) to control for the impact of disturbances in other asset markets.

currency. A decline in stock prices makes foreign investors sell the financial assets they hold in the respective currency. This leads to currency depreciation that is the signs of a_5 and a_6 will reverse.

Interest rate differential represents another possible factor to changes in the level of exchange rate. Interest rate differential aims to capture the possible impacts of the monetary policy action and local money market conditions on the exchange rate. Following Kim and Sheen (2002), I use the overnight money market rates for Japan and the U.S. Federal funds rate. It is hypothesized that a higher interest rate differential appreciates the domestic currency (yen), i.e. $a_7 < 0$. Figure 3.4 shows the behavior of the dependent and independent variables throughout the period January 2 1992 to March 31 2004.

The second line in equation 1 indicates that ε_t has a conditional normal distribution with mean zero and variance h_t . The symbol Ω_{t-1} denotes the information available to the exchange market participants at the closing of the foreign exchange market on day $t-1$.

The third line in equation 1 models the conditional volatility of the JPY/USD exchange rate as plotted in Figure 3.3. The variance h_t depends on past disturbances ε_{t-1} , the lagged variance h_{t-1} , the official foreign currency intervention $INV_{Buy,t}$, $INV_{Sell,t}$, $INVUS_{Buy,t}$, $INVUS_{Sell,t}$. An initial view would indicate that less exchange rate volatility and uncertainty seem to be preferable for the economy as a whole. Hence, interventions are effective if b_1, b_2, b_3, b_4 are negative.

Equation 1 captures the impact of foreign exchange intervention on the level and volatility of the exchange rate. This equation may reflect the possibility of having

simultaneity bias, as monetary authorities may be motivated to intervene more during periods of high exchange rate volatility (like when JMA intervened by selling dollars during 1998 Japanese financial crises) and exchange rate volatility can be triggered by expected foreign exchange intervention. However, I control this problem of simultaneity by employing the closing NY exchange rates, an internal instrument, so that the Japanese and US purchase and sale interventions precede the exchange rate observation⁹. In addition, I chose the opening levels of the DOW Jones and Nikkei 500 stock indices and lagged interest rate differential to ensure that all changes occur prior to reporting the exchange rate.

Equation 1 is estimated using 5 different GARCH regressions to capture the main characteristics of the financial times series such as fat tails, volatility clustering and the leverage effect. GARCH (1,1) normal distribution versus the student t-distribution GARCH(p,q), GARCH-in-Mean(p,q), Threshold GARCH(p,q) and Exponential GARCH(p,q). The first three models are considered symmetric models; however the last two are asymmetric models. The leverage effect means that a fall in returns is accompanied by an increase in volatility greater than the volatility induced by an increase in returns. In other words, bad news tends to increase the volatility of the exchange rate than good news; this issue is controlled in the TGARCH and the EGARCH models.

I estimate the portfolio model and the signaling model over the full time period and the three sub-periods, capturing changes in intervention regime and economic conditions. For all models other than traditional GARCH(1,1), lags have been assigned according to the value of information criteria, such that Q test on the standardized and

⁹ This way of managing the timing of the data so that intervention occurs before the exchange rate was indicated in Ballie and Osterberg 1997 and Humpage 2003

squared residuals with 5, 10, or 20 lags for the standardized squared residuals is insignificant at the 95% confidence level. Once lags are assigned, the choice of the model per sample period is based on both in sample and out of sample evaluation criterion. The best model is the one that satisfies the following measures: minimizes the Akaike information criterion (AIC) and the Bayesian Information Criterion (BIC), maximizes the Log likelihood (LL), and if conflict is to occur, I chose among conflicting models based on the one that minimizes the out of sample Root mean square error (RMSE) and Mean absolute error (MAS). Table 3.3 shows the model selection criteria for estimated GARCH model. My model selection criteria picks an EGARCH(2,1) for the full sample, T-GARCH(1,1) for the first sample period, GARCH-M (3,1) for the second sample period and E-GARCH(1,1) for the third sample period.

3.5.2 The impact of frequency and size of FXI and their efficacy on the level and volatility of the exchange rates.

In order to formulate a general conclusion regarding the impact of the frequency and size of interventions, I explicitly distinguish between the impact of the frequency and size of interventions on the level and volatility of the exchange rate, providing a detailed analysis of the effectiveness of different patterns of the Japanese FXI. I employ the entire period of intervention which is characterized by three different patterns of interventions; frequent small, infrequent large and frequent large sized interventions using the best fitting EGARCH model for the full sample period. I introduce the Frequency-Size model and the Regime Change model.

In the Frequency-Size model, I introduce the frequency and the size of intervention as independent variables affecting the level and volatility of the exchange rate. The Frequency-Size model captures the different impacts of small-frequent, large-frequent, small-infrequent and large-infrequent interventions on the level of the exchange rate as occurred throughout the full sample.

To account for the frequency of intervention, I introduce a two-week moving average measure of intervention frequency, $Freq_{buy,t}$ ($Freq_{sell,t}$), calculated by dividing the number of purchase (sale) intervention days by 10 business days. The $Freq_{buy,t}$ ($Freq_{sell,t}$) variable is multiplied by the Intervention variable to show how the effect of intervention on the level and volatility of the exchange rate depends on the frequency of intervention. It is expected that the coefficient of this variable to be negative, suggesting that frequent interventions have adverse impact on the exchange rate, however a distinct (an infrequent, that is has not been preceded by another intervention during the prior two-week window) intervention has large impact on the level of the exchange rate. This distinct and infrequent intervention is considered as a surprise to market agents and thus has an effective impact on the level of the exchange rate.

Regarding the impact of the size interventions on the level of the exchange rate, I introduce a dummy variable $Size_{buy,t}$ ($Size_{sell,t}$) that takes the value of one when the size of day t intervention exceeds average value of intervention. This average value of intervention is calculated by dividing the sum of interventions in one calendar year by the number of interventions conducted in the same year. The $Size_{buy,t}$ ($Size_{sell,t}$) variable is multiplied by the Intervention variable to show how the effect of intervention on the level and volatility of the exchange rate depends on the size of intervention. It is expected that

the coefficient of this variable is positive, suggesting that large sized intervention have large impact on the level of the exchange rate than the smaller one.

Equation 2 refers to the Frequency Size model.

$$\begin{aligned}
 ds_t = & \mu + a_1 INV_{Buy,t} + a_{1f} Freq_{buy,t} INV_{Buy,t} + a_{1s} Size_{buy,t} INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_{3f} Freq_{sell,t} INV_{Sell,t} \\
 & + a_{3s} Size_{sell,t} INV_{Sell,t} + a_4 INVUS_{sell,t} + a_5 DOW_t + a_6 Nikkei_t + a_7 (i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t \\
 (2) \quad h_t = & \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-i} + b_1 INV_{Buy,t} + b_{1f} Freq_{buy,t} INV_{Buy,t} + b_{1s} Size_{buy,t} INV_{Buy,t} + b_2 INVUS_{Buy,t} \\
 & + b_3 INV_{Sell,t} + b_{3f} Freq_{sell,t} INV_{Sell,t} + b_{3s} Size_{sell,t} INV_{Sell,t} + b_4 INVUS_{sell,t}
 \end{aligned}$$

Where

$Freq_{Buy,t}$, ($Freq_{Sell,t}$) denotes a two week moving average measure of the frequency of purchase (sale) interventions.

$Size_{Buy,t}$, ($Size_{Sell,t}$) is a dummy variable that takes the value of one when the size of day t intervention exceeds the average value of intervention.

The Regime-change model accounts for the different institutional changes in intervention that occurred throughout the full sample by introducing two dummy variables S_2 and S_3 that represent the second and third subsamples. S_2 and S_3 take the value of one when operating in the second and third subsample respectively and zero otherwise. The coefficient of intervention shows the impact intervention in the first subsample. Multiplying S_2 to the intervention variable refers to the impact of intervention in the second subsample, and by multiplying S_3 to the intervention variable refers to the impact of intervention in the third subsample. I expect that the coefficient of purchase intervention in the first subsample to be negative, in the second and third subsamples to be positive.

Equation 3 represents the Regime change model.

$$\begin{aligned}
ds_t &= \mu + a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{Sell,t} + S_2(a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} \\
&+ a_4 INVUS_{Sell,t}) + S_3(a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{Sell,t}) + a_5 DOW_t + a_6 Nikkei_t + a_7(i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t \\
(3) \quad h_t &= \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-i} + b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{Sell,t} \\
&+ S_2(b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{Sell,t}) + S_3 * b_1 INV_{Buy,t}
\end{aligned}$$

Where S_2 and S_3 are dummy variables take the value of one when operating in the second and third subsamples respectively and zero otherwise.

3.6 Empirical results

3.6.1 Effectiveness of Intervention

Table 3.4 compares results of the estimates for volume model and the indicator model each estimated once by the traditional GARCH (1,1) model and the selected GARCH model based sample selection criteria. Tables 3.4-A, 3.4-B, 3.4-C, & 3.4-D shows the resulting estimates for the full period and the three sub-periods using the daily JPY/USD exchange rate data and the Japanese and US purchases and sales intervention variables. Resulting estimates from the traditional GARCH and selected GARCH models may confirm each other and may contradict each other not only within each model but also across the two models and throughout the time periods under study.

First, the estimates of GARCH models may confirm each other within the same model throughout the four time periods. For example, based on the Portfolio model, the Japanese dollar purchases successfully induced yen depreciation throughout the full sample as well as the second and third periods but not in the first period. The current Japanese purchase intervention coefficient (a_1) is positive and highly significant. This result is confirmed by both GARCH (1,1) model and the selected models. This result is consistent with Dominguez and Frankel 1993, Dominguez 1998, and Ito (2002). In

addition the two GARCH models confirmed the negative sign and significance of the estimate of the Japan's dollar purchases representing the ineffectiveness of Japanese intervention during the first period. This ineffectiveness can be explained by the nature of Japanese intervention operations which were frequent and small in size, lacking the aspect of surprise, thereby, intervention transactions became predictable and failed to be transmitted through the portfolio channel. In addition, this result may be due to the strong appreciation of the yen during the period 1994-1995 when the yen appreciated from 100 JPY/USD to 80 JPY/USD. The result suggests that interventions are ineffective if not counterproductive, which is consistent with Ito (2003), and with Fatum and Hutchison (2002).

Second, the estimates of the GARCH models may undermine each other within the same model. In Table 3.4-A, only EGARCH(2,1) under the Portfolio model depicts a positive and significant coefficient for the US dollar purchase interventions throughout the full period, indicating the effectiveness of US intervention operations in the JPY/USD exchange market. Thereby the total effects of coordinated interventions measured by $a_1 + a_2$ will vary along with the used GARCH model. Under the Portfolio model, the joint interventions by the Japanese and US authorities were more effective when estimated using EGARCH(2,1) than GARCH(1,1) in the full period. It is worth noting that the impact of the US interventions was much higher on the JPY/USD, suggesting coordinated foreign exchange intervention is more effective than unilateral interventions when the volume model was estimated by EGARCH(2,1)¹⁰.

¹⁰ The joint interventions by the Japanese and US authorities were effective in all periods (excluding third sub-sample). For the full-sample, the value of the estimate a_1 is 0.000465, this means that on average, during the period the Japanese purchase transaction of \$1 billion moved the JPY/USD rate up by 0.5%,

Third, the estimates of the GARCH models may confirm each other across the Portfolio model and the Signaling model. This can be seen throughout the second subsample in Table 3.4-C and 3.4-D where the coefficient of the Japanese purchase intervention is positive and significant across the two models when estimated both by traditional GARCH and the selected GARCH models, suggesting effective intervention. This implies that the size of interventions (the portfolio channel) plays an important role in the effectiveness of the JMA purchase interventions for both the second and the third subsamples, despite the differences in frequency of intervention across the samples.

For the second subsample the coefficients of purchase intervention are higher than those for the third subsample, this may be attributed to the infrequent interventions, thus JMA actions were being unpredictable, and more attention was paid to the message contained in the official FEI. Therefore, the JMA were successful in sending signals to agents and effective in influencing the exchange rate, during the second subsample, however for the third subsample JMA had to purchase large volumes of US dollars in order to achieve its objective of depreciating the yen against the dollar.

Fourth, the estimates of the GARCH models may lose their significance from one model to another. This can be seen in the insignificance of the Japanese purchase intervention throughout the full sample under the Signaling model, despite being significant under the Portfolio model. This means that over the entire sample, intervention is considered frequent and therefore predictable. Thus it is the volume of intervention that affects the level of the exchange rate and not the indication of the presence of the JMA in the market.

however the US purchase of \$1 billion tended to move the JPY/USD rate by 8.3%. The impact of the US interventions was much higher on the JPY/USD.

The above results are consistent with Fatum and Hutchison (2003) in which effectiveness is boosted by the size of intervention. According to Dominguez and Frankel (1993), unanticipated interventions are most effective. When there is high frequency of intervention, the market had become too accustomed to the intervention, which tends to decrease the effectiveness of interventions.

Regarding the Japanese dollar sale intervention coefficients (a_3) are negative and only significant in the full sample and the second sub-sample under the Signaling model, indicating that dollar sales induce yen appreciation. This result confirms our previous finding that unpredictable, infrequent intervention operations tend to be more effective since the market is not accustomed to them. This is verified by the fact that there were only 29 sale operation through-out the full sample in which only 6 of them lies in the second sub-sample where JMA were adopting a surprise foreign exchange policy. The same inference applies to the US sale interventions which were only significant under the Signaling model. This finding strengthens the previous conclusion of the effectiveness of coordinated intervention to unilateral interventions. The US monetary authority in the JPY/USD market is more effective in sending signals to agents than the Japanese intervention indicators. This result can be attributed to the infrequent and unpredictable nature of the US interventions.

However, in the first sub-sample only TGARCH (1,1) picks the impact of the Japanese dollar sale intervention both under the portfolio model and the signaling model, indicating that dollar sales induce yen appreciation. Yet again, the resulting estimates of the selected TGARCH(1,1) is more convincing than the traditional GARCH(1,1), since dollar sale intervention operations were more frequent during the first sample and thus

predictable, hence yen appreciation during the first period was not only due to volume of sale operations (weakly significant coefficient) but also due to news about JMA sale operations (highly significant coefficient).

Movements in the US and Japanese stock market are strongly related to exchange rate movements on the same day, as portfolios are adjusted across borders. This is reflected in the correct signs of the significant coefficients ($a_5 > 0$ and $a_6 < 0$) across the two models and along the full sample and the three sub-samples. It is clear that across the two models that interest rate differential was only significant for the entire sample but has no significant impact on the level of the exchange rate. In addition, the coefficients of the conditional variance in the mean equation of GARCH-M model (β) in the first sub-sample are negative and significant for both the portfolio model and the signaling model. This suggests that increased volatility, proxied by the conditional variance, leads to yen appreciation in the first sub-sample.

In sum, the volume of purchase intervention operations was generally effective, except for the first sub-sample when the JPY was strongly appreciating despite the frequent purchase interventions during that period. The interventions in the second subsample were more effective due to the administrative change in the Japanese Ministry of Finance after appointing Dr. Sakakibara as the Director General of the International Finance Bureau and the adoption of unpredictable foreign exchange policy. Interventions in the third period were effective using large sized volume of intervention, suggesting the portfolio channel to be the transmission scheme of intervention during that period.

Tables 3.4 (A, B, C, & D) also report the parameter estimates of all conditional volatilities. For all the periods under study, from January 1992 to March 2003, the sum of

ARCH and GARCH coefficients is less than one. It is known that as the sum of α_1 and β_1 approaches to one this indicates that volatility shocks are quite persistent. The coefficient of the lagged squared returns α_1 is positive and statistically significant for most specifications. I conclude that strong GARCH effects are apparent for JPY/USD exchange rate. Also, the coefficient of lagged conditional variance β_1 is significantly positive and less than one, indicating that the impact of old news on volatility is significant. Higher lagged GARCH coefficients reflect a long term memory in the variance and their impact is reflected in the β_{cum} coefficient. The first explanatory variables included in the conditional variance equation are generally highly significant, indicating that the GARCH parameters ($\omega, \alpha_1, \beta_1$) have strong explanatory power.

In the two Models, the EGARCH leverage effect term γ is negative and significant for the full sample, indicating that the leverage effect exists and that increases in volatility are associated more often with large negative returns or bad news (unexpected exchange rate appreciation) than with equally large positive returns. In addition, the TGARCH leverage effect term γ is positive and significant for the first subsample, indicating that the leverage effect exists and negative shocks or bad news (unexpected exchange rate appreciation) increases volatility of the JPY/USD exchange rate compared to positive shocks of the same magnitude. It is clear that for the first subsample the estimate of lagged squared residuals α_1 is smaller than the leverage effect γ which implies that negative shocks have a larger effect on conditional volatility than positive shocks of the same magnitude.

Table 3.4 also shows the resulting estimates of the Japanese and US interventions on the volatilities of the JPY/USD exchange rate. For the full sample, Table 3.4-A,

Japanese dollar purchases were successful in reducing the volatility when estimated by the traditional GARCH in the Portfolio model. However the same estimates under the EGARCH(2,1) were insignificant though have the correct sign. In Table 3.4-A, for the full sample, the exchange rate volatilities are only affected by the size of intervention not by the news that the JMA is present in the market. This result can be extended to the third subsample where only estimates of traditional GARCH(1,1) under the volume model were significant. In Table 3.4-C, for the second subsample only GARCH(1,1) is effective in both models suggesting that both the size and the news about intervention have stabilizing effects on exchange rate volatilities. Once more this result supports my finding in the previous section that the news about the presence of JMA in the market is more effective during periods of infrequent and unpredictable interventions, while it is the size of intervention that matters during periods of frequent interventions (as implied by the third sub-sample coefficient).

On the contrary, JMA dollar purchase interventions were ineffective in reducing the volatilities during the first sub-sample. The coefficient of JMA dollar purchase interventions b_I is positive and significant when estimated by the selected TGARCH(1,1) and the traditional GARCH(1,1) models. This result is true across the volume and the indicator model, suggesting that the increased volatilities in the first period is generally due to the news about the presence of JMA in the market to purchase dollars as well as the actual volume of intervention, which is an expected result due to the frequent nature of intervention in the first period.

Alternatively, the US purchase interventions appear to have a destabilizing influence in terms of the volatility of the exchange rate during the full sample. This result

is verified by the positive and significant coefficients of the US purchase interventions (b_2) in the conditional variance equation when estimated by both GARCH models across the portfolio and the signaling model. However, this impact was stabilizing in the first and second sub-samples according to Portfolio model using the traditional GARCH specifications. Further, as per the Portfolio model, the US sale interventions were effective in reducing the volatility of the exchange rate during the full sample when estimated using traditional GARCH. However, EGARCH(2,1) alleges an opposite effect according to the Portfolio model and the Signaling model.

A number of regression diagnostics statistics are presented at the end of Table 3.4: $Q^2(20)$ denote the Box-Pierce Q-statistic (with 20 lags) for the squared standardized residuals. The traditional GARCH model shows a problem of autocorrelation in squared residuals as seen by the significant Box Pierce Q-statistic. If the variance equation is correctly specified, as in all cases the Q-statistics of the residuals are insignificant for the selected GARCH model. The ARCH LM test statistic is computed from an auxiliary test regression, to test the null hypothesis that there is no ARCH up to order 5, and 10 lags in the residuals. The LM test statistic is asymptotically distributed as a $\chi^2(q)$ under quite general conditions. As the ARCH LM (5) and ARCH LM (10) tests show, the traditional GARCH model shows a problem autoregressive heteroskedasticity in the residuals as shown by the significant ARCH LM test. However, the standardized residuals for the selected GARCH models do not exhibit additional ARCH effects. Another concerning issue against the use of traditional GARCH (1,1) models.

The additional set of models, the Frequency-Size and the Regime Change models, one can formulate general conclusions regarding the JMA interventions in the JPY/USD

interventions. According to the Frequency size model, I find that there is asymmetric impact of purchase and sale JMA interventions on the level of the exchange rate. Only JMA purchase transactions are found effective in influencing the exchange rate; however this influence is governed by the frequency and the size of intervention. Table 3.5 shows that infrequent large purchase interventions are the most effective transactions while frequent small purchase interventions are not effective and even counterproductive.

Table 3.6 shows the impact of JMA purchase intervention transactions on the percentage change of the level of the exchange rate. If day t intervention operation is the only purchase operation conducted in the prior two-week period, a one billion dollar transaction by the JMA leads to a depreciation of the yen by 0.08% if intervention is larger than the average size of interventions during the calendar year, and depreciates the yen by 0.06% if intervention is less than the average size of interventions during the calendar year.

However frequent interventions in the sense that JMA has intervened during the prior two-week period has a counterproductive impact on the level of the exchange rate regardless of the size of intervention. The frequency of intervention is a strong factor in determining the effectiveness of intervention and works against the initial goal purchase interventions. In other words, frequent purchase interventions appreciate the yen against the dollar rather than depreciate it. The range of appreciation varies with the frequency and the size of intervention too. When JMA conducts frequent large purchase operations on a daily basis throughout the prior two-week, these operations appreciate the yen by 0.018% while a small intervention appreciates the yen by 0.032% against the dollar.

As the JMA conducts less frequent purchase interventions, this improves the effectiveness of intervention by and depreciates the yen by 0.093%. Table 3.6 shows the range of change in the exchange rate due to different frequencies in intervention. To avoid counterproductive interventions, JMA should not exceed the cutoff level of the frequency; JMA should limit its number of interventions in a two week period to eight with large interventions, and to 6 with small interventions.

Table 3.6 also reveals how powerful the impact of the frequency of FXI as compared to the size of intervention on the level of exchange rate. For a given level of frequency (working horizontally), a change from a small to large intervention reduces the rate of appreciation of the exchange rate by 0.014%. However, for a given size of intervention (working vertically), a change from frequent to infrequent interventions improves the rate of depreciation by 0.093%.

These results confirm to the outcome of the Regime Change model, in which the subsamples are introduced within the model suggesting the regime change. First, there is asymmetric impact of purchase and sale intervention on the level of the exchange rates. Purchase interventions are always effective in influencing the exchange rate. Second, the effectiveness of purchase interventions varies across subsamples. In the first subsample where purchase interventions are frequent and small, these operations are counterproductive and appreciate the yen by 0.46 % against the dollar. In the second subsample where interventions are infrequent and large, purchase operations are effective in depreciating the yen by 0.57%, while in the third subsample, in which interventions are frequent and large interventions were effective in depreciating the yen by 0.49% against the dollar.

Both models confirm the effectiveness of US purchase interventions on the level of the exchange rate. Unlike the level of the exchange rate, the impact of interventions on the volatility is unclear. According to the Frequency-Size model, frequent large sized sale operations increase the volatility of the exchange rate, while purchase operations in the first subsample were effective in calming the disorderliness of the market. On the other hand, the Regime Change model shows that interventions in the first subsample reduced the volatility while interventions in the second and the third subsample increased the exchange rate volatility.

To conclude, Japanese foreign exchange intervention possessed different patterns in its effect on the level and volatility of the JPY/USD exchange rate. This study finds that the Japanese dollar purchases interventions were ineffective or even counterproductive during time periods of very frequent interventions (during the first period) while it was effective during a time-period of infrequent interventions in the second period. In fact, these findings are consistent with the study by Ito (2003) and Hoshikawa (2008). This result is attributed to the predictability of intervention during the first period, which in turn allows market participants to anticipate these operations and formulates appropriate expectations into the level of the exchange rate. For the third subsample, both the volume and the indicator of intervention are more effective in depreciating the level of the exchange rate.

These results support Almekinders (1996) view that, the more frequently a central bank intervenes, the less attention will be paid to the message contained in the official foreign currency operations. It follows that the central bank is faced with a tradeoff. It can choose to intervene more frequently in the present with a (small) chance of driving

the current spot rate closer to the target rate and/or limiting the conditional volatility of the spot rate. This will go at the cost of lowering the news –content and thus the potential effectiveness of future interventions. Thus, by refraining from intervention in the face of small changes in the exchange rate and normal levels of conditional volatility, the central banks can be viewed as investing in potential effectiveness of interventions to be undertaken at times when foreign exchange market experiences some serious instability.

3.7 Conclusion

In this paper, I examine the impact of Japanese monetary authorities' intervention transactions on the level and volatility of the JPY/USD exchange rate using different GARCH Models. According to model selection, EGARCH, Threshold GARCH and GARCH in Mean models outperform the traditional GARCH (1,1) model. Different results are obtained when estimating the effectiveness of JMA intervention on the level and volatility of the exchange rate using better fit GARCH models and traditional GARCH models. Thus, one cannot generalize results obtained from the simple GARCH model, and effectiveness of FXI is highly dependent on the employed model.

I use daily official data of the Japanese foreign exchange intervention during the period January 2 1992 to March 31 2004, dividing my research into three sub-periods and controlling for the asymmetric impact of purchase and sales interventions while testing the channel through which intervention influenced the exchange rates. I find asymmetric impact of sale and purchase operations throughout the full sample and the three subsamples. In particular, I find that sale operations are effective through the signaling channel, while purchase operations are effective through the portfolio balance channel.

Previous studies on Japanese FXI find that FXI are ineffective during periods of small and frequent interventions, while they are effective during periods of large and infrequent FXI. However they did not provide evidence of whether the cause of effectiveness or ineffectiveness is due to the size or the frequency of intervention. In the second part of this paper, I explicitly distinguish between the impact of the frequency and size of interventions on the level and volatility of the exchange rate, providing a detailed analysis of the effectiveness of different patterns of the Japanese FXI.

I find that the impact of the frequency of FXI is more important on the level of exchange rate while it is less important on the volatility as compared to the size of intervention. For a given level of frequency, a change from a small to large intervention reduces the rate of appreciation of the exchange rate by 0.014%. However, for a given size of intervention, a change from frequent to infrequent interventions improves the rate of depreciation by 0.093%, providing more evidence of why infrequent large interventions during the second period were more effective as compared to the frequent large interventions in the third period. On the other hand small frequent intervention reduces the volatility while large frequent interventions increased the exchange rate volatility.

Extending this approach of studying the effectiveness of FXI to emerging market economies while taking into consideration the spillover effects of changes in other related exchange rates in a VAR framework might be the direction of future research.

