Market Microstructure, Central Bank Intervention and Regime Switching in Exchange Rates: A Preliminary Analysis of Jamaica

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Abstract

In this paper we examine the volatility dynamics of the exchange rate when the central bank intervenes in the foreign exchange market of Jamaica. In particular, we try to determine whether the exchange rate evolves as a two-state markov process. We also investigate how intervention outcomes differ when the central bank intervenes when the market is in the relatively stable "liquidity trading" state compared to intervention when the market is in the more volatile "informed trading" state, in the spirit of the market microstructure approach to foreign exchange markets.

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1. Introduction

The exchange rate generated by the market is supposed to reflect underlying supply and demand conditions in flexible regimes with capital mobility or, put another way, it should reflect macroeconomic fundamentals in the *long term* (Rogoff 1996). The evidence has been, however, that exchange rates can depart significantly from the level implied by fundamentals in the *short term*, even in developed markets (Sarno and Taylor 2002). This reality creates a role for central bank intervention in the foreign exchange markets to keep the rate in line with the economic environment and the overall policy mix, to stabilize market expectations and to calm disorderly markets. Intervention can also complement efforts to put the macroeconomic policy mix on a sustainable part (Canales-Kriljenko, Guimaraes and Karacadag 2003).

The introduction of floating exchange rate regimes in the Caribbean brought with it the challenge of central bank intervention in the foreign exchange market. Most central bank operating these flexible regimes have intervened in the markets but over time there have been a growing pessimism about the effectiveness of intervention, especially in developed market economies (Schwartz 2000). In the case of developing countries, there is less pessimism since in these markets the intervention volumes are larger relative to total turnover in the market, the variety of regulations that restrict the size of the market, the information advantage of the central bank in the market and because in some countries the central bank may be the main conduit of foreign exchange to the market since the government is one of the main recipient of foreign exchange flows (Canales-Kriljenko, Guimaraes and Karacadag 2003). Intervention is also more important to developing countries because exchange rate stability is still a major policy objective given that the pass-through from exchange rate movements to inflation in higher in these markets compared to developed economies (Calvo and Reinhart 2002). The exposure of financial assets denominated in local currency to significant capital loss and their vulnerability to external shocks also lead to a high premium being placed on exchange rate stability in developing countries with flexible exchange rate regimes (Guimaraes and Karacadag 2004).

The empirical results of studies on the effectiveness of intervention indicates that there is mixed evidence that intervention can affect the level of the exchange rate Baille and Osterberg 1997, Dominguez and Frankel 1993, beine et. al. 2002). With respect to the variance of the exchange rate returns most studies find that volatility increases following interventions (Dominguez 1998, Baille and Humpage 1992). The methodological approaches investigating the effectiveness of intervention in the foreign exchange market are also very diverse including OLS regression of mean, risk premium and order flow equations (Dominguez and Frankel 1993a and b, Evans and Lyons 2002), event studies of intervention episodes (Fatum 2000, Fatum and Hutchison 1993a and b, Hutchison 2003), unified approach to monetary policy and foreign exchange market intervention using structural VAR (kim 2003) and the GARCH framework for evaluating the impact of intervention on the level as well as the volatility of the exchange rate, which is the most popular methodological approach since they solved many of the problems that plagued the other approaches (Dominguez 1998, Guimaraes and Karacadag 2004).

These models implicitly assume a linear relationship between intervention and the mean and variance of the exchange rate, which may not be relevant or appropriate in many cases. Indeed, many studies have argued that exchange rate behaviour generally evolve in a non-linear way (Sarno and Taylor 2002, Peel and Speight 1997). Many non-linear exchange rate models have emerged geared to better capture the data generating process in exchange rates. These include smooth transition autoregressive models (Sarantis 1999), non-parametric procedures (Diebold and Nason 1990), chaos models (Hsieh 1989) and markov switching models (Engle and Hamilton 1990).

Regime switching models are designed to capture changes in the mechanism that generates the data, with markov switching models better able to capture sharp transitions with the change in regime a random variable which has to be derived from the data (Caporale and Spagnolo 2004). Recently, markov switching regime models have increasingly been used to investigate the dynamics of intervention in the foreign exchange market (Beine et. al. 2003, Sager and Taylor 2004). These models, by allowing for more than one regime in evaluating the impact of intervention, tend to be superior to single regime type approaches in the sense that you can explicitly account for different outcomes to intervention depending on the state of the market. That is, intervention can have the desired impact when the intervention is done in an environment that sends unambiguous signals to agents in the market. For example, intervention in a high volatility environment may lower volatility but may raise it in a low volatility environment.

This notion of two regime fits well with the market microstructure approach to exchange rates. The market microstructure channel has also seen as increasingly important in explaining the intervention dynamics in foreign exchange markets. In particular, the markov switching framework by allowing for two or more regimes can more adequately capture the microstructural dynamics, that is, the liquidity trading regime where there is no informed trading and the market is characterized by exchange rate returns with relatively low mean and variance and the more volatile informed trading state characterized by exchange rate returns that have relatively higher mean and variance. In this framework central bank intervention works by emitting information to the market which modifies expectations and generates huge order flows. These orders in turn may tend to increase short-term volatility (Guimaraes and Karacadag 2004).

This paper therefore seeks to investigate the effectiveness of central bank intervention in the foreign exchange markets of selected countries in the Caribbean using the markov switching framework. In particular, following Hamilton (1994) we assume exchange rate dynamics follow a first-order markov switching process where there are two regimes, one in which the market is characterized by stable conditions (liquidity trading state) with a relatively small mean and variance and another characterized by volatility (informed trading state) with relatively higher mean and variance. We then extend this basic model by making the probability of switching from one regime to the next depend on exogenous variables, in this case central bank interventions (Filardo 1994, Diebold et.al. 1994). The paper is structured as follows; Section 2 reviews the literature on the effectiveness of central bank intervention in the foreign exchange market; Section 3 outlines the markov switching methodology, the data and the results of the attempts to measure the effectiveness of central bank intervention in the foreign exchange market and Section 5 concludes.

Section 2: Literature Review

Intervention Channels

Theoretically, interventions in the foreign exchange market can affect the exchange rate through a variety of channels that are not mutually exclusive. These include the signaling channel, the portfolio balance channel and the market microstructure channel all of which are based on their respective models of exchange rate determination. As its name implies, the signaling channel works by signaling to market participants the future stance of monetary policy. In this framework the exchange rate is treated as an asset price which is determined by the money supply. The intervention of the central bank works by moving market participants' expectations of what future monetary conditions are likely to be closer to the central banks expectations, even if the intervention is sterilized. This channel can only work effectively if the central bank has policy credibility since the lack of credibility may increase the likelihood of speculative attacks against the currency where market participants speculate against the defensive (usually) interventions of the central bank (Sarno and Taylor 2001). The fact that this channel works by changing perceptions means that it can only be effective if it is well publicized to strengthen the central bank's policy signal.

In developing countries where central banks' credibility may be weak, this channel may not be as effective as in developed market economies where the central bank has a long history of prudent macroeconomic management. As such, the magnitude of the interventions