Table 3.1: Intervention Data Summary Statistics

	Full Period	First Period	Second Period	Third Period
	Jan 2 1992– Mar 31 2004	Jan 2 1992– June 20 1995	June 21 1995-Dec 31 2002	Jan 1 2003– Mar 31 2004
Number of Observations	3195	904	1965	326
Total intervention days	340	162	51	127
Unconditional probability of Intervention	0.11	0.18	0.03	0.39
Number of days with dollar purchase	311	139	45	127
Average amount of dollar purchase (millions of dollars)	181.19	78.50	100.23	953.93
Unconditional probability of dollar purchase	0.10	0.15	0.02	0.39
Number of days with dollar sale	29	23	6	0
Average amount of dollar sale (millions of dollars)	11.68	6.11	16.18	NA
Unconditional probability of dollar sale	0.009	0.025	0.003	NA

Table 3.2: Descriptive Statistics of daily returns of the JPY/USD exchange rate:

	<i>Full Period</i>			<i>First Period</i>	<i>Second Period</i>	<i>Third Period</i>
	1/2/1992 – 3/31/2004			1/2/1992-6/20/1995	6/21/1995-12/31/2002	1/2/2003-3/31/2004
	S_t	$\ln S_t$	ds_t	ds_t	ds_t	ds_t
<i>Mean</i>	114.70	4.74	0.00	0.00	0.00	0.00
<i>Std. Dev.</i>	11.57	0.10	0.01	0.01	0.01	0.01
<i>Skewness</i>	-0.14	-0.47	-0.60	-0.24	-0.77	0.10
<i>Kurtosis</i>	3.016	3.41	8.90	6.61	9.50	3.82
<i>Jarque-Bera</i>	10.70	138.36	4827.32	499.98	3649.67	9.70
<i>Probability</i>	0.00	0.00	0.00	0.00	0.00	0.01
<i>Observations</i>	3196	3195	3195	904	1965	326
<i>ADF(Level)</i>		-1.94				
<i>ADF(1st diff)</i>		-56.11				

Notes: $ds_t = \ln(S_t / S_{t-1})$, Skewness is a measure of asymmetry of the distribution of the series around its mean. Kurtosis measures the peakedness or flatness of the distribution of the series.

Jarque-Bera is a test statistic for testing whether the series is normally distributed.

ADF regressions include intercept but not trend. I employ ADF test on the logarithms of stock indices.

ADF critical values: (1%) -3.4334, (5%) -2.8627, (10%) -2.5674

Table 3.3: Model Selection Criterion for estimated GARCH-type (p,q) models.

	<i>Full period 1/2/1992-3/31/2004</i>					<i>First period 1/2/1992-6/20/1995</i>				
<i>Selection Criteria</i>	GARCH (1,1) ^{1†}	GARCH (3,1) ^{2†}	GARCH M(2,1) ^{2†}	TGARCH (3,1) ^{2†}	EGARCH (2,1) ^{2†}	GARCH (1,1) ^{1†}	GARCH (1,1) ^{2†}	GARCH- M(2,3) ^{2†}	TGARCH (1,1) ^{2†}	EGARCH (1,1) ^{2†}
<i>AIC</i>	-6.994(5)	-7.267(1)	-7.266(4)	-7.267(1)	-7.267(1)	-7.283(5)	-7.349(2)	-7.332(4)	-7.359(1)	-7.335(3)
<i>BIC</i>	-6.966(5)	-7.232(2)	-7.232(2)	-7.231(4)	-7.233(1)	-7.203(5)	-7.265(1)	-7.226(4)	-7.265(1)	-7.244(3)
<i>LL</i>	11189(4)	11627(2)	11625(3)	11627(2)	11628(1)	3306(5)	3338(2)	3334(3)	3342(1)	3332(4)
<i>RMSE</i>	0.0070	0.0069	0.0071	0.0069	0.0068	0.0066	0.0066	0.0073	0.0066	0.0066
<i>MAE</i>	0.0051	0.0051	0.0051	0.0050	0.0049	0.0048	0.0048	0.0050	0.0047	0.0048
<i>Rank</i>	5	3	4	2	1	5	2	4	1	3
	<i>Second period 6/21/1995-12/12/2002</i>					<i>Third period 1/2/2003-3/31/2004</i>				
<i>Selection Criteria</i>	GARCH (1,1) ^{1†}	GARCH (1,1) ^{2†}	GARCH- M(3,1) ^{2†}	TGARCH (1,1) ^{2†}	EGARCH (2,1) ^{2†}	GARCH (1,1) ^{1†}	GARCH (1,1) ^{2†}	GARCH- M(1,1) ^{2†}	TGARCH (1,1) ^{2†}	EGARCH (1,1) ^{2†}
<i>AIC</i>	-6.982(3)	-6.938(4)	-7.175(1)	-6.903(5)	-7.175(1)	-7.570(4)	-7.600(3)	-7.766(2)	-7.456(5)	-7.775(1)
<i>BIC</i>	-6.940(3)	-6.893(4)	-7.125(1)	-6.855(5)	-7.123(2)	-7.465(5)	-7.480(4)	-7.380(2)	-7.532(3)	-7.647(1)
<i>LL</i>	6875(3)	6833(4)	7068(1)	6799(5)	7066(2)	1243(5)	1248(3)	1276(2)	1247(4)	1278(1)
<i>RMSE</i>	0.0073	0.0074	0.0072	0.0075	0.0072	0.0050	0.0049	0.0051	0.0049	0.0049
<i>MAE</i>	0.0053	0.0053	0.0053	0.0053	0.0053	0.0037	0.0037	0.0038	0.0037	0.0037
<i>Rank</i>	3	4	1	5	2	5	3	2	4	1

Notes: AIC is the Akaike Information Criterion for model selection, BIC is the Bayesian Information Criterion for model selection, LL is the maximum Log-Likelihood value, RMSE is the Root Mean Squared error, and MAE, is the Mean Absolute error.

1[†]. Error terms follow normal distribution. 2[†]. Error terms follow student-t distribution. Figures between brackets refer to the model ranking per criterion.

Table 3.4-A: Estimates of GARCH-type Models Full sample:

$$ds_t = \mu + a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{Sell,t} + a_5 DOW_t + a_6 Nikkei_t + a_7 (i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t$$

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-i} + b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{Sell,t}$$

	GARCH (1,1)	EGARCH (2,1)	GARCH (1,1)	EGARCH (2,1)
Model 1: The Portfolio Model			Model 2: The Signaling Model	
μ	-0.000639 (0.0006)	-0.000661 (0.0002)***	-0.00047 (0.0003)*	-0.000433 (0.0002)*
a_1	0.000472 (0.0001)***	0.000465 (0.0001)***	0.000141 (0.0004)	-0.000225 (0.0003)
a_2	0.012344 (0.0081)	0.008268 (0.0039)**	0.008422 (0.0012)***	0.006129 (0.0018)***
a_3	-0.000956 (0.0006)	-0.000931 (0.0007)	-0.002305 (0.0007)***	-0.001618 (0.001)*
a_4	-0.056648 (0.0519)	-0.056665 (0.0659)	-0.016066 (0.0019)***	-0.012993 (0.0031)***
a_5	0.054153 (0.0183)***	0.052993 (0.0087)***	0.054027 (0.0093)***	0.051067 (0.0087)***
a_6	-0.033004 (0.0177)*	-0.035539 (0.0079)***	-0.034429 (0.0087)***	-0.034547 (0.0079)***
a_7	-0.000153 (0.0001)	-0.000135 (0)***	-0.0000931 (0)*	-0.000109 (0)**
ω	0.0000301 (0)***	-0.329792 (0.092)***	0.000000772 (0)***	-0.43568 (0.1022)***
α_1	0.144112 (0.0215)***	0.129465 (0.0298)***	0.039233 (0.004)***	0.148217 (0.0301)***
γ		-0.03125 (0.0142)**		-0.042652 (0.0156)***
β_1	0.579406 (0.0756)***	0.501292 (0.2657)*	0.942848 (0.006)***	0.509949 (0.226)**
β_{cum}		0.976909 (0.00775)***		0.457828 (0.2226)**
b_1	-0.00000306 (0)***	-0.003659 (0.0063)	-0.00000002 (0.2568)	-0.018674 (0.017)
b_2	0.000174 (0.0001)*	0.67229 (0.3061)**	0.00000208 (0)***	0.587964 (0.1683)***
b_3	-0.00000422 (0)	0.014666 (0.0446)	-0.00000163 (0.167)	-0.052662 (0.0863)
b_4	-0.000188 (0)***	1.070125 (1.1153)	0.000014 (0)*	0.730461 (0.3222)**
$Q^2(20)$	48.341***	23.488	25.544	21.881
ARCH LM((5)	20.93263***	9.53	13.713**	9.763*
ARCHLM ((10)	41.86687***	11.8	15.036	10.982

Notes: $Q^2(20)$ is the Box-Pierce Q -statistics for squared standardized residuals. The Q -statistic at lag k is a test statistic for the null hypothesis that there is no autocorrelation up to order 20. The ARCH LM test is a Lagrange multiplier (LM) test for autoregressive conditional heteroskedasticity (ARCH) in the residuals. Standard errors are in parentheses. ***, **, * denote significance at the 1, 5, and 10% level, respectively.

Table 3.4-B: Estimates of GARCH-type Models – First Sample:

$$ds_t = \mu + a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{Sell,t} + a_5 DOW_t + a_6 Nikkei_t + a_7 (i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t$$

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-i} + b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{Sell,t}$$

Model 1: The Portfolio Model			Model 2: The Signaling Model	
	GARCH (1,1)	TGARCH (1,1)	GARCH (1,1)	TGARCH(1,1)
μ	-0.0000504 (0.0004)	0.000274 (0.0003)	0.000145 (0.0004)	0.000295 (0.0003)
a_1	-0.004164 (0.0012)***	-0.004731 (0.001)***	-0.002378 (0.0008)***	-0.002145 (0.0006)***
a_2	0.009054 (0.0024)***	0.006856 (0.0031)**	0.005511 (0.0048)	0.004249 (0.0017)**
a_3	-0.003688 (0.0032)	-0.005502 (0.0031)*	-0.001411 (0.0016)	-0.002347 (0.001)**
a_4	-0.154336 (0.038)***	-0.063585 (0.0734)	-0.012762 (0.0103)	-0.006464 (0.0035)*
a_5	0.147134 (0.0317)***	0.115421 (0.0298)***	0.142397 (0.0361)***	0.114936 (0.03)***
a_6	-0.053599 (0.0169)***	-0.053709 (0.0145)***	-0.051533 (0.0199)***	-0.057013 (0.0142)***
a_7	0.0000889 (0.0001)	0.000144 (0.0001)	0.000108 (0.0001)	0.000142 (0.0001)
ω	0.00000164 (0)***	0.00000119 (0)***	0.0000354 (0)***	0.00000109 (0)**
α_1	0.01615 (0.0079)**	0.024621 (0.0139)*	0.06885 (0.0275)**	0.01647 (0.00175)***
γ		0.056024 (0.0197)***		0.074522 (0.0237)***
β_1	0.928992 (0.0118)***	0.954044 (0.0185)***	0.048387 (0.00871)***	0.940697 (0.0244)***
b_1	0.0000133 (0)***	0.0000116 (0)***	0.000025 (0)***	0.00000425 (0)**
b_2	-0.0000443 (0)***	-0.0000353 (0)***	0.000124 (0.0001)*	-0.00000703 (0)
b_3	-3.78E-06 (0)	-6.33E-07 (0)	0.00000946 (0)	-0.000000628 (0)
b_4	0.000161 (0.0001)	0.0000681 (0.0001)	0.000152 (0.0004)	0.0000151 (0)
$Q^2(20)$	16.144	11.104	41.368***	17.761
ARCH LM(5)	1.6056	0.6215	9.601*	1.375
ARCHLM(10)	5.02156	3.8221	17.012*	4.876

Notes: See Table 2.4-A

Table 3.4-C: Estimates of GARCH-type Models – Second Sample:

$$ds_t = \mu + a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{Sell,t} + a_5 DOW_t + a_6 Nikkei_t + a_7 (i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t$$

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-i} + b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{Sell,t}$$

<i>Model 1: The Portfolio Model</i>			<i>Model 2: The Signaling Model</i>	
	<i>GARCH (1,1)</i>	<i>GARCH-M (3,1)</i>	<i>GARCH (1,1)</i>	<i>GARCH-M (3,1)</i>
M	-0.000427 (0.0014)	-0.000274 (0.0007)	-0.000563 (0.0017)	-0.000307 (0.0006)
a_1	0.001158 (0.0001)***	0.001189 (0.0001)***	0.0064 (0.0011)***	0.005644 (0.0008)***
a_2	0.065696 (0.01)***	0.060148 (0.0142)***	0.024334 (0.0015)***	0.024618 (0.0039)***
a_3	-0.001062 (0.0013)	-0.00095 (0.0008)	-0.006857 (0.0039)*	-0.00526 (0.0028)*
a_4	-0.055355 (0.0982)	-0.0555 (1.3551)	-0.04106 (1.4162)	-0.042472 (2.2725)
a_5	0.040659 (0.0173)**	0.042275 (0.0098)***	0.0389 (0.0227)*	0.040528 (0.0099)***
a_6	-0.031462 (0.0186)*	-0.020196 (0.0103)*	-0.032605 (0.0225)	-0.021185 (0.0104)**
a_7	-0.0001 (0.0002)	-0.000122 (0.0001)	-0.0000992 (0.0003)	-0.000127 (0.0001)
β_2		-4.376581 (0.72136)**		-4.678622 (0.72292)**
Ω	0.0000283 (0)***	0.00000052 (0)	0.0000384 (0)***	0.000000571 (0)**
α_1	0.137078 (0.0197)***	0.026547 (0.0153)*	0.136957 (0.0235)***	0.029557 (0.0121)**
β_1	0.560843 (0.0747)***	0.655746 (0.66)**	0.561397 (0.106)***	0.561201 (0.4843)***
β_{cum}		0.963779 (0.0210)***		0.457828 (0.2226)**
b_1	-0.00000546 (0)***	-0.000000714 (0)	-0.0000352 (0)***	-0.00000256 (0)
b_2	-0.0000449 (0)**	0.000059 (0)	-0.000049 (0)***	0.000026 (0)
b_3	-0.00000398 (0)*	0.000000194 (0)	0.00000152 (0.0001)	0.0000163 (0)
b_4	-0.000171 (0.0001)	0.0000312 (0.0001)	-0.000173 (0.0003)	0.0000203 (0.0001)
$Q^2(20)$	56.58***	13.757	67.894***	16.456
$ARCH\ LM((5))$	15.05844***	6.649977	15.652***	8.137
$ARCHLM((10))$	28.38672***	7.751628	34.551***	9.478

Notes: See Table 2.4-A.

Table 3.4-D: Estimates of GARCH-type Model – Third subsample:

$$ds_t = \mu + a_1 INV_{Buy,t} + a_2 INVUS_{Buy,t} + a_3 INV_{Sell,t} + a_4 INVUS_{Sell,t} + a_5 DOW_t + a_6 Nikkei_t + a_7 (i_{t-1} - i_{t-1}^*) + \beta h_{t-1} + \varepsilon_t$$

$$h_t = \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \sum_{i=1}^p \beta_i h_{t-1} + b_1 INV_{Buy,t} + b_2 INVUS_{Buy,t} + b_3 INV_{Sell,t} + b_4 INVUS_{Sell,t}$$

<i>Model 1: The Portfolio Model</i>			<i>Model 2: The Signaling Model</i>	
	<i>GARCH</i> (1,1)	<i>EGARCH</i> (1,1)	<i>GARCH</i> (1,1)	<i>EGARCH</i> (1,1)
μ	-0.01103 (0.0136)	-0.009233 (0.0061)	-0.01105 (0.0125)	-0.0052 (0.0063)
a_1	0.000464 (0.0002)***	0.00048 (0.0001)***	0.000461 (0.0001)***	0.000374 (0.00005)***
a_5	0.069235 (0.049)	0.048384 (0.024)**	0.06922 (0.0446)	0.039755 (0.0245)
a_6	-0.054047 (0.0444)	-0.067194 (0.0223)***	-0.05406 (0.0385)	-0.05733 (0.0225)**
a_7	-0.003582 (0.0048)	-0.00297 (0.0021)	-0.00358 (0.0044)	-0.00164 (0.0022)
ω	0.0000176 (0)*	-2.828501 (2.1236)	1.73E-05 (0)	-1.34454 (1.2097)
α_1	0.149631 (0.01338)***	0.103394 (0.0112)***	0.149557 (0.01416)***	0.107106 (0.00949)***
γ		0.126992 (0.0787)		0.06422 (0.0546)
β_1	0.598979 (0.233)**	0.740229 (0.1986)***	0.598778 (0.2992)**	0.881256 (0.1118)***
b_1	-0.00000197 (0)***	-0.009546 (0.0259)	-1.93E-06 (0)	0.020513 (0.0543)
$Q^2(20)$	20.243	15.032	23.274	20.900
<i>ARCH</i>				
<i>LM(5)</i>	9.6185	8.3688	8.610	8.464
<i>ARCHLM</i>				
<i>((10))</i>	11.218	9.5914	11.937	9.508

Notes: See Table 2.4-A

Table 3.5-A: EGARCH Model Estimation on the Level of the exchange rates.

<i>Full sample</i>	<i>Frequency/Size</i>	<i>Full sample</i>	<i>Regime Change</i>
μ	-0.000642 (0.0002)***	μ	-0.000489 (0.0002)**
INV_{buy}	0.000715 (0.0003)**	INV_{buy}	-0.004586 (0.001)***
$Freq_{buy} * INV_{buy}$	-0.001033 (0.0003)***	$INVUS_{buy}$	0.008882 (0.0031)***
$Size_{buy} * INV_{buy}$	0.000139 (0.0001)**	INV_{sell}	-0.003986 (0.003)
$INVUS_{buy}$	0.008076 (0.0035)**	$INVUS_{sell}$	-0.060333 (0.0781)
INV_{sell}	-0.005159 (0.0043)	$S2 * INV_{buy}$	0.005774 (0.001)***
$Freq_{sell} * INV_{sell}$	0.019074 (0.0237)	$S2 * INVUS_{buy}$	0.053645 (0.0219)**
$Size_{sell} * INV_{sell}$	0.000349 (0.0047)	$S2 * INV_{sell}$	0.00306 (0.003)
$INVUS_{sell}$	-0.052481 (0.057)	$S2 * I INVUS_{sell}$	0.005277 (1.7795)
		$S3 * INV_{buy}$	0.004863 (0.001)***
$DDOW$	0.051863 (0.0086)***	$DDOW$	0.050939 (0.0086)***
$DN500$	-0.033169 (0.0079)***	$DN500$	-0.037245 (0.0079)***
DI	-0.000133 (0)***	DI	-0.000109 (0)**

Notes: See Table 2.4-A

Table 3.5-B: EGARCH Model Estimation on the volatility of the exchange rates.

<i>Full sample</i>	Frequency/Size	<i>Full sample</i>	Regime Change
ω	-0.270444 (0.0633)***	ω	-0.371474 (0.1123)***
α_1	0.102763 (0.0183)***	α_1	0.118005 (0.0321)***
γ	-0.026932 (0.01)***	γ	-0.038421 (0.0159)**
β_1	0.980696 (0.0056)***	β_1	0.616608 (0.3162)*
β_{cum}		β_{cum}	0.355366 (0.3107)
INV_{buy}	-0.014438 (0.0207)	INV_{buy}	-0.004586 (0.001)***
$Freq_{buy} * INV_{buy}$	0.036431 (0.019)*	$INVUS_{buy}$	0.008882 (0.0031)***
$Size_{buy} * INV_{buy}$	-0.006298 (0.0057)	INV_{sell}	-0.003986 (0.003)
$INVUS_{buy}$	0.321033 (0.2437)	$INVUS_{sell}$	-0.060333 (0.0781)
INV_{sell}	1.219188 (0.6409)*	$S2 * INV_{buy}$	0.005774 (0.001)***
$Freq_{sell} * INV_{sell}$	-4.245857 (2.3465)*	$S2 * INVUS_{buy}$	0.053645 (0.0219)**
$Size_{sell} * INV_{sell}$	-0.049886 (0.0284)*	$S2 * INV_{sell}$	0.00306 (0.003)
$INVUS_{sell}$	-0.191332 (1.0161)	$S2 * I INVUS_{sell}$	0.005277 (1.7795)
		$S3 * INV_{buy}$	0.004863 (0.001)***
<i>Log likelihood</i>	11642.32	<i>Log likelihood</i>	11637.26
<i>AIC</i>	-7.27219	<i>AIC</i>	-7.281541
<i>BIC</i>	-7.224699	<i>BIC</i>	-7.228351
$Q^2(20)$	25.62	$Q^2(20)$	19.35
<i>ARCH LM((5)</i>	8.93	<i>ARCH LM((5)</i>	8.82
<i>ARCHLM ((10)</i>	11.33	<i>ARCHLM ((10)</i>	10.58

Notes: See Table 2.4-A

Table 3.6: Percentage change of exchange rate for a One billion dollar purchase intervention by JMA.

Frequency (INV days/2week)	Large	Small
10 INV. Days	-0.0179	-0.0318
9 INV. Days	-0.00757	-0.02147
8 INV. Days	0.00276	-0.01114
7 INV. Days	0.01309	-0.00081
6 INV. Days	0.02342	0.00952
5 INV. Days	0.03375	0.01985
4 INV. Days	0.04408	0.03018
3 INV. Days	0.05441	0.04051
2 INV. Days	0.06474	0.05084
1 INV. Day	0.07507	0.06117

Figure 3.1: Frequency of Japanese foreign exchange intervention over the period April 1 1999 to March 31 2004.

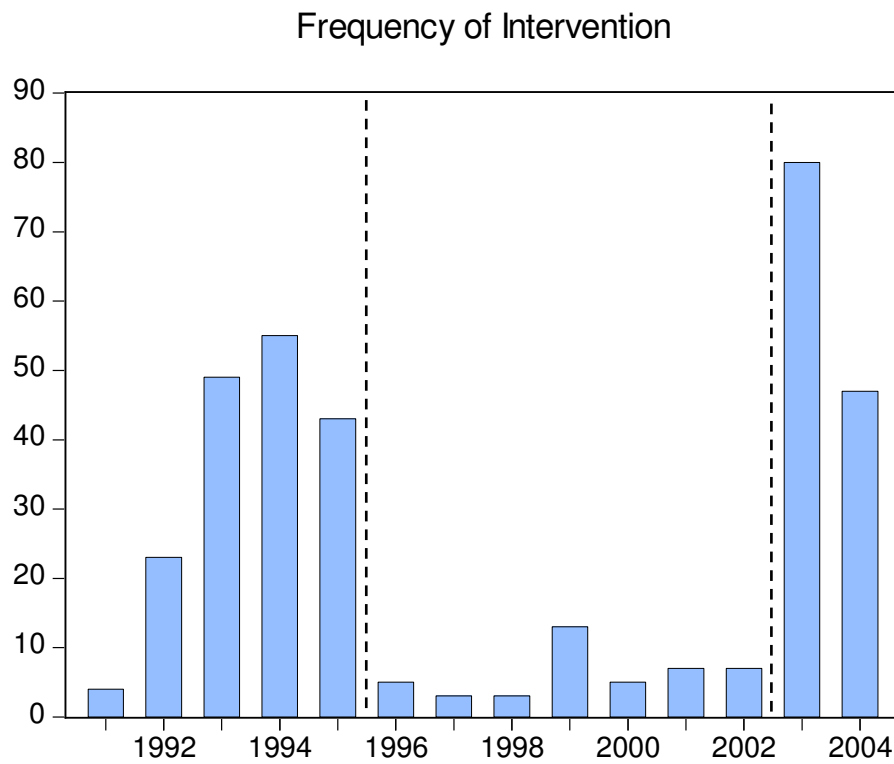


Figure 3.2: The behavior of the JPY/USD exchange rate around the Japanese and US foreign exchange intervention operations, and the 125 USD/JPY level of the exchange rate during the full period January 2 1992 to March 31 2004.

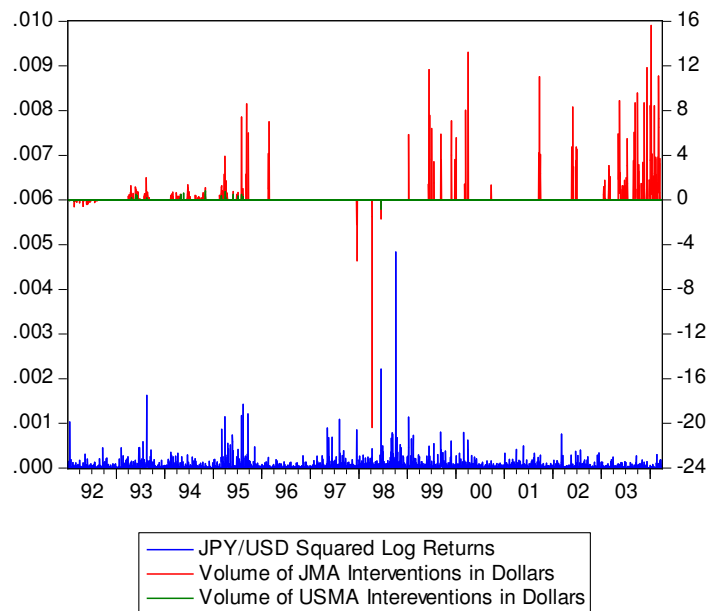
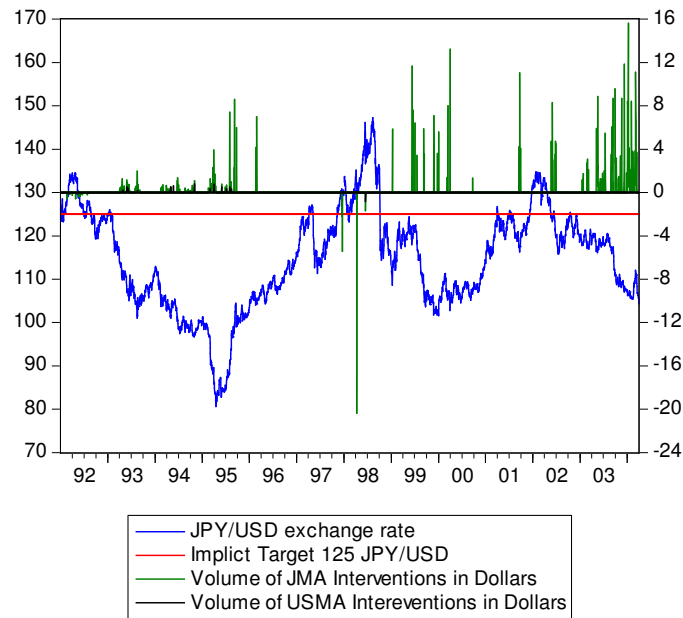
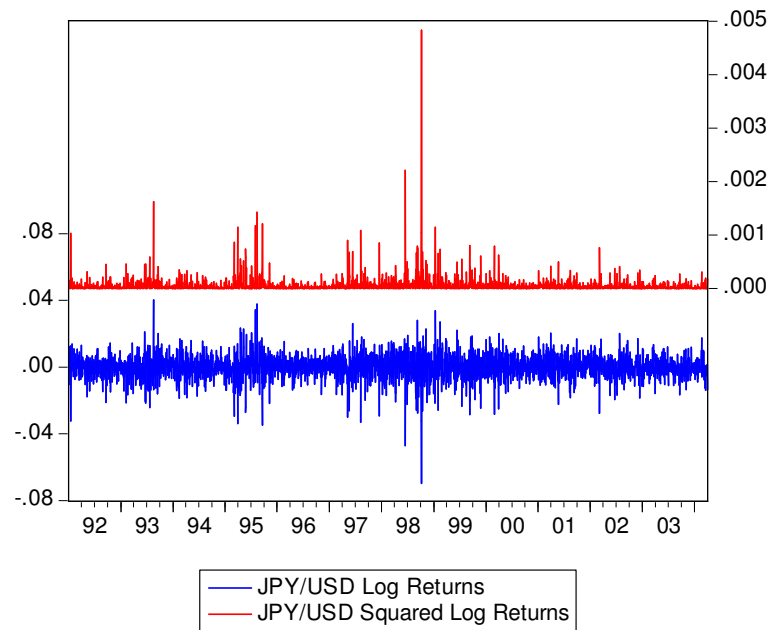
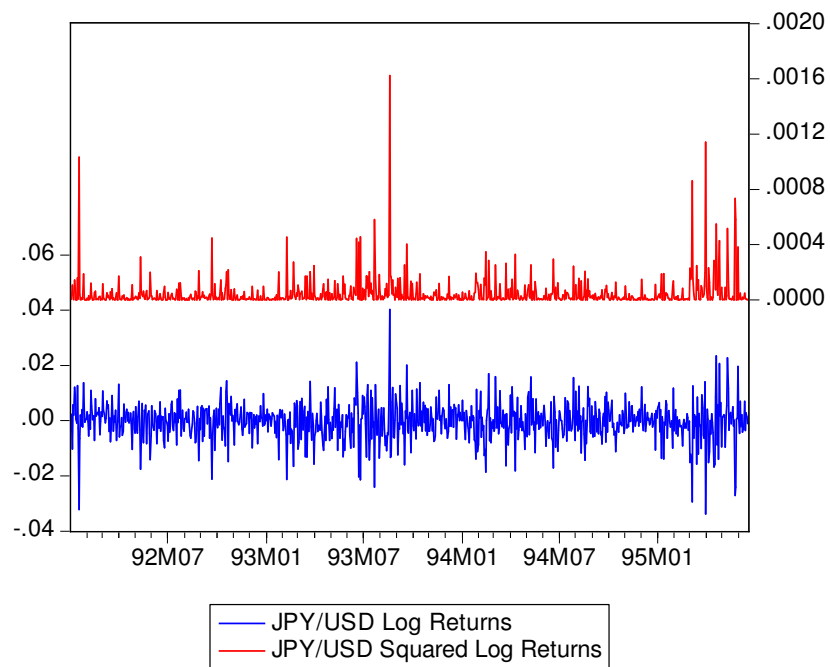


Figure 3.3: Daily returns and volatilities of the JPY/USD exchange rate.

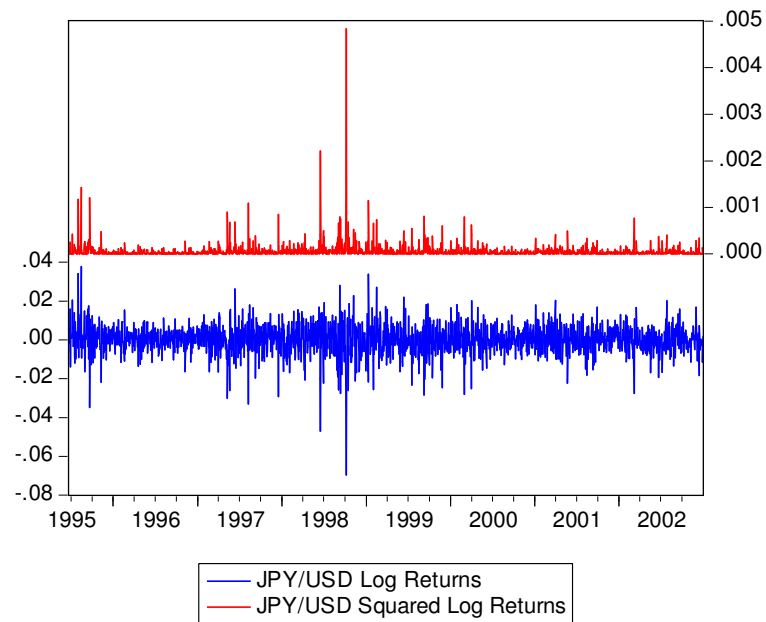


Full Period: 1/2/1991-3/31/2004

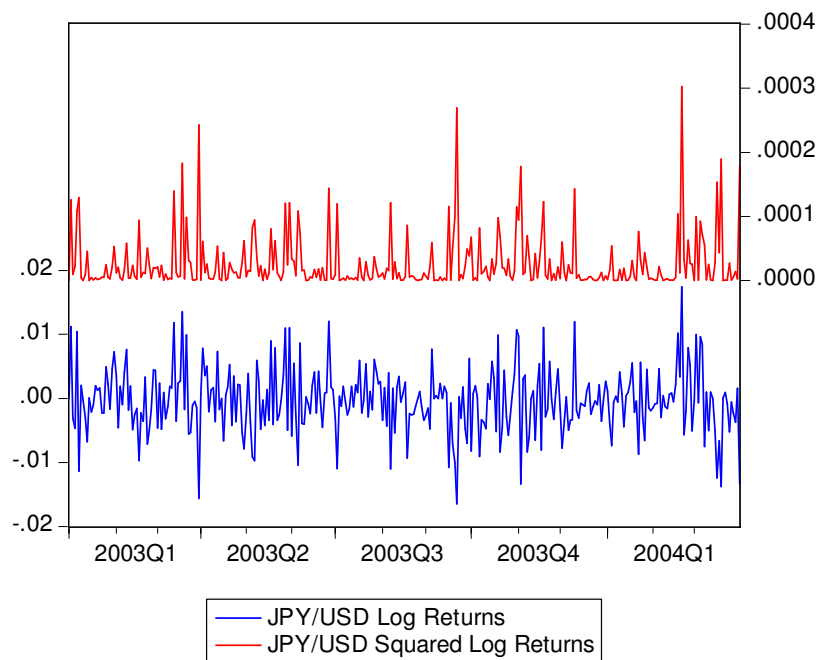


First Period: 1/2/1992-1/20/1995

Figure 3.3- continued: Daily returns and volatilities of the JPY/USD exchange rate.



Second Period: 6/21/1995-12/12/2002



Third Period: 1/2/2003-3/31/2004

Figure 3.4: The behavior of dependent and independent variables over the period January 2, 1992 to March 31, 2004

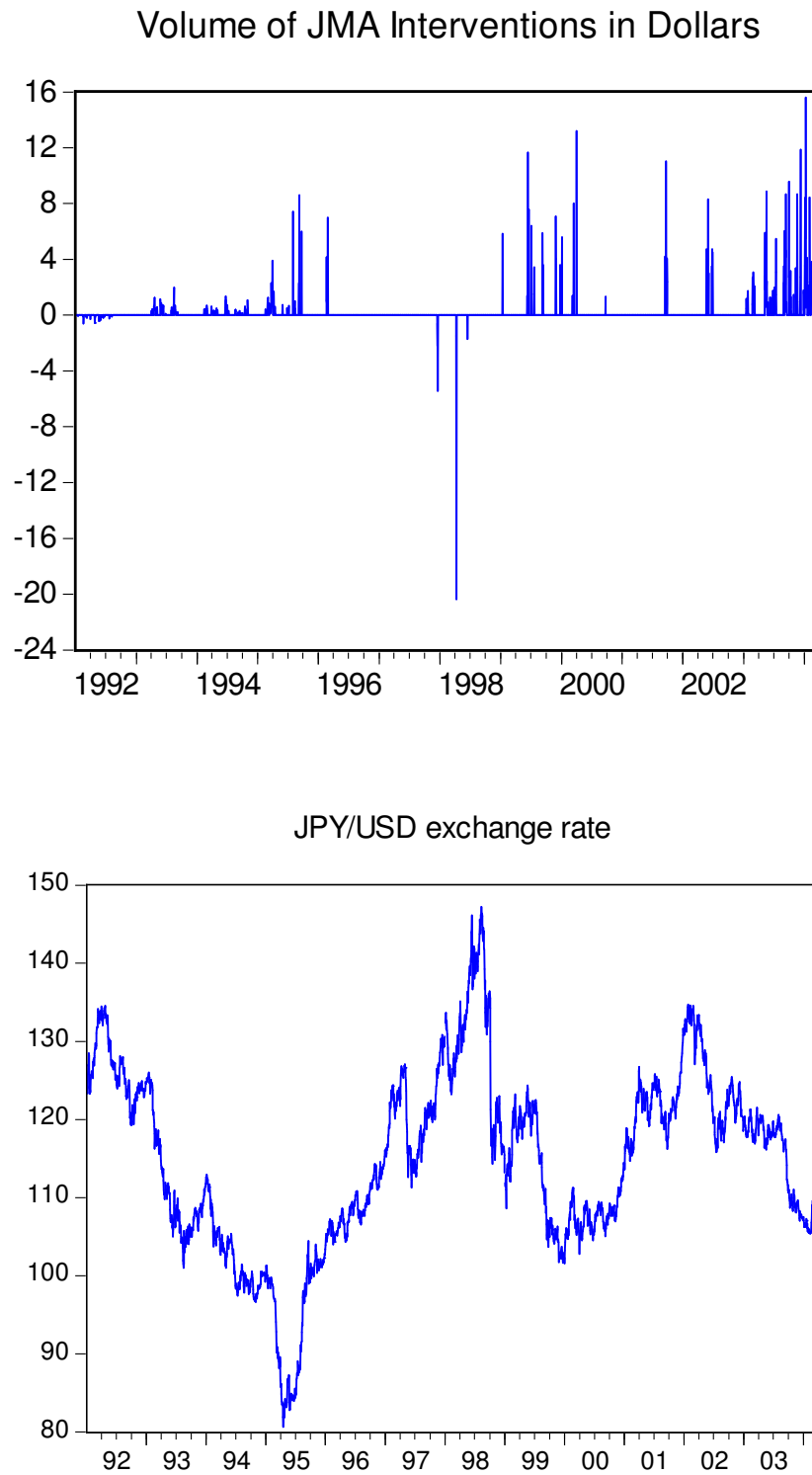


Figure 3.4-continued: The behavior of dependent and independent variables over the period January 2, 1992 to March 31, 2004

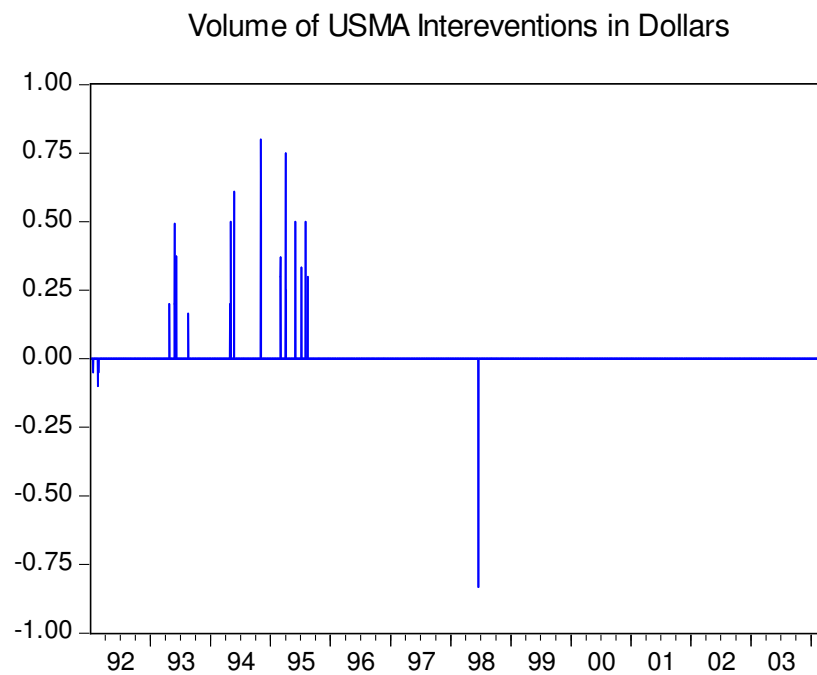
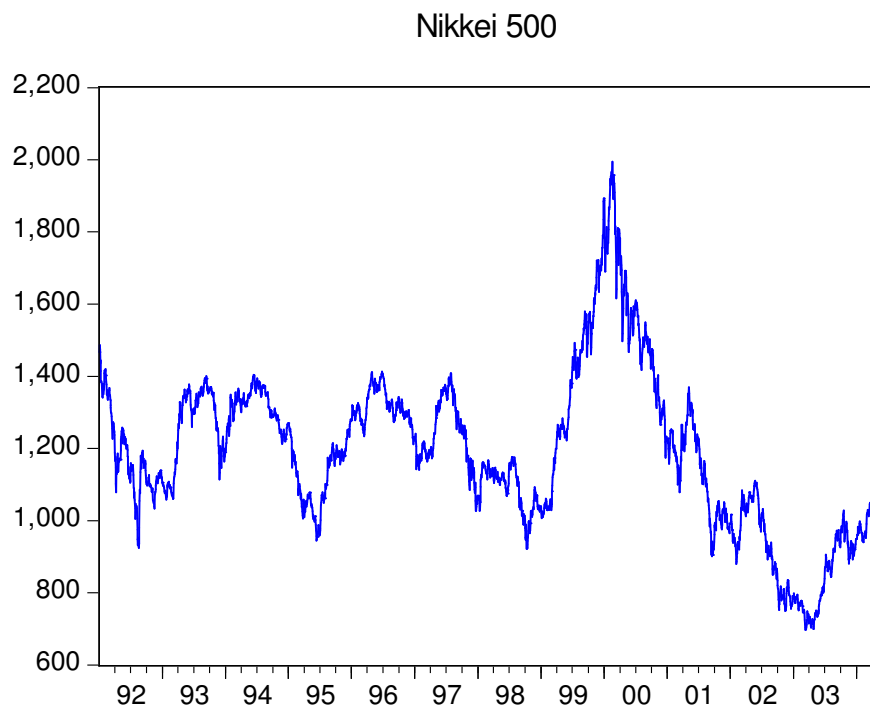
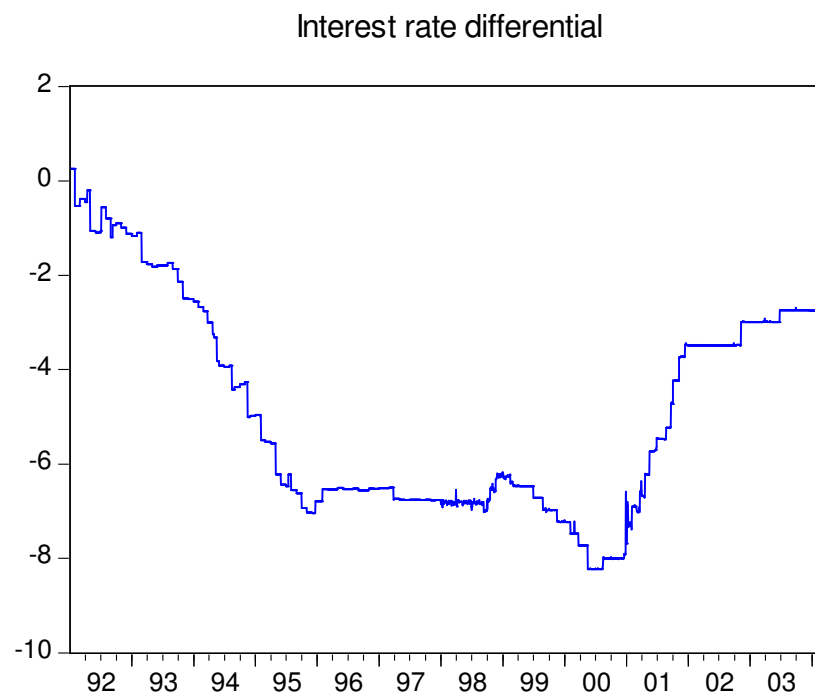
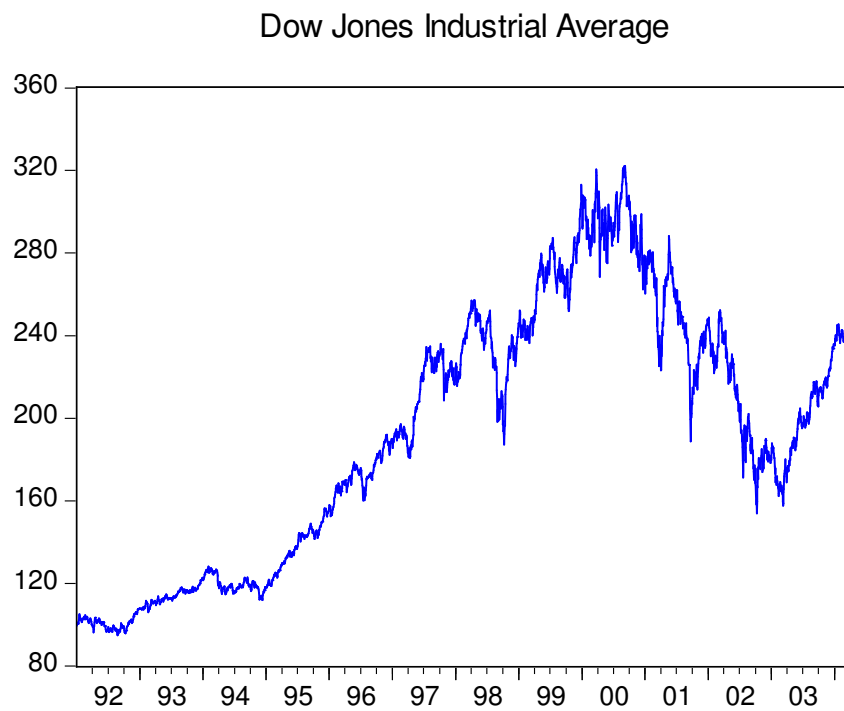


Figure 3.4-continued: The behavior of dependent and independent variables over the period January 2, 1992 to March 31, 2004



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3.8 Appendix - The GARCH-type Models

The GARCH (p,q) model by Bollerslev (1986) is based on the assumption that forecasts of time varying variance depend on the lagged variance of the asset. An unexpected increase or decrease in returns at time t will generate an increase in the expected variability in the next period. The basic GARCH (p,q) model is given by:

$$\begin{aligned} ds_t &= \mu + \sum_{i=1}^7 a_i X_{i,t} + \varepsilon_t \\ \varepsilon_t | \Omega_{t-1} &\sim N(0, h_t) \\ h_t &= \omega + \sum_{i=1}^q \alpha_i \varepsilon_{t-i}^2 + \sum_{j=1}^p \beta_j h_{t-j} + \sum_{i=1}^4 b_i X_{i,t} \end{aligned}$$

where, ds_t is the return on JPY/USD exchange rate, $X_{i,t}$ is the set of explanatory variables as explained above, error ε_t is assumed to be normally distributed with zero mean and conditional variance h_t , ω is the mean of volatility, ε_{t-1}^2 is the lag of the squared residual from the mean equation which reflects the news about volatility from the previous period (the ARCH term), q is the order of ARCH process, h_{t-1} is the conditional variance which is the last period forecast variance (the GARCH term) and must be nonnegative, the estimate of β shows the persistence of volatility to a shock or, alternatively, the impact of old news on volatility, and p is the order of GARCH process. It is expected that $\omega \geq 0, \alpha_i \geq 0, \beta_i \geq 0$, and in GARCH (1,1) model it is expected that $\alpha_1 + \beta_1 < 1$ but close to unity, with $\beta_1 > \alpha_1$. The basic GARCH model is symmetric and does not account for the asymmetry effect that is inherent in the financial time series data which is known as the leverage effect.

Financial theory suggests that an increase in variance results in a higher expected return. To account for this, GARCH-in-Mean models are also considered. GARCH in

Mean (GARCH-M) was proposed by Engle, Lilien and Robins (1987). This model characterizes the evolution of the mean and the variance of a time series simultaneously. It allows the conditional variance to be a determinant of the process; GARCH-M corresponds to expected exchange rate returns being proportional to its variance. The basic GARCH-M (p,q) model is given by:

$$ds_t = \mu + \sum_{i=1}^7 a_i X_{i,t} + \beta_1 h_t + \varepsilon_t$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t)$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \beta h_{t-1} + \sum_{i=1}^4 b_i X_{i,t}$$

if β_1 is positive (and significant), then increased risk leads to a rise in the mean return.

Furthermore, the Threshold-GARCH model was introduced by Zakoian (1994) and Glosten, Jaganathan and Runkle (1993). The TGARCH modifies the original GARCH specification using a dummy variable. The TGARCH model is based on the assumption that unexpected changes in the exchange rate returns have different effects on the conditional variance of the returns. The TGARCH model is given by:

$$ds_t = \mu + \sum_{i=1}^7 a_i X_{i,t} + \varepsilon_t$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t)$$

$$h_t = \omega + \alpha \varepsilon_{t-1}^2 + \gamma \varepsilon_{t-1}^2 d_{t-1} + \beta h_{t-1} + \sum_{i=1}^4 b_i X_{i,t}$$

where $d_t=1$ if $\varepsilon_t < 0$ and $d_t=0$ otherwise. In this model, good news ($\varepsilon_t > 0$) and bad news ($\varepsilon_t < 0$) have differential effects on the conditional variance. Good news (yen depreciation) has an impact of α , while bad news (yen appreciation) has an impact of $\alpha + \gamma$. If $\gamma > 0$ then the leverage effect exists and bad news increases volatility, while if $\gamma \neq 0$ the news impact is asymmetric.

Exponential-GARCH (EGARCH) models were designed to capture the leverage effect noted in Black (1976) and French et al. (1987). A simple variance specification of the EGARCH is given by:

$$ds_t = \mu + \sum_{i=1}^7 a_i X_{i,t} + \varepsilon_t$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, h_t)$$

$$\ln h_t = \omega + \alpha \left| \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} \right| + \gamma \frac{\varepsilon_{t-1}}{\sqrt{h_{t-1}}} + \beta \ln h_{t-1} + \sum_{i=1}^4 b_i X_{i,t}$$

The logarithmic form of the conditional variance implies that the leverage effect is exponential (so the variance is nonnegative). The presence of leverage effects can be tested by the hypothesis that $\gamma < 0$. If $\gamma \neq 0$; the impact is asymmetric.

4. Motivation behind the Japanese foreign exchange intervention in the JPY/USD exchange market.

4.1 Introduction

Foreign Exchange Intervention (FXI) continued to be a commonly used tool for influencing exchange rates albeit the switch to the floating exchange regime after the breakdown of the Bretton Woods system in the early 1970s. Monetary authorities of advanced economies have immensely operated on unilateral and coordinated FXI during the seventies and the eighties of the last century. The Japanese monetary authorities (JMA) continued to intervene even seriously during the last two decades, while the US and the European countries rarely intervened during that period.

JMA intervened in the JPY/USD exchange market over 340 days and have played a major role in limiting the yen from appreciation against the US dollar by conducting foreign exchange operations that ranged from being very large scaled operations that exceeded 20 billion USD in a single day to less than one million dollar in another occasion. This research examines the motivation behind the Japanese FXI in the JPY/USD market during the period January 2 1992 – March 31 2004. The purpose of this paper is to estimate the reaction function of the JMA and uncovering the key determinants of the JMA intervention.

Monetary authorities intervene in the foreign exchange markets to achieve certain objectives. The frequently mentioned motivation for intervention is to prevent excessive

changes in the exchange rate that would affect international trade. Unnecessary appreciation and depreciation bothers exporters and importers respectively. Dominguez (1998) reported that the IMF Executive Board provided its member countries in 1977 three guiding principles for intervention policy: "... (1) Countries should not manipulate exchange rates in order to prevent balance of payments adjustment or to gain unfair competitive advantage over others; (2) Countries should intervene to counter disorderly market conditions; and (3) Countries should take into account the exchange rate interests of others."

Empirical research has examined the reaction function of Japanese foreign exchange intervention by accounting for deviations of exchange rates from certain targets, with little attention being paid to the volatility of the exchange rate as a key factor prompting the JMA to intervene in the JPY/USD market.

This paper proposes an intervention reaction function that emphasizes the different objectives of the central bank for the level and volatility of the exchange rate. I also account for the different patterns of interventions of JMA throughout the period under study, dividing it into three sub-samples; each has its own pattern of intervention. I estimate the JMA reaction function for FXI using different measures of volatility. I employ the exchange rate volatility using better fitting GARCH models and using the simple GARCH (1,1) model (previously estimated in Chapter 3). These volatilities are then introduced to the Japanese FXI reaction function while accounting for periods of yen appreciation and the differential effects of unusually high volume of volatility, along with the commonly used objectives of the deviations from exchange rate targets and interest rate differential.

I find that the main common factors prompting JMA interventions throughout the Full sample and the first two sub-samples are the deviations from the monthly exchange rate

target, an implicit target of 125 yen/\$ and modest volatility of the exchange rate as well as interest rate differential. On the contrary, only volatility of exchange rate is found to be the key motive behind the JMA intervention during the third period. This can be related to the fact that the third period is characterized by special economic features like the zero interest rate policy and deflation. I find that Intervention occurred in clusters, past intervention encourages further intervention in the following day by reducing the political costs of convincing JMA to intervene.

The organization of the paper is as follows. After a brief literature review, section III provides Data and section IV presents stylized facts. Section V introduces the methodology. Section VI shows the estimation of the reaction function of the JMA. Section VII concludes.

4.2 Literature Review

A large amount of literature is devoted to study the effectiveness and motivation for foreign exchange intervention in developed countries currencies, focusing on the US dollar, the German mark, and the Japanese yen. The models used to study the effectiveness of intervention produced widely conflicting results and depend heavily on their assumptions and methodologies in trying to capture all the relevant features of an economy, particularly the behavior of financial markets. Dominguez and Frenkel (1993), Edison (1993), Sarno and Taylor (2001), and Neely (2005) provide a detailed survey of the literature. In this section I focus on those studies that are mainly related to the motivation for FXI by monetary authorities.

Almekinders and Eijffinger (1996) employed a GARCH model for exchange rates to allow interventions to have an effect on both the mean and the variance of exchange

rate returns. Then they estimate the intervention reaction function for the Federal Reserve and the Bundesbank by combining the model with a loss function for the central bank. Their estimation results for the implied friction model reproduce the familiar ‘leaning against the wind’ policy by the Bundesbank and the Federal Reserve. Furthermore, the central banks appear to have reacted to increases in the conditional variance of daily DM/\$-returns.

Galati and Melick (1999) and Galati et al (2005) first estimate a reaction function then use the fitted values as instruments in regressions that estimate the effects of intervention. They find that JMA appeared to intervene mainly in response to deviations of the exchange rate from some implicit target levels, and to a rise in market uncertainty. Humpage, Owen F. (1999) studied the U.S. intervention during the period 1987-1990 using daily data on the DEM/USD and the JPY/USD exchange rates. His results from a logit model suggest that coordinated intervention has a higher probability of success than unilateral intervention. The probability of success also increases with the dollar amount of an intervention. Ballie and Osterberg (1997) adopt a binary choice dependent variable method, a probit analysis, and find that the probability of intervention is determined by the magnitude of deviation of the nominal exchange rate from a target level and by the current volatility of the exchange rates.

Ramaswamy and Samiei (2000) use daily data for JPY/USD during the period 1995-99 to estimate the reaction function of the JMA using a probit model. They find that excessive appreciation and depreciation of the yen provoke interventions, and that interventions occur in clusters—if there is one today, there will likely be another tomorrow. Ito 2002 estimated the reaction function of the Japanese monetary authorities.

Japanese interventions were found to be prompted by rapid changes in the yen/dollar rate and the deviation from the long-run mean. The interventions in the second half were less predictable than the first half.

Another approach adopted by Ito and Yabu (2004) develop and estimate an intervention reaction function for the Japanese authorities involving a “political cost” which must be taken into account by the authorities when deciding whether or not to enter the market. They find that interventions often came in reaction to large exchange rate movements on the previous days, and that deviations from a long-term moving average also tends to lead to a decision to intervene. Frenkel et al. (2005) examines the motivation for the Japanese intervention policy. They find that Japanese authorities regularly responded to deviations of the JPY/USD from short term and long term exchange rate target.

4.3 Stylized Facts

Japan fixed its exchange rate at 360 yen per US dollar in the 22 years period starting from 1949 to 1971. It was during this period that Japan witnessed economic growth. Overall real economic growth has been called a "miracle": a 10% average in the 1960s. The Japanese yen has been appreciating since December 1971. During the phase 1971-85, yen appreciation took place without any fluctuating in the trend. Growth rates averaged a 5% in the 1970s and a 4% in the 1980s. After the plaza Accord in 1985, the Japanese currency appreciated repeatedly from 1985-1995 creating the bubble in Japanese land and equity values from 1987-1990 and then with the inevitable collapse of the bubble, threw Japan into a deflationary slump in the 1990s.

In such a situation Japanese industries invested abroad to capture the offshore markets. This in turn depressed the domestic industrial growth and employment. Domestic investments dipped and all these led to the deflation in the Japanese economy. Growth slowed markedly in the late 1990s; largely due to the Bank of Japan's failure to cut interest rates quickly enough to counter after-effects of over-investment during the late 1980s. Japan entered a liquidity trap.

To rescue the economy, Japan incurred huge budget deficits to finance large public works programs. By 1998, Japan's public works projects still could not stimulate demand enough to end the economy's stagnation. The Japanese government undertook "structural reform" policies intended to press speculative excesses from the stock and real estate markets. Unfortunately, these policies led Japan into deflation on numerous occasions between 1999 and 2004. The interest rates set by the Bank of Japan has greatly influenced the exchange rate of Yen. In the face of a rise in the interest rate the investors would want higher returns from Yen assets. This will further push up the Yen currency. This will have a negative impact on the export side although the import bills will fall. In these times, Japan is operating with zero interest rate policy and this has made it the largest investors in foreign securities.

At this juncture the Japanese government intervened rapidly in the foreign exchange market to curb Yen appreciation in order to support the export sector. Japan also intervened by selling dollars at times when the yen was depreciating too rapidly. Figure 4.1 shows the frequency of intervention as the number of intervention days per year during the full period April 1 1991 to March 31 2004. It is clear from Figure 4.1 that the Japanese intervention transactions were implemented in small sized, high frequencies

during years 1992, 1993, 1994, 1995, and in large sized, low frequencies during years 1996, 1997, 1998, 1999, 2000, and 2001, and large sized, high frequencies during years 2003, and 2004. These differences in frequencies are caused in part by the change of administrative personnel of the Vice president of Finance for International Affairs. I excluded year 1991 from my study, since it reflects a low frequency intervention period in which there were only 4 days of interventions and it was followed by high frequency intervention period.

The Japanese and the US intervention data series used in the empirical study measure consolidated daily official transactions in billions of dollars at the market values. Overall, since January 2, 1992 till March 31, 2004, Japanese monetary authorities intervened on 340 days against the U.S. dollar over a sample size of 3195 observations; of which 311 days involved official purchases of dollars and 29 days involved official sales of dollars. The higher tendency towards purchasing US dollars reflects the attempt of the Japanese authorities to counter or slow the appreciation of the yen. During that period, the United States joined Japan in a coordinated intervention effort in 21 occasions, most of which were dollar purchases.

My model is estimated over the full period and three sub-periods that lie within the full period of intervention, to allow for different intervention policies and economic conditions. The sub-periods used in the empirical tests throughout the paper were chosen on the basis of changes in intervention regimes reflected by changes in amount, frequency, and persistence of intervention as well as in the degree of coordination with the United States as suggested by Ito (2002) and Chaboud & Humpage (2005) and Rasmus & Fatum (2007).

The first period, January 2nd 1992 to June 20, 1995 was characterized by frequent, persistent and relatively small interventions. The intervention size and frequencies greatly changed before and after June 21, 1995, when DR. Sakakibara became Director General of the International Finance Bureau of ministry of Finance. Japan intervened on 162 days over a period of 904 days, of which 139 times to buy US dollars and on 23 times to sell US dollars. The U.S. intervened 17 times -3 sales and 14 purchase of USD- of the 21 joint operations with Japanese monetary authorities over the first period.

The second period begins on June 21 1995 to December 31 2002, marks a shift in the strategy to large infrequent interventions. During which the Japanese ministry of Finance undertook 51 interventions, 45 times to buy USD and 6 times to sell USD over a period of 1965 days. The United States occurred in 4 occasions, 3 times to buy USD and one time to sell USD. The third sub-sample begins January 2 2003 and ends March 31 2004, the Japanese authorities were only purchasing US dollars on 127 days out of 326 days and there were no US interventions.

Figure 4.2 depicts the behavior of the JPY/USD exchange rate round the Japanese and the US foreign exchange intervention operations. Figure 4.3 presents the plots of JPY/USD exchange rate returns and volatilities (defined as squared returns) over time showing the high volatility clustering.

Furthermore, I present four statistics which are calculated using the observations in the full sample: Skewness, Kurtosis, Jarque-Bera and Augmented Dickey Fuller (ADF). The return series of the JPY/USD exchange rate has negative mean and skewness¹¹ representing the prevailing yen appreciation pressure against the dollar. The

¹¹ Negative skewness implies that the distribution has a long left tail.

values for kurtosis are high (close to three) in all cases. So, the distributions are peaked relative to normal. The Jarque-Bera test rejects normality at the 5% level for all distributions. So, the samples have all financial characteristics: volatility clustering and leptokurtosis. Furthermore, in terms of stationarity, the results from the ADF tests indicate that the series is $I(1)$, and therefore, time-series models can be used to examine the behavior of volatility over time.

4.4 Data

The Japanese monetary authorities (JMA) recently published historical data on foreign exchange intervention, permitting increasing research on the most active intervention policy among industrial nations in the past decade. The Japanese Ministry of Finance started to release to the public in July 2001 historical data, with currency pair details, at a daily frequency going back to April 1991. According to the official Ministry of Finance data, Japan undertook frequent and massive foreign exchange market interventions between 1991 and early 2004, most of the time in a manner consistent with promoting a yen depreciation or limiting a yen appreciation. The foreign exchange intervention data are published in billions of yen, which is then converted into millions of dollars. Table 4.1 summarizes the intervention data statistics during the full period from January 2 1992 to March 31 2001.

The data on the JPY/USD exchange rate are daily NY closing spot exchange rates obtained from the Global Financial Data. I analyze the log returns of the exchange rate series. Table 4.2 presents various descriptive statistics for the JPY/USD exchange rate over the full period from January 2, 1992 to March 31, 2004. The negative mean and

skewness reflect the prevailing yen appreciation pressure against the dollar. The kurtosis is significantly above 3 representing a leptokurtic distribution of yen/dollar exchange rate returns, which does not constitute a problem in our estimation because the GARCH specification identified by Bollerslev (1986) takes a time dependent variable as a possible reason for leptokurtic into account.

The data employed in this study comprise 3195 daily observations of the JPY/USD exchange rate covering the period 1/2/1992 – 3/31/2004. Table 4.2 gives the descriptive statistics for daily JPY/USD exchange rate and returns. Daily returns are computed as logarithmic price relatives: $ds_t = \ln(\frac{S_t}{S_{t-1}})$, where S_t is the daily JPY/USD exchange rate.

4.5 Methodology

4.5.1 Estimating the reaction function of the Japanese Monetary Authorities

This part of the study follows Almekinders and Eijffinger (1996), Ballie and Osterberg (1997) and Ito and Yabu (2004) approach, and assumes that the BoJ intervenes with the objective of minimizing disorderliness over time in the foreign exchange market, depending on the perception of the effectiveness of that intervention and subject to a floor constraint on its losses. Thus it would intervene in foreign exchange markets to correct a perceived trend and to smooth volatility.

If the exchange rate appreciates (depreciates) above (below) a certain level, the monetary authorities might intervene to smooth the fluctuations of the level of the exchange rate and to maintain competitiveness of the export industry by preventing the

currency from appreciating beyond certain levels¹². This implies a leaning against the wind policy, in which deviations from a desirable target level will be countered, mostly to limit the yen from appreciating against the US dollar. Ito (2002) identified an implicit target level of 125 yen/dollar. The Japanese monetary authorities never purchased the dollar when the values of the dollar was higher than 125 JPY/USD, and never sold the dollar when yen/dollar rate was below the 125 JPY/USD level. Further foreign exchange intervention may also aim to reduce exchange rate volatility, which is usually high and pervasive in countries with free trade and capital flows such as US and Japan.

Econometric modeling of the daily intervention series poses some practical challenges owing to the unique nature of the series. As shown in Table 4.1, it has the feature of zero inflated process – 2855 observation out of 3195 has a value of zero. An implication is that the dependent variable, i.e. the intervention series, is discontinuous and so modeling it using standard regression techniques is inappropriate. The conventional OLS estimation technique assumes that the residuals of the reaction functions are independent of the explanatory variables. However, this assumption does not hold when large proportions of the observations are zero, as is the case with central bank interventions.

To control this problem, I employ the ordered probit model, as adopted by Ito and Yabu (2004), which involves specifying three separate distributional assumptions for the intervention series, corresponding to the three different states of intervention outcome. This approach considers three types of events for the intervention series; buying intervention, selling intervention, and zero intervention.

¹² The Louvre-target zones established in 1987 intended to prevent the exchange rate from surpassing certain levels between dollar, yen, and German mark.

The central bank is assumed to react to market conditions and constraints (as defined by the explanatory variables), but only after an intervention threshold is reached. In other words, the central bank will not intervene to influence the exchange rate unless the perceived necessity to enter the market exceeds a certain level. These thresholds are estimated using the ordered probit model and may differ for buying and selling interventions. These thresholds can be seen as the political cost.

The dependent variable estimated in the reaction function is the intervention indicator (-1, 0, or 1) rather than the actual volume of interventions.¹³ One might think that using the indicator variable is inferior to using the actual volume of intervention. However, this specification is suitable for the way the intervention is reported by the JMA; how much to intervene will be adjusted within the day depending on the success of intervention that is measured by the explanatory variables which are known to the authorities at the dawn of day t . Since authorities may intervene more than once during the day to influence the exchange rate, the use of the volume of intervention would have been more accurate. But since intra-day information of intervention is not disclosed, the indicator specification will be more precise.

In particular, the ordered probit model follows this specification: the intervention variable is a function of the change in the JPY/USD exchange rate on day $t-1$ (short term target), the change in the JPY/USD rate in the previous 21 business days (medium term target), the change in the JPY/USD rate one year moving average (260 business days, long term target) and the deviation of the JPY/USD rate on day $t-1$ from 125 yen/dollar, to capture the “leaning against the wind policy”.

¹³ The intervention variable is set equal to +1 if there was dollar-purchase intervention, -1 if there was dollar-selling intervention, and 0 for days in which there was no intervention.

Due to the relatively high probability that an intervention may be correlated (once intervened, another intervention is likely to occur), I include the one period lagged dependent variable in the vector of explanatory variables to test the persistence of JMA to intervene on a daily basis. In addition, a one period lagged intervention by the US Federal Reserve is included as US intervention may prompt Japanese intervention the day after.

Since the monetary authorities might also attempt to reduce exchange rate volatility, I employ the conditional variance previously estimated via the better fitting GARCH models for each time period, thereby presenting my results in two models. Model A uses the conditional volatilities measured by the previously selected GARCH models and Model B uses the conditional volatilities measured by traditional GARCH (1,1) model.

In order to test for the impact of the volatility of the exchange rate during yen appreciation episodes, I introduce a dummy variable for yen appreciation that takes the value of one when yen is appreciating and zero otherwise. In addition, I also employ another dummy variable that picks the differential impact of the size of the volatility on JMA intervention. This measure of the size of exchange rate volatility takes the value of one when the measured conditional volatility is greater than the average unconditional volatility and zero otherwise. This variable allows testing the hypothesis that during periods of unusually high volumes of volatility, the JMA may prefer to stay out of the market and dwarf from intervening, waiting for the appearance of a clearer trend. Thus, while a small trend deviation or small rise in market volatility may invite an intervention response, beyond some high level of volatility the central bank may withdraw its intervention.

In view of the fact that interventions are conducted sporadically with several interventions over the course of a few days or weeks, such sporadic intervention means that it has an unusual distribution. The low frequency monthly macro data can hardly capture the characteristic of the distribution and will miss the important high frequency interactions thus complicates the task of sorting out the interaction between intervention and the exchange rate. The only daily macro series available to the author is the interest rate. Whenever local or foreign interest rates change, the differential may lead to the well known anticipated overshooting of the spot exchange rate. If the JMA estimate that overshooting will occur, it may choose to intervene to mute the potentially distorting effects of the overshooting.

Equation 2 estimates the JMA reaction function using the ordered probit analysis.

$$\text{Eq 2 } IINV_t = \beta_1 IINV_{t-1} + \beta_2 IINVUS_{t-1} + \beta_3 (s_{t-1} - s_{t-2}) + \beta_4 (s_{t-1} - s_{t-21}) + \beta_5 (s_{t-1} - s_{t-260}) \\ + \beta_6 (s_{t-1} - s_{125}^T) + \beta_7 (h_{t-1})(Dapp_{t-1}) + \beta_8 (h_{t-1})(Dapp_{t-1})(Dsize_{t-1}) + \beta_9 (i_{t-1} - i_{t-1}^*) + \varepsilon_t$$

where,

$IINV_t$ is a dummy variable that takes the value of one if there is a buy intervention by JMA (i.e. purchase of US dollars with yen), negative one if there is a sell intervention by JMA (i.e. sale of US dollars for yen) and zero otherwise.

$IINVUS_t$ is a dummy variable that takes the value of one if there is a buy intervention by USMA (i.e. purchase of US dollars with yen negative one if there is a sell intervention by USMA (i.e. sale of US dollars for yen) and zero otherwise.

$(s_{t-1}-s_{t-2})$ is a short term target of the foreign exchange rate, measured as the log difference of current exchange rate and the previous day exchange rate.

$(s_{t-1}-s_{t-21})$ is a medium term target of the foreign exchange rate, measured as the log difference of current exchange rate and the 21 day (one month) moving average exchange rate.

$(s_{t-1}-s_{t-260})$ is a long term target of the foreign exchange rate, measured as the log difference of current exchange rate and the 260 day (one year) moving average exchange rate.

$(s_{t-1} - s_{125}^T)$ is a cutoff implicit target of the foreign exchange rate, measured as the log difference of current exchange rate and the exchange rate level of 125yen/dollar.

h_{t-1} is the conditional variance of daily exchange rate returns generated from relevant GARCH model for each period in the previous section

$Dapp_{t-1}$ is a dummy variable that takes the value one if the yen is appreciating against the dollar, and zero otherwise.

$Dsize_{t-1}$ is a dummy variable that takes the value one if the size of the measured volatility exceeds the average level, and zero otherwise.

$i_t - i_t^*$ is the interest rate differential, which is the spread between the Japanese inter-bank overnight interest rate and the US Federal funds rate.

In general the intervention action is assumed to occur after the breaching of positive and negative thresholds. Denoting $f(\cdot)$ as the right hand side of equation 2 excluding the error, I assume:

$$\begin{aligned} IINV_t &= 1 & \text{if} & & f(\cdot) > \theta^+ \\ IINV_t &= 0 & \text{if} & & \theta^- \leq f(\cdot) \leq \theta^+ \\ IINV_t &= -1 & \text{if} & & f(\cdot) < \theta^- \end{aligned}$$

where $IINV_t$ is the dependent variable, and $\theta^+ (>0)$ and $\theta^- (<0)$ are the thresholds which must be exceeded before the central bank acts to buy or sell foreign currency, respectively. The above formula states that $IINV_t = 1$ if the JMA conducted a purchase intervention in the JPY/USD market and that $IINV_t = -1$ if the JMA conducted a sale intervention in the JPY/USD market. Similarly, $IINV_t = 0$ if the JMA did not intervene in the JPY/USD market.

Maximizing the likelihood function of these models provides estimates of the tolerance thresholds. The resulting likelihood of equation 2 becomes¹⁴

$$L = \prod_{IINV > 0} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(IINV + \theta^+ - X\Omega)^2}{2\sigma^2}} * \prod_{IINV = 0} \left\{ \Phi\left(\frac{\theta^+ - X\Omega}{\sigma}\right) - \Phi\left(\frac{\theta^- - X\Omega}{\sigma}\right) \right\} * \prod_{IINV < 0} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{(IINV + \theta^- - X\Omega)^2}{2\sigma^2}}$$

where Φ is the standard normal cumulative density function.

4.6 Empirical results

4.6.1 Reaction function estimation

The maximum likelihood estimation results for the ordered probit models for the JMA are reported in Tables 4.3, 4.4, and 4.5. The estimation periods are for the full sample and for each of the subsample periods. I report two sets of results for each GARCH model used as a measure of foreign exchange volatility. In the third sub sample, I exclude the US intervention variable in which there was no US intervention.

Results are generally the same in both models except for the coefficients of conditional volatility. The coefficient of lagged Japanese interventions is positive and significant, ($\beta_I > 0$), throughout all the time periods. A significant lagged intervention coefficient reflects the persistence in intervention, which implies that the likelihood of interventions increases if there was an intervention the day before. This result confirms that continuous interventions reduce costs of intervention like the political and transactions costs¹⁵. Lagged US intervention variables are negative in the first and second

¹⁴ See Greene, 2000 pp.875-879, and Almekinder and Eijffinger (196) for further details.

¹⁵ Ito & Yabu (2007) assumed that political costs associated with intervention in day t – whether to persuade the Minister of Finance in Japan or to get a tacit approval from the United States – are expected to decline if intervention was incurred in day $t-1$.

time period ($\beta_2 < 0$), this can be explained by the notion that US intervention are always coordinating with the Japanese interventions, and are implemented upon the request of the JMA.

Coefficients capturing the influence of deviations of the yen/dollar exchange rate from its target rates on the interventions of the JMA as shown in Table 4.3. A negative coefficient of β_3 , β_4 , β_5 , β_6 implies that yen appreciation from its target levels tends to prompt intervention in buying dollars. It is clear that the JMA was not relying on deviations from short term target rates; this is given by the insignificant β_3 . However, coefficients of deviations from medium term and implicit targets have the expected sign ($\beta_4 < 0$, $\beta_6 < 0$) and are in general significant for the full sample, first sub-sample and the second sub-sample periods. This result suggests that there was a tendency to lean against the wind, in the medium term and the implicit target increasing the likelihood of JMA to intervene and purchase US dollar to prevent yen appreciation against the dollar during full sample and the first two sub-samples.

Deviations from the long term target is only significant in the first sample, meaning that the JMA was taking into account the movements of the exchange rate away from its medium term, long term , and implicit target when making its intervention decisions. In contrast, there is no evidence that the leaning against the wind policy had a significant role in prompting the JMA to intervene in the third subsample. In other words, neither an explicit nor the implicit target is found effective in conducting an intervention along the third time period.

Interest rate differential was significant in prompting JMA to intervene throughout the full sample and the first two sub-samples; this result is supported by the

positive and significant coefficient of β_9 . This result suggests that the probability of JMA intervention increases as the domestic interest rate departs from the foreign interest rate. The coefficient for interest rate differential β_9 is negative and insignificant for the third sample. This can be explained by the zero interest rate policy that characterizes the third period of 2003 and 2004. During this time, the JMA are losing the most commonly used and powerful monetary tool of interest rate, therefore, the JMA had to explore new means to stimulate the economy. Under such circumstances, both the intervention itself and its impact may differ from the previous practice. In addition, intervention add to the profitability of the JMA, given the zero interest rate policy, a positive spread in favor of US interest rates produces more interest income by investing in US interest bearing assets, making Japan the largest investor in foreign securities.

Differences in the results in Table 4.3 and 4.4 are seen in the impact of the measured conditional volatility on the JMA interventions. The estimated positive sign for β_7 is highly significant in the full sample and the second and third sub-samples according to Table 4.3 where volatility is estimated using the better fit GARCH models and in the full sample and the first sample only in Table 4.4 where volatility is estimated using traditional GARCH (1,1) model. This result suggests that a high but moderate conditional variance associated with an appreciation of the yen would lead to an intervention purchase of US dollar.

The coefficient β_8 picks up the differential effects, if any, of conditional volatility on days with larger than sample average conditional volatility. According to Table 4.3, I observe that on the days of above average volatility, a further rise in volatility associated with an appreciation leads to the sale of US dollars, which might seem to be going

against the smoothing aim of the JMA. Note however that on the magnitude of β_8 is generally close to β_7 , with the opposite sign suggesting that on the days of high volatility the total effect of the current conditional variance is the sum of the two coefficients, and so the positive effects shown in the former is nearly cancelled out by the latter. Thus, the JMA backed off from its objective of dampening the conditional volatility of the exchange rate on days of above average volatility. On days of lower volatility, only β_7 is relevant as the β_{size} term is zero. In sum, empirical evidence indicates that, though the JMA intervened to smooth the market's volatility, it stayed out of the market on above-average volatility days owing to the lower likelihood of the effectiveness of intervention on such high volatility trading days.¹⁶

Tables 4.3 and 4.4 also show the thresholds or the neutral bands of no intervention, which are found to be very close when estimated by both models when the volatility is estimated using better fit and the traditional GARCH models. The neutral band is estimated to be (-2.6, +2.1), (-2.4, +1.8), and (-4.3, +1.6) for the full sample period, first and second sub-sample period according to better fit models. Figure 4.5 presents four different panels of the behavior of the fitted values of intervention around the neutral bands for the full sample, and the three sub-samples. Figure 4.5 depicts that the first time period has a narrower neutral band than the second time period. The difference in the neutral band gives quite different prediction on interventions, and this is consistent with observations of the frequency of intervention as shown in Table 4.1. With the narrow band in the first sub-sample, it can be seen that interventions are frequent,

¹⁶ These results were also supported by the separate purchase and sale transactions estimates using the Probit model as seen in Table 8A, and 8B.

while with the wide band in the second sub-sample, the frequency of interventions was fewer.

The neutral bands are asymmetric; that is the magnitude of the upper band and lower band are different throughout the panels. For the full sample and the first two sub-samples, one can find that the JMA were more lenient towards yen depreciation than yen appreciation. This can be detected by comparing the absolute values of the lower and upper bounds. A higher lower bound in absolute term indicates that the band is asymmetric toward yen depreciation than yen appreciation. In other words political costs were biased in preference for yen depreciation. It is also worth noting that for the third sample the political cost was very high despite the frequent interventions. During 2003 and 2004, the Japanese economy was undergoing the liquidity trap, where JMA were losing their powerful monetary tool of interest rate manipulation. Thus, the only way to influence the exchange rate was by frequently intervening in the foreign exchange market purchasing larger volumes of US dollars.

As robustness check, comparing my results to Ito (2007), my model provides slightly higher Pseudo R-squared for the full sample, the first and the second sub-samples, 40%, 41% and 25% respectively and 33% for the third sample. My model is broad enough to account for more determinants of the JMA reaction function unlike Ito (2007) that focused only on deviations from exchange rate targets.

It is clear that only changes in conditional volatility of the exchange rate have prompted the JMA to intervene during the period of 2003 and 2004. As presented in Table 4.1 that the frequency of interventions has changed during this period, the JMA intervened 127 times. Interventions were never so frequent not only in the preceding 6

years but throughout the prior 12 years according to official reports. It is difficult to statistically distinguish the key determinants of the intervention reaction function as compared to the previous period. The strategies manipulated by the JMA during this period made uncovering intervention determinants challenging.

4.7 Conclusion

In this paper, I estimate the reaction function of the JMA in the JPY/USD exchange rate market for each time period using ordered probit model, after introducing the conditional volatilities measured by the previously better fit GARCH models and the traditional GARCH model in two separate regressions. The volatility of exchange rate estimated using the better fit models have different impacts on the JMA reaction function from those volatilities estimated using traditional GARCH models. This suggests that how the volatility is measured is very critical when considering the determinants of the intervention reaction function.

I find that the main factors prompting JMA interventions during the full sample period when estimating JMA reaction function using volatilities generated by better fit GARCH models are deviations from the monthly exchange rate target and the implicit target, volatility of the exchange rate when the yen is appreciating and the interest rate differential.

For the first period, deviation from the monthly and the yearly exchange rate target, the implicit target, and the interest rate differential. During the second period, intervention operations were more affected by deviations of the exchange rate from its monthly and its implicit targets and volatility of exchange rate during periods of yen appreciation. Regarding the third period persistence in intervention and volatility of exchange rate during periods of yen appreciation are the main factors driving JMA to intervene.

Overall, JMA is found to smooth out the market by eliminating residual volatility once a clear trend has been established. In periods of excessive volatility when the trend is unclear, the smoothing operations may be useless.

Introducing more variables capturing monetary and fiscal policy changes in the sample period, taking into consideration the spillover effect of changes in the Euro, Chinese Yuan and Korean Won on the yen/dollar exchange rate in a VAR framework might be the direction of future research.

Table 4.1: Intervention Data Summary Statistics

	Full Period	First Period	Second Period	Third Period
	Jan 2 1992– Mar 31 2004	Jan 2 1992– June 20 1995	June 21 1995-Dec 31 2002	Jan 1 2003– Mar 31 2004
Number of Observations	3195	904	1965	326
Total intervention days	340	162	51	127
Unconditional probability of Intervention	0.11	0.18	0.03	0.39
Number of days with dollar purchase	311	139	45	127
Average amount of dollar purchase (millions of dollars)	181.19	78.50	100.23	953.93
Unconditional probability of dollar purchase	0.10	0.15	0.02	0.39
Number of days with dollar sale	29	23	6	0
Average amount of dollar sale (millions of dollars)	11.68	6.11	16.18	NA
Unconditional probability of dollar sale	0.009	0.025	0.003	NA

Table 4.2: Descriptive Statistics of daily returns of the JPY/USD exchange rate:

	<i>Full Period</i>			<i>First Period</i>	<i>Second Period</i>	<i>Third Period</i>
	1/2/1992 – 3/31/2004			1/2/1992-6/20/1995	6/21/1995-12/31/2002	1/2/2003-3/31/2004
	S_t	$\ln S_t$	ds_t	ds_t	ds_t	ds_t
<i>Mean</i>	114.70	4.74	0.00	0.00	0.00	0.00
<i>Std. Dev.</i>	11.57	0.10	0.01	0.01	0.01	0.01
<i>Skewness</i>	-0.14	-0.47	-0.60	-0.24	-0.77	0.10
<i>Kurtosis</i>	3.016	3.41	8.90	6.61	9.50	3.82
<i>Jarque-Bera</i>	10.70	138.36	4827.32	499.98	3649.67	9.70
<i>Probability</i>	0.00	0.00	0.00	0.00	0.00	0.01
<i>Observations</i>	3196	3195	3195	904	1965	326
<i>ADF(Level)</i>		-1.94				
<i>ADF(1st diff)</i>		-56.11				

Notes: $ds_t = \ln(S_t / S_{t-1})$, Skewness is a measure of asymmetry of the distribution of the series around its mean. Kurtosis measures the peakedness or flatness of the distribution of the series.

Jarque-Bera is a test statistic for testing whether the series is normally distributed.

ADF regressions include intercept but not trend. I employ ADF test on the logarithms of stock indices.

ADF critical values: (1%) -3.4334, (5%) -2.8627, (10%) -2.5674

Table 4.3: Maximum Likelihood estimates of the ordered probit model (volatilities estimated by selected GARCH-type models:

$$IINV_t = \beta_1 IINV_{t-1} + \beta_2 IINVUS_{t-1} + \beta_3 (s_{t-1} - s_{t-2}) + \beta_4 (s_{t-1} - s_{t-21}) + \beta_5 (s_{t-1} - s_{t-260}) + \beta_6 (s_{t-1} - s_{125}^T) + \beta_7 (h_{t-1})(Dapp_{t-1}) + \beta_8 (h_{t-1})(Dapp_{t-1})(Dsize_{t-1}) + \beta_9 (i_{t-1} - i_{t-1}^*) + \varepsilon_t$$

	<i>Full Sample</i>	<i>First Sample</i>	<i>Second Sample</i>	<i>Third Sample</i>
	<i>EGARCH(2,1)</i>	<i>TGARCH(1,1)</i>	<i>GARCH-M(3,1)</i>	<i>EGARCH(1,1)</i>
β_1	1.928459 (0.0934)***	1.357182 (0.1483)***	1.510027 (0.2402)***	1.669765 (0.1755)***
β_2	-0.858748 (0.3065)***	-0.43811 (0.3789)	-2.33771 (0.3949)***	
β_3	5.626242 (4.8681)	0.668626 (9.6168)	10.12977 (8.5366)	23.03754 (16.9122)
β_4	-12.02435 (2.2835)***	-22.4352 (4.8695)***	-17.6834 (3.5968)***	-0.834808 (7.6885)
β_5	-0.716815 (0.6618)	-7.100956 (2.4741)***	-0.84919 (1.0219)	2.454107 (7.794)
β_6	-3.374125 (0.4207)***	-11.4494 (2.2255)***	-5.44678 (0.9348)***	-8.045441 (5.0967)
β_7	8.484764 (2.3072)***	3.664656 (4.3822)	6.627399 (3.4994)*	18.98425 (9.3855)**
β_8	-8.431181 (2.3346)***	1.309757 (4.4452)	-8.8105 (3.8635)**	-21.30894 (9.9691)**
β_9	0.05168 (0.0213)**	0.49044 (0.1268)***	0.197608 (0.054)***	-0.997423 (1.0709)
θ^-	-2.564664 (0.1597)***	-2.46068 (0.1986)***	-4.27376 (0.3828)***	
θ^+	2.098523 (0.1169)***	1.798275 (0.1862)***	1.64636 (0.2804)***	4.591864 (3.194454)
<i>Pseudo R-squared</i>	0.398569	0.406384	0.255987	0.3438
<i>LR statistic</i>	941.4726	398.7725	130.4729	149.1802
<i>Prob (LR statistic)</i>	0	0	0	0

Notes: LR statistic gives the value of the test statistic for the likelihood ratio test that the explanatory variables have no impact on the volume of intervention. Standard errors are in parentheses. ***, **, * denote significance at the 1, 5, and 10% level, respectively.

Table 4.4: Maximum Likelihood estimates of the ordered probit model (volatilities estimated by GARCH(1,1) model:

$$IINV_t = \beta_1 IINV_{t-1} + \beta_2 IINVUS_{t-1} + \beta_3 (s_{t-1} - s_{t-2}) + \beta_4 (s_{t-1} - s_{t-21}) + \beta_5 (s_{t-1} - s_{t-260}) \\ + \beta_6 (s_{t-1} - s_{125}^T) + \beta_7 (h_{t-1})(Dapp_{t-1}) + \beta_8 (h_{t-1})(Dapp_{t-1})(Dsize_{t-1}) + \beta_9 (i_{t-1} - i_{t-1}^*) + \varepsilon_t$$

	<i>Full Sample</i>	<i>First Sample</i>	<i>Second Sample</i>	<i>Third Sample</i>
	<i>GARCH(1,1)</i>	<i>GARCH(1,1)</i>	<i>GARCH(1,1)</i>	<i>GARCH(1,1)</i>
β_1	1.936185 (0.0934)***	1.383114 (0.1486)***	1.484645 (0.2377)***	1.694853 (0.1771)***
β_2	-0.84246 (0.3081)***	-0.44396 (0.3772)	-2.30863 (0.3858)***	
β_3	5.846458 (4.8572)	0.352084 (9.6067)	10.4787 (8.0629)	16.63953 (15.4535)
β_4	-12.0242 (2.2553)***	-22.8675 (4.7809)***	-16.6028 (3.3176)***	-6.069634 (7.3548)
β_5	-0.505405 (0.6381)	-6.653725 (2.4988)***	-0.6649 (0.9859)	3.986647 (7.7038)
β_6	-3.408913 (0.4173)***	-12.0007 (2.2571)***	-5.39411 (0.8848)***	-8.838476 5.480639
β_7	3.958877 (1.0057)***	9.190862 (4.665)**	1.447037 (1.8336)	5.480639 (4.9381)
β_8	-3.807974 (1.1522)***	-5.22991 (4.7101)	-1.53871 (2.3188)	-3.062587 (4.7834)
β_9	0.059016 (0.0206)***	0.523854 (0.1291)***	0.218088 (0.0554)***	-1.044129 (1.0605)
θ^-	-2.583511 (0.1584)***	-2.43442 (0.1997)***	-4.3546 (0.3877)***	
θ^+	2.081447 (0.1141)***	1.865208 (0.1871)***	1.467621 (0.2952)***	4.742453 (3.742453)
<i>Pseudo R-squared</i>	0.398811	0.407523	0.246124	0.335842
<i>LR statistic</i>	942.0431	399.8898	125.4459	145.7272
<i>Prob (LR statistic)</i>	0	0	0	0

Notes: LR statistic gives the value of the test statistic for the likelihood ratio test that the explanatory variables have no impact on the volume of intervention. Standard errors are in parentheses. ***, **, * denote significance at the 1, 5, and 10% level, respectively.

Table 4.5: Maximum Likelihood estimates of purchase transactions using the Probit model:

$$INVbuy_t = \beta_1 INVbuy_{t-1} + \beta_2 INVUSbuy_{t-1} + \beta_3 (s_{t-1} - s_{t-2}) + \beta_4 (s_{t-1} - s_{t-21}) + \beta_5 (s_{t-1} - s_{t-260}) + \beta_6 (s_{t-1} - s_{125}^T) + \beta_7 (h_{t-1})(Dapp_{t-1}) + \beta_8 (h_{t-1})(Dapp_{t-1})(Dsize_{t-1}) + \beta_9 (i_{t-1} - i_{t-1}^*) + \varepsilon_t$$

	Full Sample		First Sample		Second Sample		Third Sample	
	GARCH(1,1)	EGARCH(2,1)	GARCH(1,1)	TGARCH(1,1)	GARCH(1,1)	MGARCH(3,1)	GARCH(1,1)	EGARCH(1,1)
<i>C</i>	-1.73768 (0.1038)***	-1.69692 (0.1037)***	-1.90035 (0.217)***	-1.80015 (0.2137)***	-1.47602 (0.3002)***	-1.66205 (0.2843)***	4.742453 (3.742453)	4.591864 (3.194454)
β_1	1.811745 (0.0984)***	1.792184 (0.0973)***	1.454972 (0.1681)***	1.416378 (0.1666)***	1.182583 (0.2429)***	1.197725 (0.2461)***	1.694853 (0.1771)***	1.669765 (0.1755)***
β_2	-0.72246 (0.3436)**	-0.80857 (0.3492)**	-0.30458 (0.4289)	-0.29366 (0.4298)				
β_3	7.127476 (5.757)	8.761016 (5.7127)	5.896851 (10.7785)	6.138774 (10.7417)	3.59462 (8.3172)	2.093683 (8.6316)	16.63953 (15.4535)	23.03754 (16.9122)
β_4	-14.6669 (2.7053)***	-15.3949 (2.7241)***	-28.0711 (5.8916)***	-27.6271 (5.9861)***	-16.9132 (3.4733)***	-18.556 (3.9381)***	-6.06963 (7.3548)	-0.83481 (7.6885)
β_5	-0.6604 (0.9541)	-0.78593 (0.9963)	4.832664 (2.8112)*	5.150075 (2.774)*	-0.43225 (1.0328)	-0.58104 (1.0739)	3.986647 (7.7038)	2.454107 (7.794)
β_6	-3.77092 (0.567)***	-3.76557 (0.5668)***	-8.7423 (2.4258)***	-7.69108 (2.3669)***	-5.3032 (0.9966)***	-5.48981 (1.066)***	-8.83848 (5.0226)*	-8.04544 (5.0967)
β_7	4.365781 (1.0835)***	6.246453 (2.327)***	10.44888 (5.0806)**	2.15091 (4.9303)	2.281679 (1.8656)	8.149552 (3.4018)**	5.480639 (4.9381)	18.98425 (9.3855)**
β_8	-4.02984 (1.2543)***	-6.21678 (2.4919)**	-6.38585 (5.0528)	2.672182 (4.8857)	-1.99511 (2.275)	-10.2317 (3.7704)***	-3.06259 (4.7834)	-21.3089 (9.9691)**
β_9	0.157184 (0.0244)***	0.152074 (0.025)***	0.391109 (0.1418)***	0.330245 (0.1384)**	0.216333 (0.0589)***	0.197626 (0.0581)***	-1.04413 (1.0605)	-0.99742 (1.0709)
<i>Pseudo R-squared</i>	0.447115	0.443881	0.453668	0.451708	0.21372	0.227031	0.335842	0.3438
<i>LR statistic (Prob)</i>	911.1431(0)	904.5529(0)	351.5705(0)	350.0513(0)	91.58533(0)	97.28957(0)	145.7272(0)	149.1802(0)

Notes: LR statistic gives the value of the test statistic for the likelihood ratio test that the explanatory variables have no impact on the volume of intervention. Standard errors are in parentheses. ***, **, * denote significance at the 1, 5, and 10% level, respectively.

Figure 4.1: Frequency of Japanese foreign exchange intervention over the period April 1 1999 to March 31 2004.

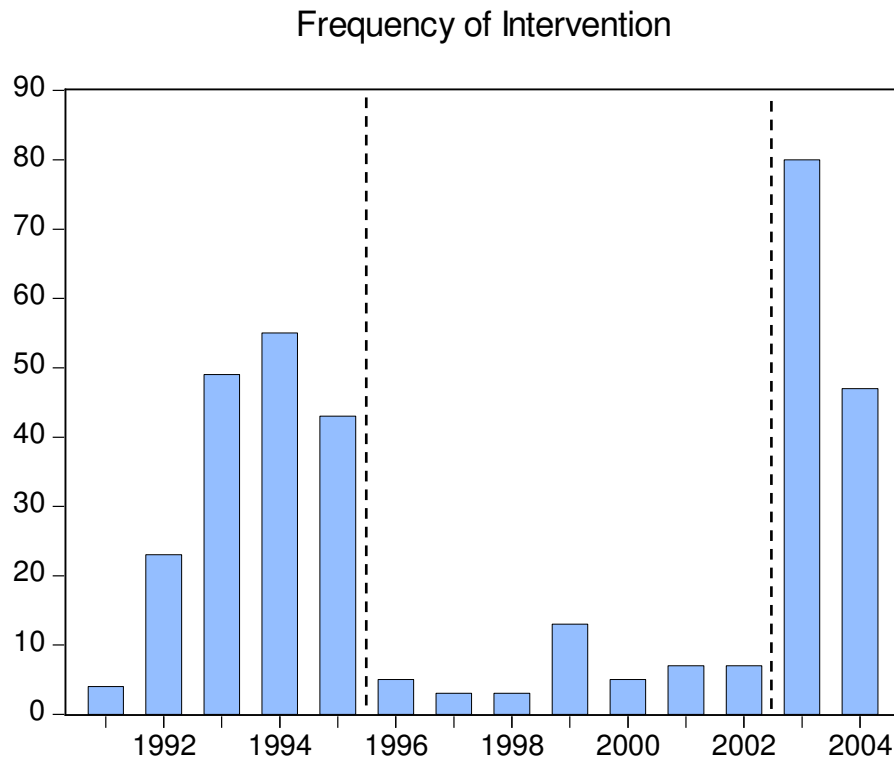


Figure 4.2: The behavior of the JPY/USD exchange rate around the Japanese and US foreign exchange intervention operations, and the 125 USD/JPY level of the exchange rate during the full period January 2 1992 to March 31 2004.

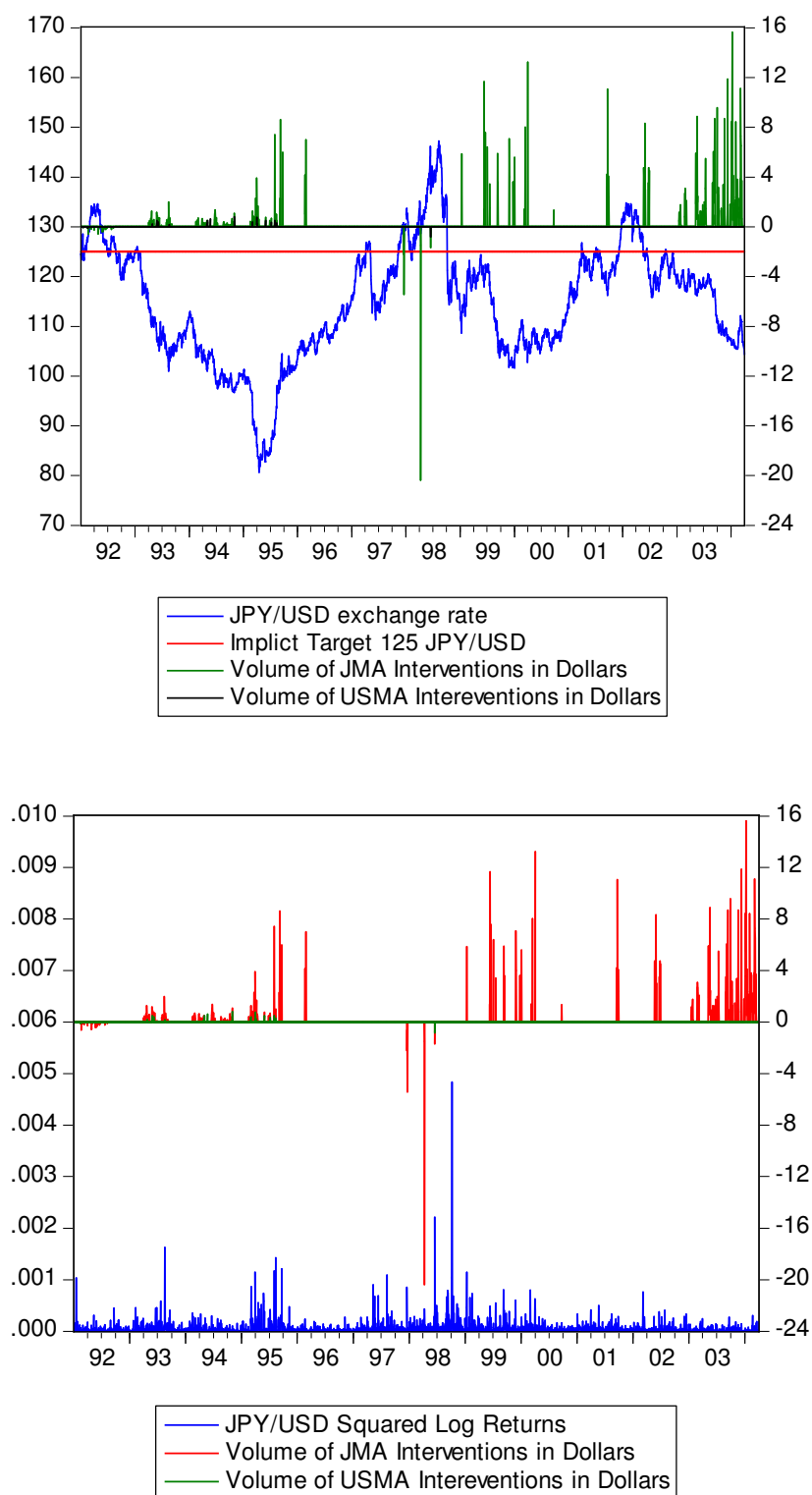
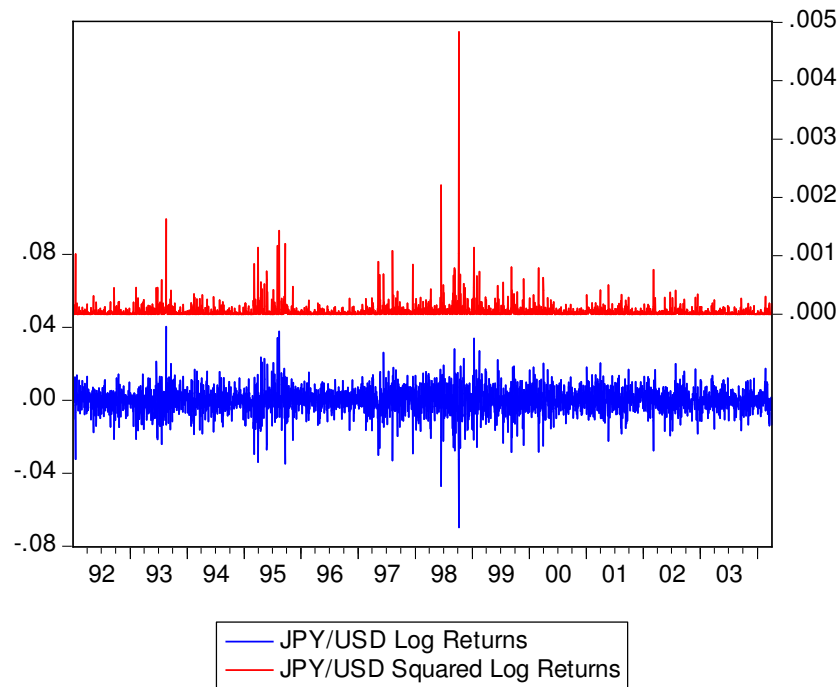
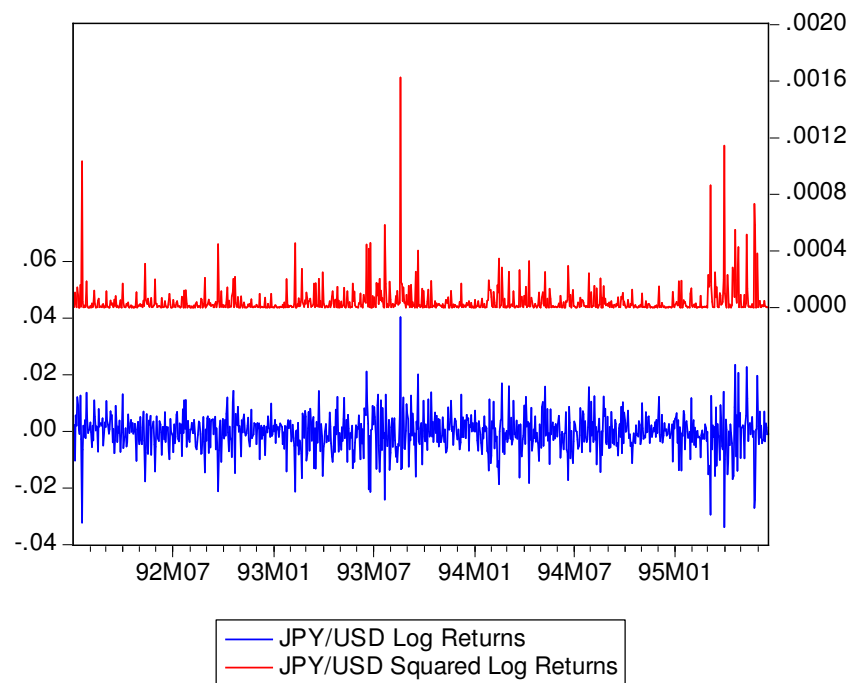


Figure 4.3: Daily returns and volatilities of the JPY/USD exchange rate.

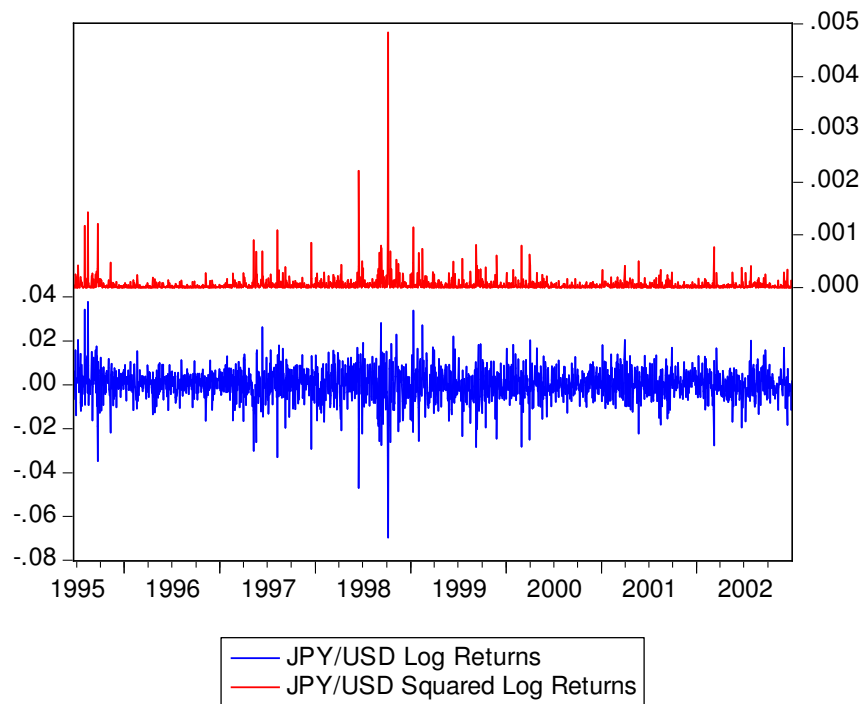


Full Period: 1/2/1991-3/31/2004

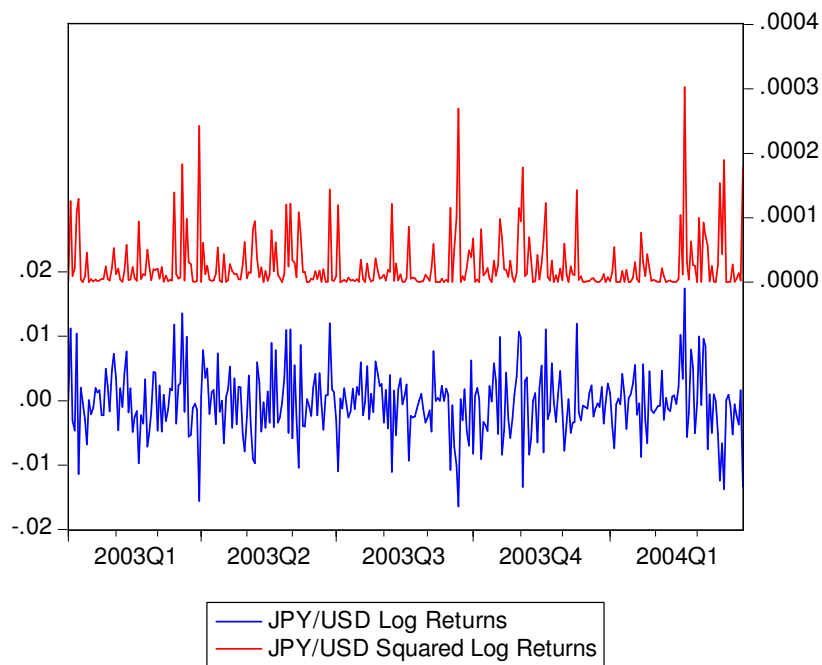


First Period: 1/2/1992-1/20/1995

Figure 4.3-continued: Daily returns and volatilities of the JPY/USD exchange rate.



Second Period: 6/21/1995-12/12/2002



Third Period: 1/2/2003-3/31/2004

Figure 4.4: Exchange rate and the magnitude of intervention:

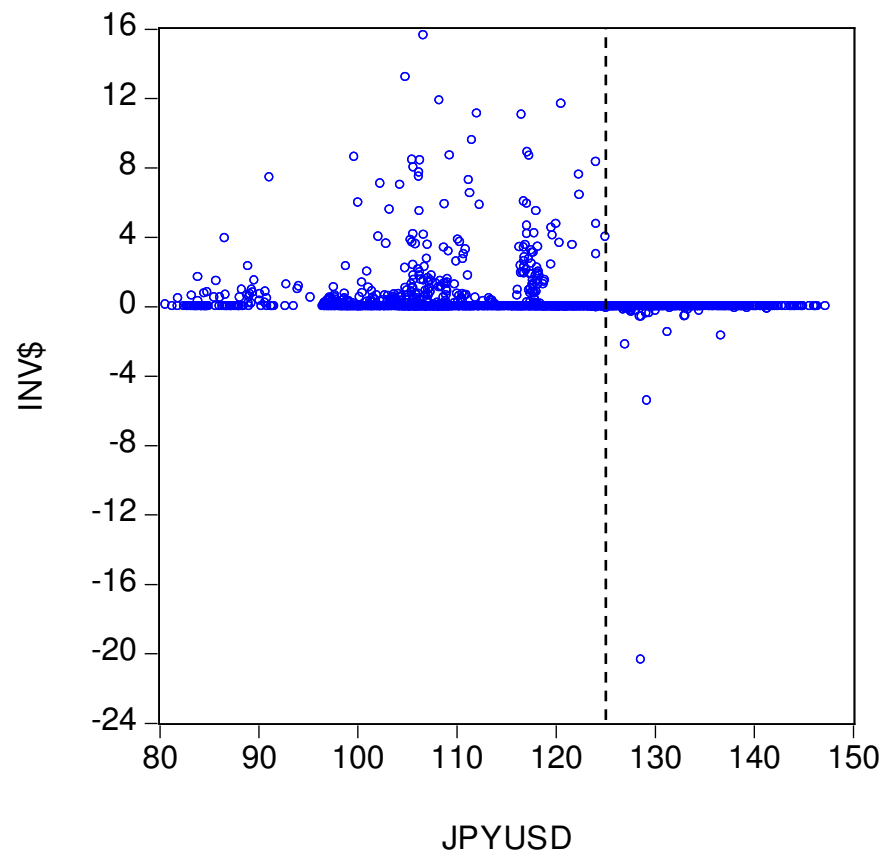
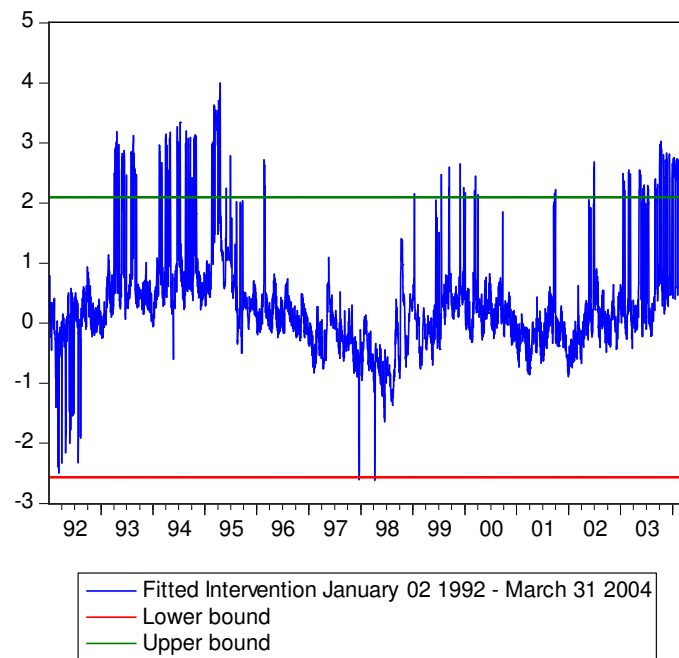
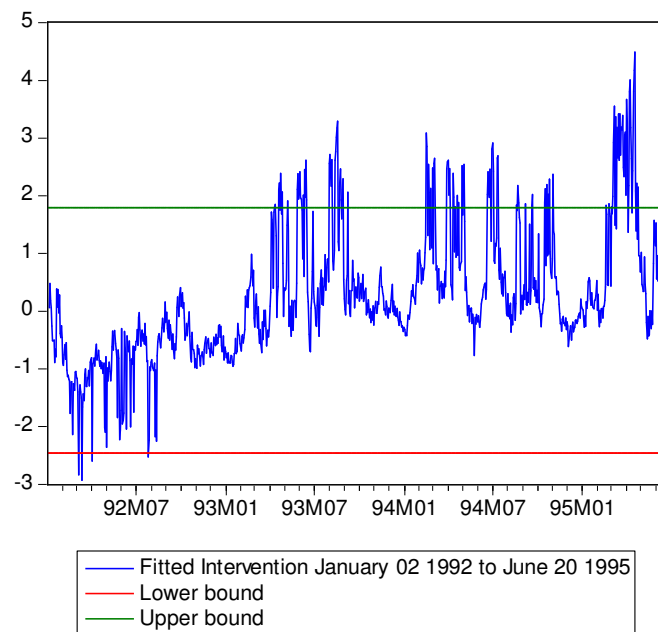


Figure 4.5: Neutral band and fitted value of Intervention:

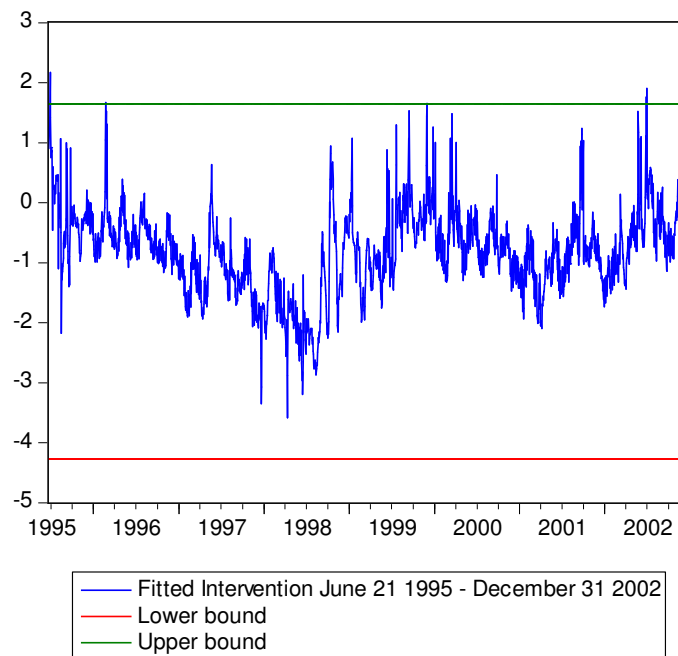


Neutral band and fitted value of Intervention: Full sample

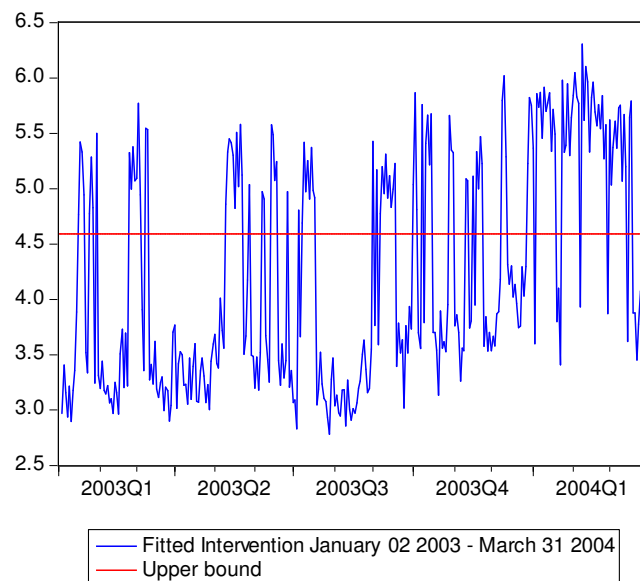


Neutral band and fitted value of Intervention: First sample

Figure 4.5-continued: Neutral band and fitted value of Intervention:



Neutral band and fitted value of Intervention: Second sample



Neutral band and fitted value of Intervention: Third sample

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5. Is Central Bank Intervention Effective under Inflation Targeting Regimes? The Case of Turkey

5.1 Introduction

In recent years, many emerging market economies have switched to floating exchange rate regime as a basic requirement for Inflation Targeting (IT) framework to anchor their high inflation rate. Adopting IT regime is maintained by a tightening monetary policy that increases real interest rates, which consequently appreciates the domestic currency. In the mean time, many of these countries are facing large trade deficits that are mainly reduced by the frequent use of foreign exchange intervention (FXI) to depreciate their domestic currencies and improve their external competitiveness. Thus central banks in these economies are facing conflicting objectives towards currency depreciation for external competitiveness and appreciation brought by inflation targeting.

The Turkish economy in the post crisis period provides a good example in this context. Turkey is one of those emerging markets that have adopted IT gradually on two phases implicitly then explicitly. The implicit IT regime introduced by the Central Bank of Turkey (CBT) in January 2002 encompasses the core attributes of IT specifically the announcement of a formal target for intervention. The Explicit IT regime is then introduced in January 2006 after achieving successful disinflation, improvements in fiscal conditions and improvements in the banking system, bringing further transparency in the new framework.

Adhering to the objective of IT framework, the CBT has explicitly stated that it would be ready to intervene in the foreign exchange market to remove any excessive

volatility that could have damaged the functioning of the financial markets. However, the CBT have been using different forms of intervention in its FX markets; direct interventions and preannounced auctions intervention. In particular direct FXI are implemented when the Lira/dollar exchange rate reaches very low levels. In other words, the CBT was directly intervening in the FX market when the Turkish lira was further appreciating against the dollar.

The Turkish experience is of great magnitude not only as an emerging economy adopting IT to control inflation while implementing FXI to maintain exchange rate stability, but also because Turkey is closely related to the European Union (EU). First, Turkey as a candidate for the EU membership is required to contain its inflation which is consistent with Maastricht criteria for joining the European Monetary Union. Second, Turkey is a member of the EU Customs Union since 1995 and the EU represents its largest trade partner thus the TRY/EUR exchange rate is an important aspect in this relationship, which may be affected by CBT FXI in the TRY/USD market through the spillover effect. In other words, the CBT intervention into the TRY/USD may have implications on the value of the TRY/EUR.

There is a large literature devoted to the effectiveness of central bank FXI. However, only scant research is done on the functioning of FXI as a monetary instrument within an IT regime in emerging markets. Domac and Mendoza (2004) argued that FXI can effectively coexist within IT regimes by reducing excessive volatility in exchange rates and not defending a particular exchange rate. However, Herrera and Ozbay (2008) and Akinici (2005), in their study on Turkey, find evidence that interventions increase the volatility of the TRY/USD exchange rate.

This study assesses the effectiveness of the FXI in Turkey during the post crises period, and since the inception of the IT regime. In this paper I use a Multivariate Vech-GARCH model test two main hypotheses regarding the (CBT) interventions: First, testing whether there is a room for an effective FXI under IT regimes, in other words, is it possible that FXI can influence the exchange rate or its role is only limited to reducing volatility of exchange rates. This testing also allows for determining whether the official announcements of the CBT are supported empirically. Second, testing whether CBT FXI in the TRY/USD market has any spillover effects on the TRY/EUR market, under both the implicit IT and the explicit IT regimes while controlling for the impact of news on EU membership.

This study is using the longest sample in the post crisis period relative to other current studies on CBT interventions, allowing for the distinction of two structural breaks during the period under study that are mainly related to the change in the form of CBT interventions, in addition to a clear distinction of the CBT operation under the implicit IT and the explicit IT regimes.

This paper contributes to the literature on CBT FXI during IT regimes in two aspects. First, by accounting for the IT regime in the model, this makes it possible to prove that there is a room for direct FXI to coexist within an IT regime, and to influence the domestic currency to improve competitiveness in the tradable goods markets as long as current inflation rates are below their target rates or within the uncertainty band, in contrast to Domac and Mendoza (2004) argument that asserts on the role of FXI in reducing the volatility and against defending a particular exchange rate.

I find that CBT announcement of its commitment to a floating exchange rate regime and not targeting the level of the exchange rate are not supported by empirical results. FXI by the CBT through both direct and auction purchase interventions lead to depreciation of the lira against the dollar and the euro. In particular, CBT direct interventions lead to lira depreciation during the Implicit IT regime however the auction interventions lead to lira depreciation during the explicit IT regimes.

Second, I find two types of spillover effects of CBT intervention in the TRY/USD market on the level of the TRY/EUR and its co-movement with the TRY/USD exchange rate, suggesting that the TRY/EUR is implied by TRY/USD along with independent shocks due to USD/EUR. Therefore, agents' expectations of future TRY/EUR exchange rates are affected by changes in TRY/USD exchange rates, which may be due to FXI intervention.

The paper is structured as follows. After a brief literature review, section III provides stylized facts and section IV presents the data used in the analysis. Section V introduces the methodology. Section VI shows empirical results by assessing the efficacy of FX intervention of the CBT. Section VII concludes.

5.2 Literature Review

Empirical studies on intervention can be divided into two main areas. The first one assesses the impact of foreign exchange intervention on the level and volatility of the exchange rate. The second one estimates the central bank reaction function, looking for the factors that prompt the monetary authorities to intervene. In this section I focus on

the first kind of studies that are related to emerging markets in general and Turkey in particular.

A large amount of literature is devoted to study the effectiveness of FX intervention in developed countries currencies, and mainly focus on the US dollar, German mark, and Japanese yen. The models used to study the effectiveness of intervention produced widely conflicting results and depend heavily on their assumptions and methodologies in trying to capture all the relevant features of an economy, particularly the behavior of financial markets. Dominguez and Frenkel (1993), Edison (1993), and Sarno and Taylor (2001) provide a detailed survey of the literature for advanced economies.

In contrast, the empirical literature on emerging market countries where data limitations are much more severe is still relatively scant, though some recent work provides a broad sense of intervention's effectiveness in these countries. The Mexican peso, Czech Koruna and Turkish Lira are the most studied currencies.

For emerging market economies, the effectiveness of intervention is highly sample-dependent with conclusions varying significantly across countries. However, the evidence also highlights some broad similarities. In particular, the effectiveness of intervention appears to be dependent on the monetary policy framework pursued and whether the intervention was publicly announced or not.

Regarding the impact of FXI on the level of the exchange rate, studies reveal mixed results. Tapia and Tokman (2004) studied the effectiveness of intervention in Chile using both daily and intraday data. Their analysis indicated that the effectiveness of intervention operations varied throughout the sample in line with the changing policy framework of the central bank. They found that although actual intervention appeared to

have a small and generally insignificant effect on contemporaneous exchange rate movements, public announcements of potential interventions had significant effects on the level of the exchange rate.

Galate et al (2005) use official statistics on Central bank intervention by the Czech National Bank in conjunction with options market data, to study the impact of intervention during 2001-02. They find that central bank intervention had some weekly statistically impact on the spot rate and the risk reversal but this impact was small.

Kamil (2008) examines the effectiveness of Colombian Central Bank's intervention in stemming domestic currency appreciation under an inflation targeting regime. The results indicate that the FX intervention was effective during 2004-2006, when the currency purchases were undertaken during the period of monetary easing. During 2007, on the other hand, intervention was ineffective in reversing or slowing down domestic currency appreciation, as large scale intervention became incompatible with meeting the inflation target in an overheating economy.

Guimarães and Karacadag (2004) emphasized the role of public announcements in the case of Mexico and Turkey. They also find only weak supportive evidence for the effectiveness of intervention on the level of the exchange rate in Mexico and Turkey. Given policy objectives, however, such findings do not necessarily indicate a failure of intervention. For Mexico, the bulk of intervention undertaken during the sample period was aimed at accumulating reserves rather than influencing the underlying exchange rate trend. In Turkey's case, the apparent ineffectiveness of intervention in influencing the level of the exchange rate may reflect the nature of intervention policies there. In particular, the vast majority of official interventions were conducted in the context of pre-

announced foreign exchange auctions, where the timing and amounts were largely predetermined and known by market participants. Hence, the potential impact of interventions may have operated through the signaling channel well in advance of actual interventions themselves.

Among those that find a significant effect on the level, Domaç and Mendoza (2004) found asymmetric effects in Mexico and Turkey, concluding that central bank foreign exchange sales (but not purchases) were generally effective in influencing the level of the exchange rate in both countries. In particular, a net sale of US\$100 million appreciated the exchange rate by 0.08% on average in Mexico and 0.2% in Turkey.

Akinci (2005), in his study on Turkey, finds insignificant impact of FX purchase and sale interventions on the level of TRY/USD exchange rates.

The evidence is more clear-cut in terms of the impact of intervention on the volatility than the level of the exchange rate. Pattanaik and Sahoo (2002) find that intervention operations of the Reserve Bank of India had been effective in containing volatility of the rupee, although the degree of influence did not appear to be very strong. The evidence is generally more positive. For the Philippines, Abenoja's (2003) study using daily intervention data from 1992 to 2003 indicated that although intervention reduced volatility contemporaneously, while persistent operations increased volatility. This might suggest that successive interventions lead to greater market uncertainty.

Domaç and Mendoza (2002) find in the context of Mexico and Turkey that intervention reduced exchange rate volatility in both countries. For Mexico and Turkey, and in contrast to Domaç and Mendoza (2002), Guimarães and Karacadag (2004) also did not find a significant impact of intervention on exchange rate volatility.

Herrera and Özbay (2008) examine the foreign currency intervention in Turkey, within a uni-variate framework for the Central Bank of Turkey (CBT). Their result indicates that interventions increase volatility. Akinci (2005) used GARCH models that differentiated both purchase and sale interventions. He finds mixed results on the impact of volatility; purchase interventions either have insignificant impact on volatility in one model or tend to reduce volatility in another model whereas sale interventions increase volatility.

Many of the above studies involving GARCH framework are conducted using uni-variate models. Only recently, few researches are done using multi-variate GARCH models to examine the dynamic interactions of major currencies. Pinar et al (2008) examines the impact of FX intervention of the CBT in a multivariate GARCH framework during the period 2002-2005, find that unannounced direct intervention is more effective in stabilizing the Turkish Lira market than announced auctions, and that intervention through the auctions program tends to increase the volatility.

In summary, empirical studies on FXI in emerging markets reveal mixed effects of intervention on the level and volatility of exchange rates. In general, studies emphasizing on other countries find mixed impacts of FXI on the level of the exchange rate (Kamil 2008), while most of the other studies report this impact as weak or insignificant. In Turkey, both sale and purchase interventions were effective in influencing the exchange rate. On the other hand, the impact on volatility almost similar across countries, where FXI is found effective in reducing the volatility, except recent studies by Pinar (2008), Herrera (2008) and Akinci (2005) which find that FXI is associated with higher exchange rate volatility in Turkey.

5.3 Stylized Facts

The Turkish economy was hit by two crises in the 1990s. The first one started in early 1994. The second one erupted in the second half of November 2000. The Turkish economy has been characterized by high levels of inflation and several stabilization attempts since the early 1980s. At the end of 1999, the Turkish government signed a stand-by agreement with the IMF and started to implement a new inflation stabilization program, based on a fixed exchange rate. The program was unsuccessful as it started with an already overvalued currency and the overvaluation continued during the program which also led to increased imports and a high current account deficit.

Weak macroeconomic fundamentals along with fragile banking sector led to the financial turmoil of 2000-2001 which caused the CBT to abandon the fixed parity and announce that the country moved into a floating exchange rate regime. In several announcements, authorities made it clear that the Central Bank would stick to this policy. The after effects of the crises were devastating, as the nominal exchange rate depreciated by 50% by the end of February 2001 and by 86% two months later in April 2001, inflation increased by 73% in the following year and the economy contracted significantly with the collapse of the banking system. The challenge for the Central Bank was to re-establish confidence and contain volatility in financial markets while implicitly targeting inflation under a floating exchange rate system. Among the factors turning this into a challenge are a history of high inflation, no experience of a free float and a high level of liability dollarization and currency substitution in the economy.

The crisis led to a new economic program funded by the IMF and a new approach to monetary policy (Akyurek, 2006). Accordingly, in January 2002 the Central Bank of

Turkey (CBT) began implementing an implicit inflation targeting framework (IIT), which encompassed core attributes of an inflation targeting (IT) regime including, among other requirements, the announcement of a formal target for inflation. Coupled with fiscal discipline and economic reforms, under the IT framework, inflation declined from over 70% to below 8% by year-end 2005 while the CBT consistently outperformed its year-end point targets measured by the consumer price index (CPI). In due course, the CBT cut its overnight policy rate from 59% to 13.5%. It seemed more or less that during this period of disinflation, structural transformation and transitional dynamics, the CBT was searching for an equilibrium real interest rate adequate with lower inflation.

Given successful disinflation, improvements in fiscal conditions and the banking system in particular, the CBT introduced full-fledged explicit IT at the beginning of 2006, which brought further transparency to the new framework. During the first year of explicit IT, year-end inflation (9.86%) exceeded the target (5%) by a wide margin. The year saw a sudden reversal of capital inflows in May-June mainly driven by the deterioration in investor sentiment towards emerging markets in general. The exchange rate depreciated by close to 30% and the CBT raised its policy rate from 13.25% to 17.50%. While inflation returned to pre-shock levels after about a year, it remained above the path leading to the 4% year-end target set for 2007 and 2008.

In regards to FX intervention, CBT intervenes in the FX markets using different forms in the post 2001 floating exchange rate regime; unannounced direct purchase and sale of the U.S. dollar against the Turkish Lira, FX purchases and sales through previously announced auctions, and altering the lending rates of the Central Bank.

Within the framework of the floating exchange rate policy that has been implemented since the year 2001, the exchange rates are determined by the demand and supply conditions of the market. However the CBT announced that it could intervene in the exchange rate markets in cases where exchange rates display or are expected to display excessive volatility in both directions. As CBT has declared the commitment to the flexible exchange rate regime, interventions have not been directed towards a possible change in the level of TRY/USD or TRY/EUR. Under this framework, the CBT conducts the unannounced direct interventions¹⁷.

Besides, the CBT may also hold foreign exchange buying or selling auctions to build up reserves for the foreign debt payments of the treasury and other foreign currency denominated obligations of the CBT. In order to minimize the pressure on supply and demand conditions in the foreign exchange market, the CBT conducts FX buying and selling auctions, whose terms and conditions are announced with due notice. The annual auction program is announced in the press release of the previous year, which uncovers the auction amount, and the maximum daily amount, leaving the bank with the choice of the optional amount depending on supply and demand conditions. The CBT does not alter the program unless extraordinary differences are observed in the foreign exchange liquidity.

In reserve accumulation Central Bank's announcement is in the direction of foreign currency purchases during excess supply of foreign currency. In order to achieve

¹⁷ For the purpose of transparency, data on the direct FX sale/purchase interventions carried out since 2002 have been started to be published through press releases at the same day when the intervention was made. The amount that was bought or sold at an intervention is published on the first working day of the month which comes after 3 months following the intervention date.

the pair of objectives at hand CBT must possess a strong foreign currency position. CBT is constrained by the announced exchange rate regime. In this regard, the interventions and auctions have to be conducted in a way to avoid affecting the equilibrium value of the currency.

In 2002 total purchases through currency purchase options reached 800 million US dollar level whereas in 2007 this number increased to 10 billion US dollars. However, total direct purchases reached 20 billion US dollar in 2005 on 6 days only. It is argued by the CBT that auctions have minimum impact on the level and the volatility of the foreign currency market since the amount purchased daily is very small given the size of the market and they are pre-announced therefore markets already infuse the effect into the price before the operation takes place.

Short term interest rates have been used as a main policy instrument under the floating exchange rate regime. Decisions on interest rates have been made depending on assessments arising from the pre-set Monetary Policy Committee (MPC) meetings. Besides, the rationale behind interest rate decisions has been released within two business days in a press release called “Inflation and Outlook” together with the general economic outlook. Decision on the short term interest rates, which is the main policy instrument, was made by taking into account the factors that influence future inflation in line with price stability goal.

Figure 5.1 depicts the frequency of CBT direct intervention and auction intervention. Figure 5.2 depicts the behavior of the TRY/USD and TRY/EUR exchange rate and volatilities (defined as squared returns) around the CBT FX intervention operations, showing the high volatility clustering.

Furthermore, Table 5.1 presents four statistics which are calculated using the observations in the full sample: Skewness, Kurtosis, Jarque-Bera and Augmented Dickey Fuller (ADF). The values for kurtosis are high (close to three) in all cases. So, the distributions are peaked relative to normal. The Jarque-Bera test rejects normality at the 5% level for all distributions. So, the samples have all financial characteristics: volatility clustering and leptokurtosis. Furthermore, in terms of stationarity, the results from the ADF tests indicate that the series is $I(1)$, and therefore, GARCH models can be used to examine the behavior of volatility over time.

5.4 Data

The CBT recently published historical daily frequency data on FX intervention on its website, permitting increasing research on Turkey as an emerging economy. According to the CBT, Turkey undertook frequent and massive foreign exchange market interventions between 2002 and late 2008. During this period the CBT intervened in the TRY/USD exchange market over 1000 days conducting FX operations that ranged from being large scaled operations that exceeded one billion USD in a single day to around 3 million dollar in another occasion. Table 5.2 summarizes the intervention data statistics during the full period from April 2002 to November 2008.

The data on the TRY/USD and TRY/EUR exchange rates are daily closing spot exchange rates obtained from the CBT official website. I analyze the log returns of the daily exchange rate series defined as $ds_t = \ln\left(\frac{S_t}{S_{t-1}}\right)$, where S_t is the daily TRY/USD or TRY/EUR exchange rates. Table 5.2 presents various descriptive statistics for the

TRY/USD exchange rate over the full period from April 2 2002 to November 20 2008 comprising 1731 daily observations. The kurtosis is significantly above 3 representing a leptokurtic distribution of yen/dollar exchange rate returns, which does not constitute a problem in our estimation because the GARCH specification identified by Bollerslev (1986) takes a time dependent variable as a possible reason for leptokurtic series into account.

The data on inflation targets and news about Turkey-EU membership are from CBT annual reports and Reuter's news.

5.5 Methodology

5.5.1 Testing the efficacy of intervention on the level and volatility of the exchange rates

GARCH models have recently been used to measure the impact of the foreign exchange intervention on both the level and volatility of the exchange rate using exogenous intervention data in both the conditional mean and variance equations. In this section, I investigate whether the CBT FX interventions in the TRY/USD market have an impact on the level and volatility of the TRY/USD and TRY/EUR exchange rates using diagonal Week 6 Materials (mini lecture, presentation and graded conference 6) are posted now. I also posted your grades for GC5 conference Vech - multivariate GARCH and the CCC- multivariate GARCH model.

The multivariate GARCH model not only explains the movements of conditional variances over time for each asset return series as does the uni-variate model, but also captures the way that covariances vary across time, thereby permitting the analysis of the

influences of another bilateral rate in the foreign exchange market. In this paper, there are two underlying exchange rates; the TRY/USD and the TRY/EUR. The reason for choosing these exchange rates is obvious for the case of Turkey. The importance of the USD lies not only in being a major and stable reserve currency, but also the CBT have been only buying and selling USD through direct and auction intervention in the TRY/USD market.

Regarding the Euro, even though Turkey is not yet a member of the European Union, Turkey is in the accession process to the European Union and has close ties with European countries. According to the Turkey and EU Seventh Report of session 2007-2008: (i) Turkey is the only candidate for membership that has entered into a customs union with the EU since 1995. (ii) EU is Turkey's largest trading partner; 52% of Turkey's exports went to EU in 2006, while EU countries supply almost 42% of Turkey's imports. (iii) 60% of foreign direct investment (FDI) in Turkey comes from the EU. Given the breadth and depth of Turkey's relationship with the EU, it is no wonder that Euro is powerfully affecting the Turkish economy.

Bollerslev, Engle and Wooldridge (1988) introduced the basic framework for a Multivariate GARCH model by extending the GARCH representation in the uni-variate case to the to an N-variate model. The widely used specifications of the Multivariate GARCH model in the literature include the VEC model, and the CCC model and their diagonal counterparts.

The VEC model is a dynamic model with time-varying means, variances, and covariances for n components of the dependent variables. The VEC representation is very general, and involves a large number of parameters. Thus, empirical applications

require further restrictions and simplifications. The diagonal form of the VECH representation is frequently used in empirical studies. Under the diagonal form, each variance (covariance) term follows a GARCH-type equation with the lagged variance (covariance) term and the product of the corresponding lagged residuals as the right-side variables in the conditional variance (covariance) equation.

Bollerslev (1990) suggested a constant-conditional-correlation Multivariate GARCH (CCC-MGARCH) model that can overcome these difficulties. The CCC model parameterizes the time-varying conditional co-variances to be proportional to the product of the corresponding conditional standard deviations. Bollerslev stated that under the assumption of constant correlations, the maximum likelihood estimate (MLE) of the correlation matrix is equal to the sample correlation matrix. Positive definiteness of the variance covariance matrix is controlled by the correlation matrix which is always positive definite, the optimization will not fail as long as the conditional variances are positive. The main difference between the CCC model and the VECH model is in the assumption of constant correlation among variables. The total number of parameters in the CCC model is less than that in the VECH model.

This assumption greatly simplifies the computational burden in estimation. Because of its computational simplicity, the CCC-MGARCH model is widely used in empirical research. The constant-correlation assumption provides a convenient MGARCH model for estimation; many studies find that this assumption is not supported by some financial data. Engle (2002) extended the CCC-model to a Dynamic CC-MGARCH model by allowing the conditional correlations to be time varying. Thus

incorporating time-varying correlations and retaining the appealing feature of satisfying the positive definitive condition during the optimization.

In this study, I choose the diagonal VEC model since the estimated variance/covariance matrix satisfies the positive definite condition and the model is less restricted. The general diagonal VEC model as proposed by Bollerslev, Engle and Wooldridge (1988), and is specified as follows:

$$y_t = b + \varepsilon_t$$

$$VECH(H_t) = C + \sum_{i=1}^q A_i VEC(\varepsilon_{t-i} \varepsilon_{t-i}') + \sum_{j=1}^p B_j VEC(H_{t-j})$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, H_t),$$

Where y_t is a $(N \times 1)$ vector of asset returns, b is a $(N \times 1)$ vector of constants, ε_t is a $(N \times 1)$ vector of innovations, $VECH(.)$ is the column-stacking operator and takes the upper triangular portion of a matrix into a column vector, and C is a $((N(N+1)/2) \times 1)$ vector containing unconditional variances and covariances. A_i and B_j are $((N(N+1)/2) \times (N(N+1)/2))$ matrices of GARCH process parameters. H_t is the $(N \times N)$ matrix of the conditional variance co-variance of the returns.

The diagonal VEC GARCH model makes it possible to estimate simultaneously the impact of FX interventions on the dynamics of exchange rate returns, their volatility and their correlations, unlike the CCC model that is estimated in two steps by fitting a uni-variate GARCH(1,1) model to the individual exchange rate movements, then the conditional covariance matrix is calculated from constant correlations and time varying GARCH residuals.

I extend the diagonal VEC model by adding exogenous variables; the intervention variable and the deviation from inflation targets into the variance and the

covariance equations as well as the mean equation. The extended VEC GARCH (1,1) model can be written as shown in Equation 1. Equation 1 provides the process of the TRY/USD and the TRY/EUR exchange rates as a bi-variate GARCH(1,1) set of equations which allows actual volumes of intervention along with other macroeconomic variables to have an exogenous effect on the mean and the variance of the exchange rate returns. The bi-variate GARCH (1,1) model is given by:

$$\begin{aligned}
 y_{1,t} &= \mu_1 + a_1 INV_{Direct,t-1} + b_1 INV_{Auction,t-1} + c_1 (\pi_{t-1} - \pi_{t-1}^T) + \varepsilon_{us,t} \\
 y_{2,t} &= \mu_2 + a_2 INV_{Direct,t-1} + b_2 INV_{Auction,t-1} + c_2 (\pi_{t-1} - \pi_{t-1}^T) + \varepsilon_{us,t} \\
 (1) \quad h_{11,t} &= \omega_{11} + \alpha_{11} \varepsilon_{1,t-1}^2 + \beta_{11} h_{11,t-1} + \varphi_{11} INV_{Direct,t-1} + \psi_{11} INV_{Auction,t-1} + \lambda_{11} (\pi_{t-1} - \pi_{t-1}^T) + \delta_{11} ENews_{t-1} \\
 h_{22,t} &= \omega_{22} + \alpha_{22} \varepsilon_{2,t-1}^2 + \beta_{22} h_{22,t-1} + \varphi_{22} INV_{Direct,t-1} + \psi_{22} INV_{Auction,t-1} + \lambda_{22} (\pi_{t-1} - \pi_{t-1}^T) + \delta_{22} ENews_{t-1} \\
 h_{12,t} &= \omega_{12} + \alpha_{12} \varepsilon_{12,t-1}^2 + \beta_{12} h_{12,t-1} + \varphi_{12} INV_{Direct,t-1} + \psi_{12} INV_{Auction,t-1} + \lambda_{12} (\pi_{t-1} - \pi_{t-1}^T) + \delta_{12} ENews_{t-1} \\
 \varepsilon_t | \Omega_{t-1} &\sim N(0, H_t)
 \end{aligned}$$

where $y_{1,t}$ and $y_{2,t}$ is the logarithmic returns of the TRY/USD and TRY/EUR spot exchange rates over the 24 hour period from the closing of the foreign exchange market on day t-1 until day t's closing,

$INV_{direct,t}$ denotes CBRT foreign exchange volume of purchases in millions of US dollars.

$INV_{auction,t}$ denotes CBRT foreign exchange volume of purchases in millions of US dollars.

$(\pi_{t-1} - \pi_{t-1}^T)$ denotes the inflation differential from target inflation rates

$ENEWS_t$ is a dummy variable that takes the value of 1 when there is news about Turkey-EU membership

ε_t is the residual of the mean equation,

h_t is the conditional variance of the exchange rate .

The first line in equation 1 characterizes the mean of the stochastic process which generates the TRY/USD exchange rate return series. If $\mu > 0$ ($\mu < 0$) this denotes a constant rate of appreciation (depreciation) of the US dollar against the Lira. The exchange rate is assumed to be influenced by current official FX interventions $INV_{Direct,t}$ and $INV_{Auction,t}$, defined as the volumes of net purchases of US dollars by the CBT. Purchase

interventions by the CBT are effective if a_I and b_I are positive implying that current purchases of US dollar by the CBT lead to a higher exchange value of US dollar in terms of the Lira (that is an appreciation of the dollar and depreciation of the Lira). The exchange rate is also assumed to be affected by inflation news in the form of deviations of current inflation from target inflation rate; c_I is expected to be positive reflecting that positive inflation surprises leads to depreciation in the Lira.

Similarly, the second line in equation 1 characterizes the mean of the stochastic process which generates the TRY/EUR exchange rate return series. Though the CBT did not intervene in the TRY/EUR market, the reason to include this exchange rate is to assess the spillover effect of CBT intervention in the TRY/USD market on the TRY/EUR exchange rate due to the strong ties between Turkey and EU.

The third line in equation 1 models the conditional volatility of the TRY/USD exchange rate as plotted in Figure 5.3. The variance h_t depends on past disturbances ε_{t-1} , the lagged variance h_{t-1} , the official foreign currency intervention $INV_{Direct,t}$ and $INV_{Auction,t}$, as well as inflation news. An initial view would indicate that less exchange rate volatility and uncertainty seem to be preferable for the economy as a whole. Hence, interventions are effective if ϕ_{11} and ψ_{11} are negative. I also include the impact of news about the Turkey's accession to the EU on the volatility of the exchange rates through $EUNews_t$. Again, the fourth line represents the spillover effects of the CBT intervention in the TRY/USD market on the volatility of the TRY/EUR exchange rate.

The fifth line represents the conditional covariance which is also assumed to be influenced by FX purchases of US dollar, inflation surprises and Turkey-EU news. The last line in equation 1 indicates that ε_t has a conditional normal distribution with mean

zero and variance-covariance matrix H_t . The symbol Ω_{t-1} denotes the information available to the exchange market participants at the closing of the foreign exchange market on day $t-1$.

Equation 1 captures the impact of foreign exchange intervention on the level and volatility of the exchange rate. This equation may reflect the possibility of having simultaneity bias, as monetary authorities may be motivated to intervene more during periods of high exchange rate volatility (like when the CBT intervened by selling dollars during June 2006) and exchange rate volatility can be triggered by expected foreign exchange intervention. However, I control this problem of simultaneity by employing the lagged intervention operations, an internal instrument, so that the CBT purchase interventions precede the exchange rate observation.

5.6 Empirical results

5.6.1 Structural Breaks

Structural changes have occurred in the Turkish economy through the period under study. By the beginning of 2006 the CBT announced the switch from implicit IT to explicit IT regime. In addition forms of intervention have changed throughout the whole period from the use of auctions intervention to the use of both direct and auctions intervention back to only using auctions intervention.

The regression analysis will be conducted to test rigorously the presence of Structural breaks during the full sample period. A sup (F_T) test, a la Andrews (1993), is conducted on the linear version of the first line in equation 1 to test and search for an unknown break date. The possible structural break dates are the middle 70% of the

sample period. Namely the first 15% and the last 15% percent are excluded from the test for structural break. Table 5.3 shows the resulting Andrews test. Two Break points are found, suggesting 3 different subsamples as follows:

- First sample starts on April 1, 2002 and ends October 22, 2003.
- Second Sample starts on October 24, 2003 and ends May 15, 2006
- Third Sample starts on June 30, 2006 and ends November 20, 4 2008

These structural breaks correspond to institutional changes in the Turkish economy. The CBT halted on the use of the auction intervention program on October 22nd, 2003 after a daily continuous use of that program since May 6th, 2003 with, almost a non-stop intervention through daily auction program for 122 days consecutively. The CBT resumed its intervention through the auction program on January 23rd, 2004. May 15th 2006 was the last day in which the CBT has used the direct purchase interventions in the TRY/USD market. During the period May 16, 2006 to June 29, 2006, the CBT intervened directly by selling dollars in the TRY/USD market on three business days only. Beyond June 30, 2006 the CBT stopped using direct intervention in the TRY/USD market and relied only on the auction interventions. Because of the limited number of FX sale operations conducted by the CBT through direct intervention and no sale operations were conducted through the auctions program throughout the whole period, I decided to focus only on the impact of FX purchase operations. Thus, I dropped the period May 16, 2006- May 29, 2006 from sub-samples.

Despite the fact that structural break tests did not report a structural break in the beginning of 2006, I decided to divide the whole sample into two sub-samples to

distinguish between the impacts of CBT intervention during the implicit IT regime versus the explicit IT regime, in addition to the above mentioned three sub-samples.

5.6.2 Effectiveness of Intervention

Table 5.4 conveys the results of the estimates for volume of net purchases of FX by the CBT using the multivariate diagonal Vech GARCH model for the full sample and the three suggested subsamples as well as the implicit and explicit IT regimes. Results reported in Table 5.4 show a constant rate of appreciation of the lira against the dollar and the euro. This is shown by the negative a significant coefficient of μ in all samples. CBT direct interventions have a positive and significant impact on TRY/USD exchange rate level throughout the full sample. This finding suggests a depreciation of the Lira as a result of CBT direct purchase operations. This result is in contrary of CBT frequent announcements of its commitment to the flexible exchange rate regime and not targeting the level of the exchange rate. In the same time this CBT intervention has positive impact on the TRY/EUR exchange rate level, indicating that intervention in the TRY/USD market have spillover effects in the TRY/EUR market, even though there is no direct intervention in the TRY/EUR market.

By analyzing the impact of CBT direct interventions along the sub samples reveals its asymmetric effect on exchange rate returns through the implicit IT and explicit IT regime. One can find that the CBT was only effectively intervening in the TRY/USD market during the implicit IT regime. Table 5.4 shows that CBT direct intervention was only effective during the second subsample. This outcome can be explained by the fact

that during the period of implicit IT regime, mainly during the second period, inflation rates were either below the target rates or within the uncertainty band¹⁸.

This can be illustrated by Figures 5.3A and 5.3B, which show the behavior of the inflation rates around the actual and trend of announced target rates. According to Figure 5.3A, the inflation rate was either below its actual target rate or its maximum bound throughout a consecutive fourteen month period (April 2004 – May 2005). However, by looking at the trend line of the inflation targets, one can see that over a period of consecutive sixteen months (February 2004 – May 2005), the inflation rate was below its maximum bounds. Thus, CBT can intervene in the exchange rate market as long as the primary objective of the CBT of price stability is achieved. Turkey was beset by large current account deficit, thus to improve its competitiveness in the tradable goods markets, depreciating the currency will not be in conflict with the inflation targeting framework. This outcome is in contrast to previous argument by Domac and Mendoza (2004) that asserts on the role of FXI in reducing the volatility and against defending a particular exchange rate.

Yet again, CBT auctions interventions have significant impact on the levels of the TRY/USD exchange rates through the full sample, suggesting that CBT purchase interventions through the auctions program are effective to depreciate the Lira against the dollar. However, unlike direct interventions, CBT auction interventions were effective during explicit IT regime and the third sub-sample. This finding is supported by the CBT announcement that the aim of the CBT auctions is to build up reserves for the foreign

¹⁸ The uncertainty band was set by the CBT as 2 percentage points above or below the inflation targets.

debt payments of the treasury and other foreign currency denominated obligations of the CBT, during the first and second subsamples.

It is worth noting that these auctions are previously announced in the press release of the prior year, so there is no surprise factor in these auctions. Guimarães and Karacadag (2004) provided an explanation for a similar outcome, which is that earlier announcements of intervention auctions may have operated effectively through the signaling channel well in advance of actual interventions themselves. This can explain the insignificance of coefficients of the CBT auction interventions through the implicit IT regime and the first and second subsample.

On the other hand, the effectiveness of the auction program can be explained by the unannounced optional amounts of USD that the CBT has to buy beyond the predetermined auction amount during the time of the auctions. These optional amounts were very small if not zero during the first and the second sub-samples however in the third sub-sample these optional amounts were very high and may exceed the initial value of the auction amount.

Despite the CBT announcements about limiting its intervention to reduce excessive volatility of the exchange rates, both direct and auction interventions have insignificant impact on the variances of the exchange rates. This result is inconsistent with the outcome of Pinar et al (2008) who conclude that direct intervention serve the purpose of decreasing volatility in the FX market and only auction interventions tend to increase volatility.

A valuable outcome of the use of this bi-variate GARCH model is its ability to identify the spillover effect of CBT interventions in the TRY/USD market on the

dynamics of the exchange rate movements in the TRY/EUR market. My estimation captures three types of spillover effects¹⁹. First on the level of the exchange rates, Table 5.4 reports spillover effects by looking at the coefficients of interventions in the mean equation of the TRY/EUR returns. It is clear that TRY/EUR exchange rate returns were affected in the same way (same direction of change during the same time period) as the TRY/USD returns due to CBT direct and auctions interventions.

Additionally, CBT direct interventions in the TRY/USD trigger a second type of spillover effect in terms of the co-movement of the two exchange rates during the full sample, the implicit IT regime, and mainly during the second subsample. Figure 5.4 shows the dynamic correlations for the USD and the EUR throughout the full sample period. This suggests that the TRY/EUR is implied by TRY/USD along with independent shocks due to USD/EUR. Therefore, agents' expectations of future TRY/EUR exchange rates are affected by changes in TRY/USD exchange rates, which may be due to FXI intervention.

These spillover effects are consistent with Beine (2004) results and suggest that a specific CBT intervention in the TRY/USD market conveys some signal which is not only useful for the participants of that market but also leads to some reactions of agents involved in the TRY/EUR market. Overall these results bring further evidence that central bank interventions do not affect exchange rates through a pure portfolio effect but through a signaling impact altering agents' expectations of the future exchange rates.

Turning to the impact of inflation news on the volatility of the exchange rates, inflation surprises have quite significant positive impacts on the volatilities of both exchange

¹⁹ Uni-variate GARCH models do not detect any robust spillover effect.

rates. During all samples except the second subsample, monthly inflation announcements led to an economically significant increase in the conditional volatility of the exchange rates in the subsequent day, as the inflation rate started to significantly deviate away from its target, this generates foreign exchange market uncertainty, thus having a destabilizing effect on the volatility of the TRY/USD market. Inflation surprise also tends to increase the volatility in the TRY/EUR market during the same samples. One reason why inflation surprises were insignificant during the second subsample is that during this period the inflation rate has been either falling at the beginning of the period, or within the uncertainty band of inflation for eight consecutive months in the middle of the period, or slightly higher than upper bound towards the end of the period. This behavior of the inflation rate around its target levels increased confidence to market agents on the performance of the monetary authorities towards achieving the IT regime reflecting insignificant impact on the volatilities of the exchange rate.

In regards to the impact of news on Turkey's accession to the EU, I find that the volatilities not only in the TRY/EUR market but also in the TRY/USD market tend to increase due to news announcement regarding Turkey-EU access negotiations.

5.7 Conclusion

This study assesses the effectiveness of the FXI in Turkey during the post crises period, and since the inception of the IT regime. The most important finding of this paper is brought up by testing whether there is a room for an effective FXI under IT regimes. In other words whether effectiveness is only limited to reducing volatility or is it possible that FXI can influence the exchange rate. I find that there is always a room for direct FXI to coexist within an IT regime, and to influence the domestic currency to improve

competitiveness in the tradable goods markets as long as current inflation rates are below their target rates or within the uncertainty band, in contrast to previous argument that limits the role of FXI in reducing the volatility and against defending a particular exchange rate.

I also find spillover effects of CBT intervention in the TRY/USD market on the level of the TRY/EUR and its co-variance with the TRY/USD, suggesting that the TRY/EUR is implied by TRY/USD along with independent shocks due to USD/EUR. Therefore, agents' expectations of future TRY/EUR exchange rates are affected by changes in TRY/USD exchange rates, which may be due to FXI. This in turn invites further research to study correlations across currencies for the purpose of short run currency portfolio optimization in emerging market economies that are frequently intervening in their FX markets.

Table 5.1 Diagnostics test statistics

	<i>TRY/USD</i>	<i>TRY/EUR</i>
	4/2/2002 – 11/20/2008	4/2/2002 – 11/20/2008
	ds_t	ds_t
<i>Mean</i>	0.000126	0.00034
<i>Std. Dev.</i>	0.009557	0.009482
<i>Skewness</i>	0.010925	0.633881
<i>Kurtosis</i>	21.70055	7.861114
<i>Jarque-Bera</i>	25252.06	1822.368
<i>Probability</i>	0.00	0.00
<i>Observations</i>	1733	1733
<i>ADF(Level)</i>	-40.589	-42.0365
<i>Probability</i>	0.00	0.00

Notes:

$ds_t = \ln(S_t / S_{t-1})$, Skewness is a measure of asymmetry of the distribution of the series around its mean. Kurtosis measures the peakedness or flatness of the distribution of the series. Jarque-Bera is a test statistic for testing whether the series is normally distributed. ADF regressions include intercept but not trend. I employ ADF test on the logarithms of stock indices. ADF critical values: (1%) -3.4334, (5%) -2.8627, (10%) -2.5674

Table 5.2: Intervention Data Summary Statistics

	Direct Interventions	Preannounced Auctions
	April 2 2002– Oct 20 2008	April 2 2002– Oct 20 2008
Number of Observations	1731	1731
Total intervention days	21	1015
Unconditional probability of Intervention	0.01	0.59
Number of days with dollar purchase	15	1011
Average amount of dollar purchase (millions of dollars)	1702.3	38.1
Unconditional probability of dollar purchase	0.009	0.15
Number of days with dollar sale	6	2
Average amount of dollar sale (millions of dollars)	354	500
Unconditional probability of dollar sale	0.0035	0.0023

Table 5.3: Quandt-Andrews unknown breakpoint test:

Null Hypothesis: No breakpoint within trimmed data

Equation Sample: 4/03/2002 11/20/2008	Value	Prob.
Test Sample: 4/02/2003 11/22/2007		
Number of breaks compared: 1212		
Maximum LR F-statistic (10/23/2003)	30.5516	0.0009
Maximum Wald F-statistic (10/23/2003)	30.5516	0.0009
Exp LR F-statistic	11.2714	0.0013
Exp Wald F-statistic	11.2714	0.0013
Ave LR F-statistic	16.3911	0.001
Ave Wald F-statistic	16.3911	0.001
Equation Sample: 10/23/2003 10/20/2008		
Test Sample: 7/28/2004 2/15/2008		
Number of breaks compared: 928		
Maximum LR F-statistic (5/16/2006)	31.0385	0.0007
Maximum Wald F-statistic (5/16/2006)	31.0385	0.0007
Exp LR F-statistic	12.0337	0.0006
Exp Wald F-statistic	12.0337	0.0006
Ave LR F-statistic	18.4444	0.0002
Ave Wald F-statistic	18.4444	0.0002
Note: probabilities calculated using Hansen's (1997) method.		

Table 5.4: Estimates of the Vech-GARCH (1,1) Model:

$$y_{1,t} = \mu_1 + a_1 INV_{Direct,t-1} + b_1 INV_{Auction,t-1} + c_1 (\pi_{t-1} - \pi_{t-1}^T) + \varepsilon_{us,t}$$

$$y_{2,t} = \mu_2 + a_2 INV_{Direct,t-1} + b_2 INV_{Auction,t-1} + c_2 (\pi_{t-1} - \pi_{t-1}^T) + \varepsilon_{us,t}$$

$$h_{11,t} = \omega_{11} + \alpha_{11} \varepsilon_{1,t-1}^2 + \beta_{11} h_{11,t-1} + \varphi_{11} INV_{Direct,t-1} + \psi_{11} INV_{Auction,t-1} + \lambda_{11} (\pi_{t-1} - \pi_{t-1}^T) + \delta_{11} EUnews_{t-1}$$

$$h_{22,t} = \omega_{22} + \alpha_{22} \varepsilon_{2,t-1}^2 + \beta_{22} h_{22,t-1} + \varphi_{22} INV_{Direct,t-1} + \psi_{22} INV_{Auction,t-1} + \lambda_{22} (\pi_{t-1} - \pi_{t-1}^T) + \delta_{22} EUnews_{t-1}$$

$$h_{12,t} = \omega_{12} + \alpha_{12} \varepsilon_{12,t-1}^2 + \beta_{12} h_{12,t-1} + \varphi_{12} INV_{Direct,t-1} + \psi_{12} INV_{Auction,t-1} + \lambda_{12} (\pi_{t-1} - \pi_{t-1}^T) + \delta_{12} EUnews_{t-1}$$

$$\varepsilon_t | \Omega_{t-1} \sim N(0, H_t)$$

	Full sample 4/1/02-0/20/08	IIT 4/1/02-12/31/05	EIT 1/2/06-10/20/08	1 st subsample 4/1/02-10/22/03	2 nd subsample 10/24/03- 5/15/06	3rd sub-sample 6/30/06- 10/20/08
μ_1	-0.001095 (0.000184)***	-0.000862 (0.000217)***	-0.001411 (0.000352)***	-0.000612 (0.00038)	-0.000744 (0.000254)***	-0.00163 (0.000449)***
a_1	0.021117 (0.009131)**	0.015464 (0.008935)*	-0.001728 (0.063277)	0.063213 (0.059534)	0.016443 (0.008329)**	
b_1	0.14424 (0.051168)***	0.098897 (0.068407)	0.215663 (0.080885)***	0.008168 (0.152028)	0.070765 (0.069929)	0.227493 (0.124103)*
c_1	-0.034987 (0.123849)	-0.028149 (0.171505)	-0.088259 (0.277977)	-0.016767 (0.281139)	-0.150626 (0.229115)	-0.115206 (0.280382)
μ_2	-0.000767 (0.000199)***	-0.000324 (0.000246)	-0.001045 (0.000384)***	0.0000861 (0.000495)	-0.00027 (0.000268)	-0.0016 (0.000448)***
a_2	0.024672 (0.007381)***	0.027652 (0.009908)***	0.014385 (0.083331)	0.0728 (0.132327)	0.019075 (0.007162)***	
b_2	0.137853 (0.055806)**	-0.045213 (0.083014)	0.201102 (0.094271)**	-0.06625 (0.194365)	-0.065635 (0.080779)	0.319956 (0.121985)***
c_2	0.065233 (0.140255)	0.025322 (0.184635)	0.183549 (0.243485)	0.054594 (0.215911)	0.169583 (0.250976)	0.09576 (0.286619)
ω_{11}	0.00000136 (0.00000036)***	0.00000217 (0.00000057)***	0.00000105 (0.00000112)	0.00000142 (0.00000125)	0.000000531 (0.00000034)	0.00000377 (0.00000175)**
α_{11}	0.125914 (0.013884)***	0.156967 (0.023537)***	0.117822 (0.018651)***	0.095085 (0.026777)***	0.125149 (0.022699)***	0.110297 (0.023979)***
β_{11}	0.850178 (0.013211)***	0.797315 (0.023178)***	0.85337 (0.019245)***	0.814594 (0.039048)***	0.862137 (0.02088)***	0.810799 (0.028381)***
φ_{11}	0.000052 (0.0000306)*	0.0000533 (0.0000507)	0.000109 (0.00022)	0.000232 (0.000388)	0.0000294 (0.0000268)	
ψ_{11}	0.000112 (0.0001)	0.0000214 (0.000141)	0.000233 (0.000424)	0.000392 (0.000416)	-0.00000437 (0.000105)	0.000375 (0.000399)
λ_{11}	0.002226 (0.000633)***	0.002258 (0.000873)***	0.006398 (0.001516)***	0.006312 (0.002235)***	0.000643 (0.000817)	0.009282 (0.003408)***
δ_{11}	0.005017 (0.001114)***	0.005213 (0.001502)***	0.06992 (0.002208)***	0.07287 (0.029863)**	0.00000442 (0.001526)	0.015102 (0.002364)***

Table 5.4- continued: Estimates of the Vech-GARCH (1,1) Model:

	Full sample 4/1/02-10/20/08	IIT 4/1/02-12/31/05	EIT 1/2/06-10/20/08	1 st subsample 4/1/02-10/22/03	2nd subsample 10/24/2003 - 5/15/06	3 rd subsample 6/30/06- 10/20/08
Ω_{22}	0.00000135 (0.00000046)***	0.00000166 (0.00000066)**	0.00000197 (0.00000117)***	0.000000977 (0.00000161)	0.000000576 (0.00000046)	0.00000507 (0.00000192)***
α_{22}	0.112389 (0.01281)***	0.088063 (0.016319)***	0.13192 (0.021446)***	0.052422 (0.017738)***	0.078124 (0.017712)***	0.133312 (0.026458)***
β_{22}	0.870597 (0.013142)***	0.880979 (0.020419)***	0.840988 (0.021446)***	0.914414 (0.029124)***	0.906989 (0.022222)***	0.798447 (0.03277)***
φ_{22}	0.0000642 (0.0000364)*	0.0000435 (0.0000493)	0.000128 (0.000166)	0.000372 (0.000527)	0.0000276 (0.0000297)	
ψ_{22}	0.0000451 (0.000108)	0.0000186 (0.000148)	-0.00000659 (0.000268)	0.000182 (0.000543)	-0.0000294 (0.000117)	0.0000541 (0.000404)
λ_{22}	0.001948 (0.000778)**	0.002678 (0.001245)**	0.004323 (0.001921)**	0.003369 (0.001586)**	0.001277 (0.001178)	0.006314 (0.003458)*
δ_{22}	0.004986 (0.001388)***	0.003373 (0.002337)	0.006682 (0.002855)**	0.039012 (0.02297)*	0.00000123 (0.000927)	0.015048 (0.002924)***
ω_{12}	0.00000081 (0.00000027)***	0.00000128 (0.00000039)***	0.00000157 (0.00000097)***	0.000000752 (0.00000109)	9.57E-08 (0.0000002)	0.00000406 (0.0000016)**
α_{12}	0.118014 (0.012156)***	0.117502 (0.01678)***	0.123592 (0.018654)***	0.069304 (0.018455)***	0.097141 (0.016848)***	0.120999 (0.023735)***
β_{12}	0.861059 (0.011897)***	0.8359 (0.017761)***	0.846915 (0.018942)***	0.863268 (0.02773)***	0.885199 (0.01756)***	0.801125 (0.029405)***
φ_{12}	0.0000523 (0.0000222)**	0.0000668 (0.00003)**	0.000121 (0.000191)	0.000294 (0.000376)	0.0000427 (0.0000214)**	
ψ_{12}	0.0000769 (0.0000798)	-0.0000946 (0.0000943)	-0.0000265 (0.000237)	0.000148 (0.000398)	0.0000394 (0.0000579)	0.000143 (0.000363)
λ_{12}	0.001803 (0.000554)***	0.001996 (0.000835)**	0.004596 (0.001335)**	0.004611 (0.001722)***	-0.000906 (0.000484)*	0.007633 (0.003112)**
δ_{12}	0.00479 (0.000812)***	0.005989 (0.00133)***	0.007542 (0.001963)***	0.053318 (0.024631)**	0.00000233 (0.000837)	0.014536 (0.001693)***
LL	12638.64	7233.151	4593.273	2919.737	5085.646	4458.702
AIC	-14.74695	-14.71532	-14.69653	-14.21001	-15.18813	-14.75441
BIC	-14.65144	-14.56558	-14.48246	-13.93422	-14.99888	-14.57145
Q(10))	16.56823	22.45516	14.34746	14.99606	12.34908	17.16343

Notes: Q(r) denotes the Ljung-Box statistics for the rth order serial correlation in the standardized cross product of the residuals. Standard errors are in parentheses. ***, **, * denote significance at the 1, 5, and 10% level, respectively.

Figure 5.1: Frequency of CBT foreign exchange intervention over the period April 1 2002 to October 20 2008

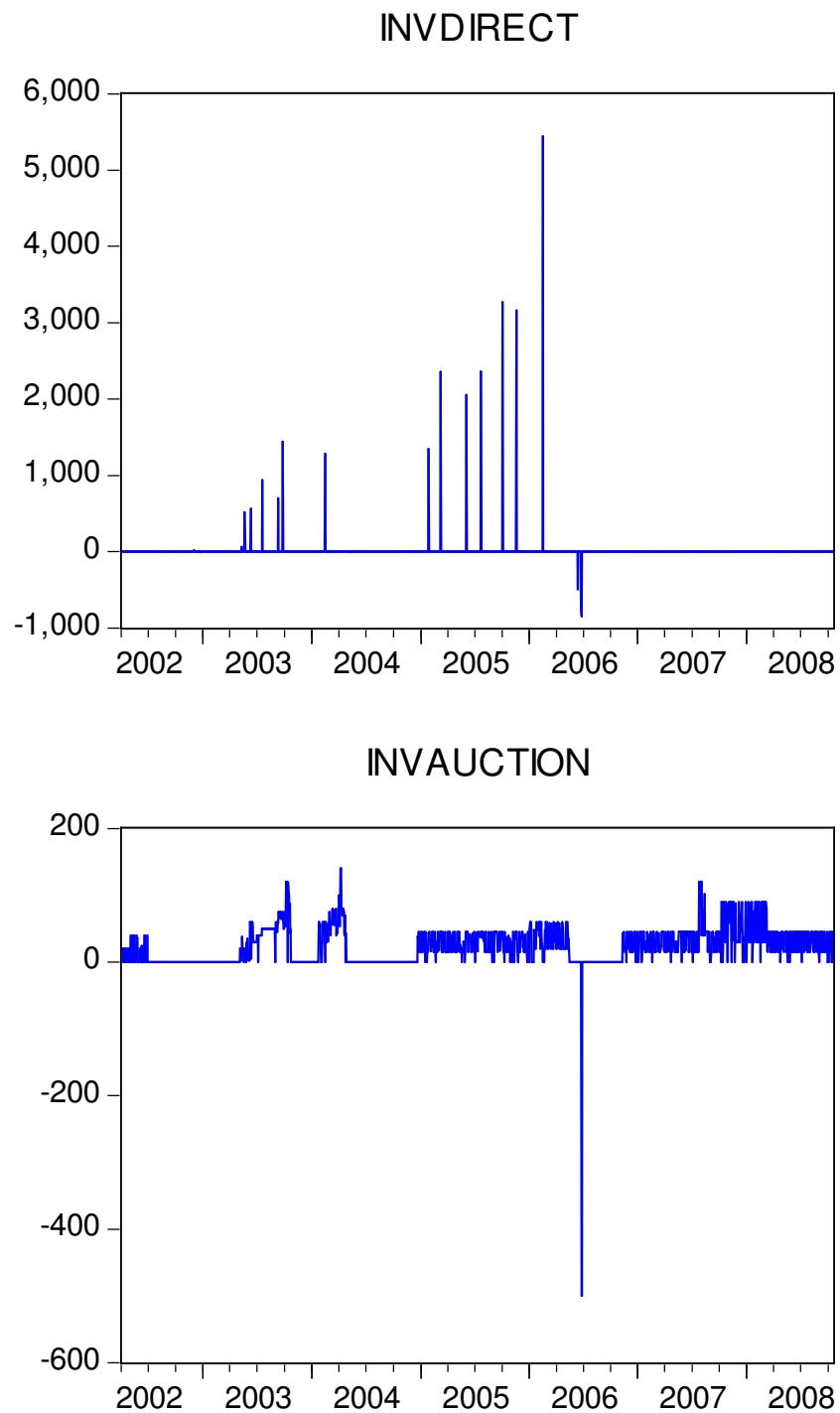


Figure 5.2: The behavior level and volatility of the TRY/USD and TRY/EUR exchange rates around the CBT foreign exchange intervention operations, during the full period April 1 2002 to October 20 2008.

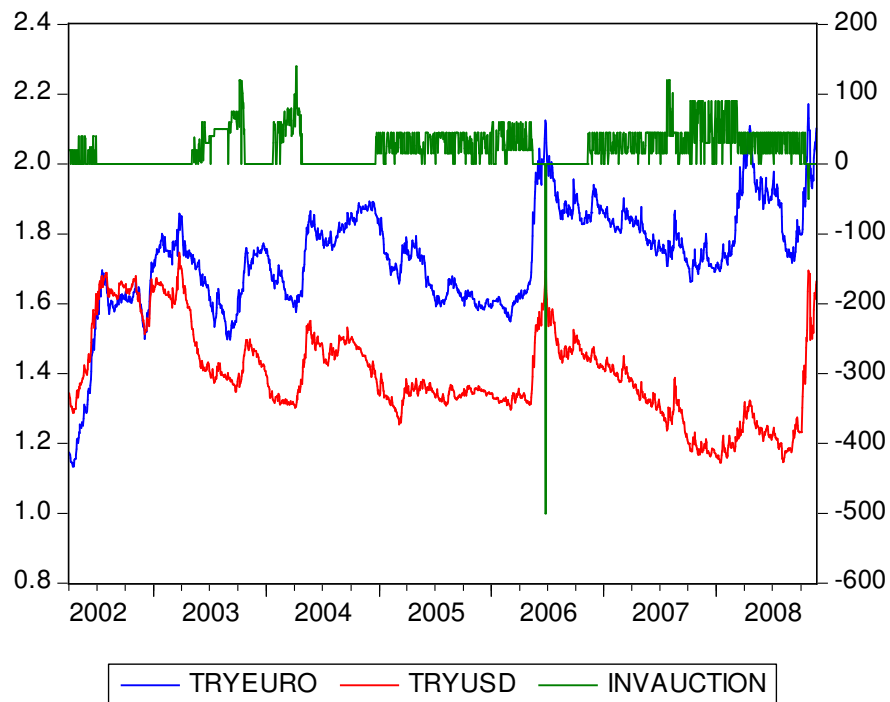
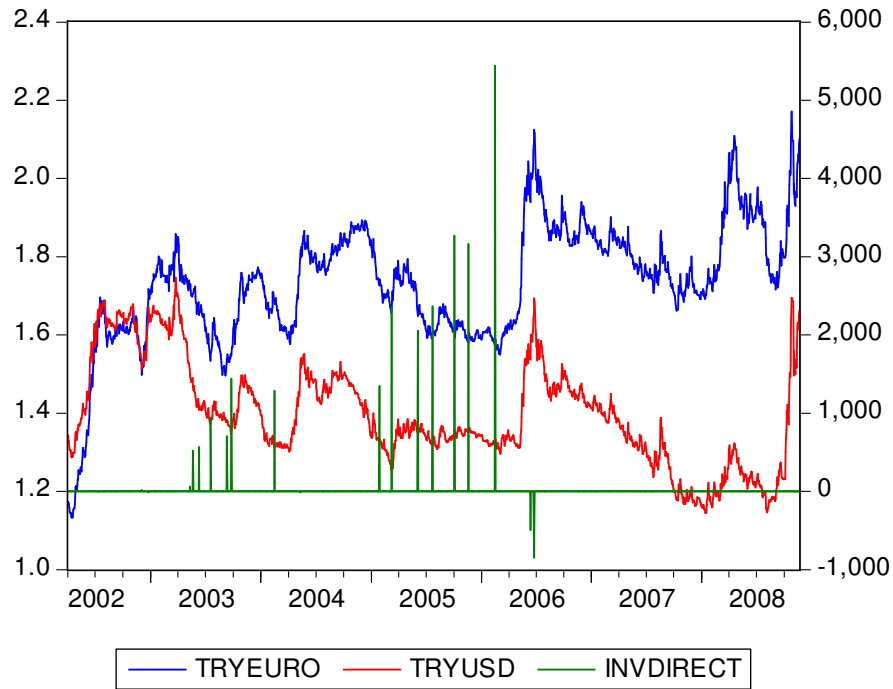


Figure 5.2-continued: The behavior level and volatility of the TRY/USD and TRY/EUR exchange rates around the CBT foreign exchange intervention operations, during the full period April 1 2002 to October 20 2008.

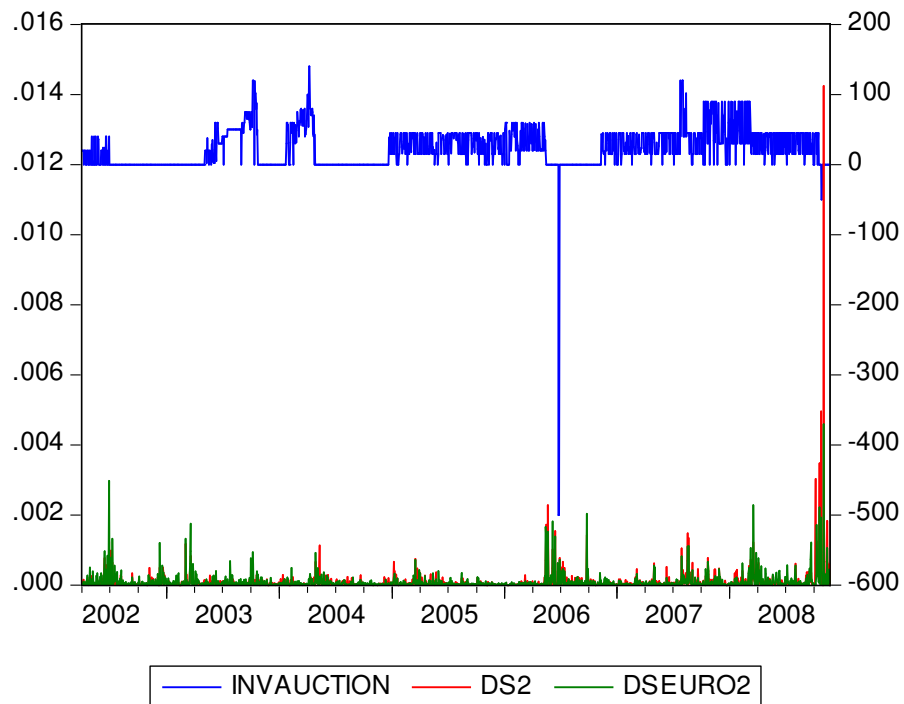
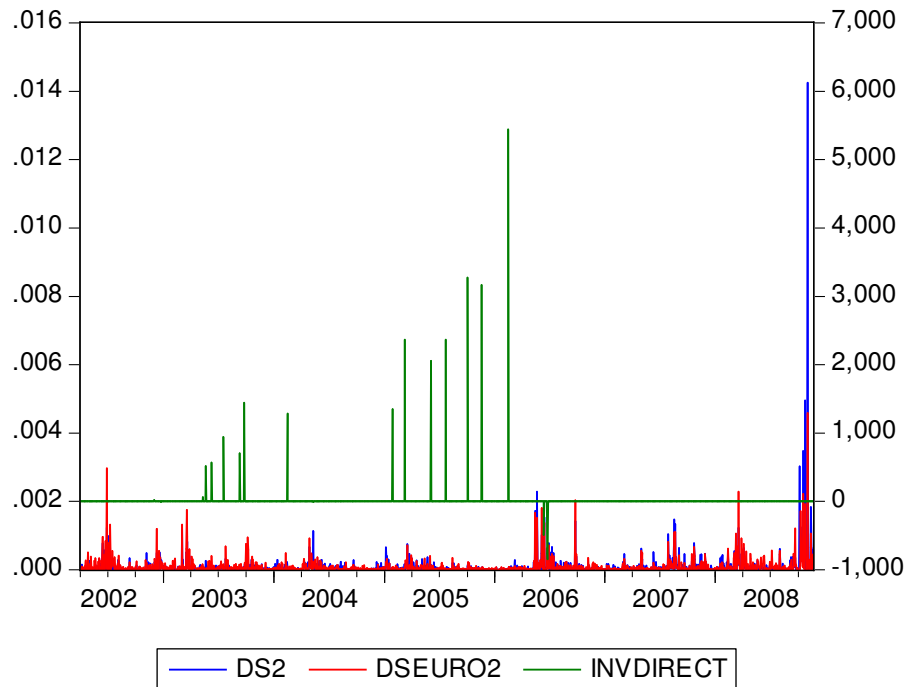


Figure 5.3: The behavior of inflation rate around its actual and smoothed inflation targets.

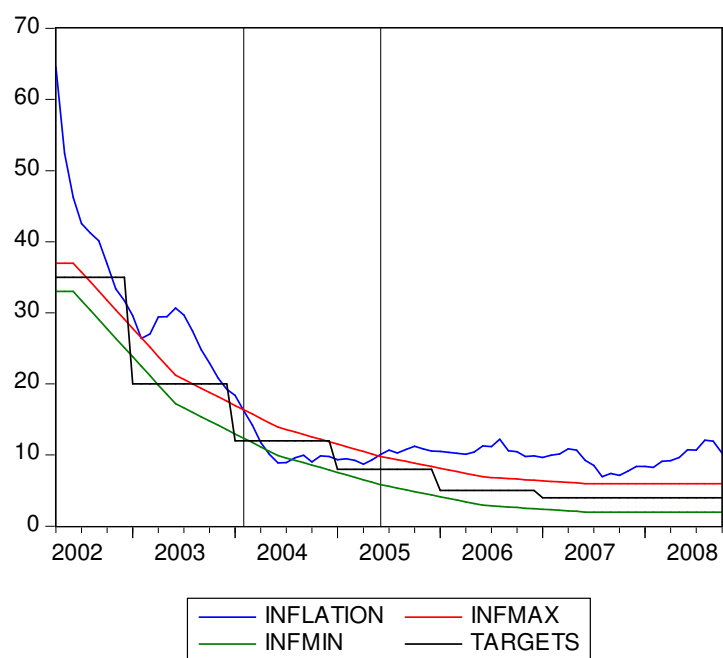


Figure 5.3A

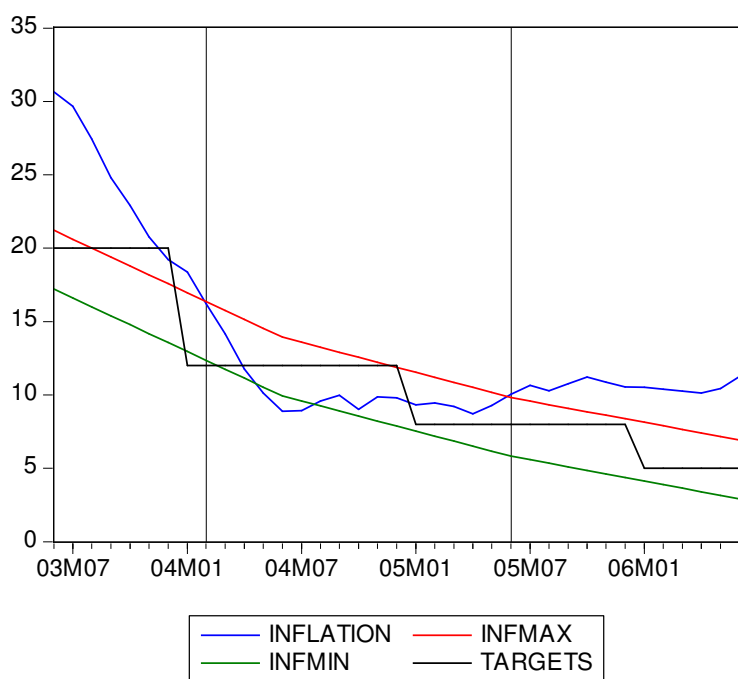
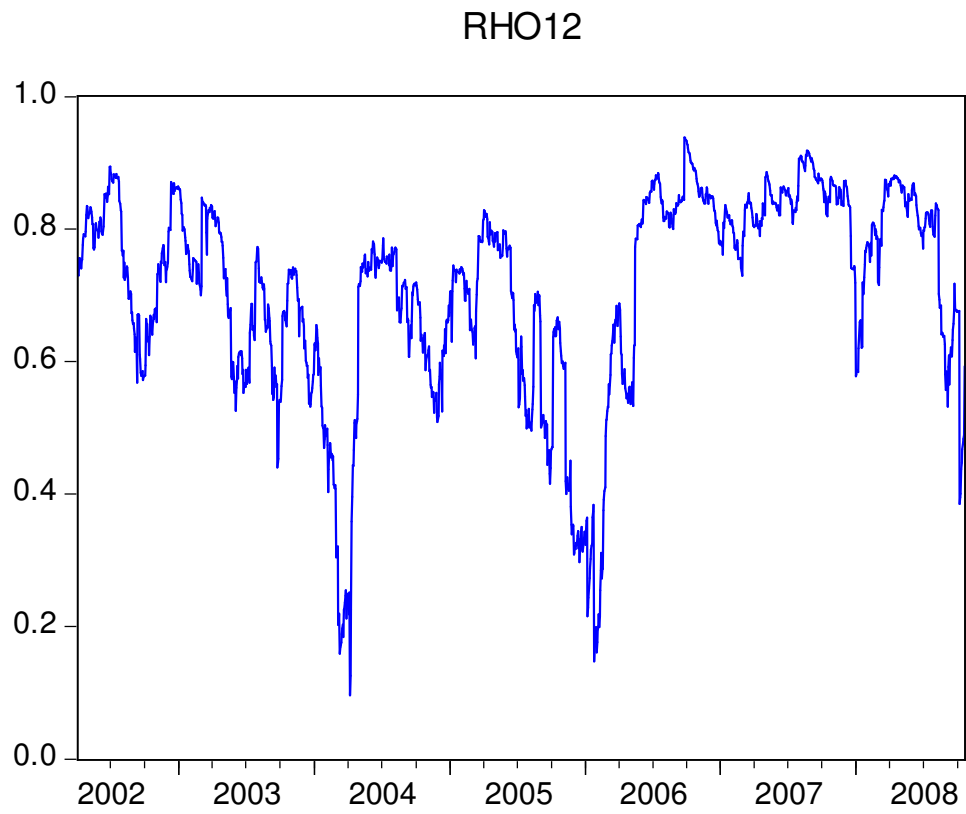


Figure 5.3B

Figure 5.4: Correlation between USD-EUR: April 1, 2002 –October 20, 2008



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5.8 Appendix - Inflation Targeting

Inflation targeting has been proven to be a durable monetary strategy, compared to others such as targeting monetary aggregates or using the exchange rate as a nominal anchor. After 1990 when New Zealand made history as the first country to adopt inflation targeting, more than 20 countries have become inflation targeting economies. Only two of them abandoned inflation targeting - Finland and Spain - not because of economic restriction, but because of joining the European Monetary Union, thereby they have to maintain the European Central Bank inflation targets.

Inflation targeting began to be adopted by emerging market economies with flexible exchange rates, such as Turkey, at the urging of the International Monetary Fund (IMF), based on the success of inflation targeting in developed countries in the early 1990s.

Inflation targeting is an economic policy in which the central bank estimates and makes public a projected, or “target”, inflation rate and then attempts to steer actual inflation towards the target through the use of interest rate changes and other monetary tools. According to Barry Eichengreen (2003), Inflation targeting is defined as a monetary policy operating with four elements: (1) An institutionalized commitment to price stability as the primary goal of monetary policy, which lends credibility to that objective and gives the central bank the independence needed to pursue it. (2) Mechanisms rendering the central bank accountable for attaining its monetary policy goals, making the pursuit of goals politically acceptable and impose costs on incompetent central banks. (3) Its forward-looking nature through public announcements of targets for inflation draws attention to future inflation and helps in improving transparency,

providing for better communication and helping economic agents understand the central bank objectives. (4) A policy of communicating to the public and the markets the rationale for decisions taken by the central bank.

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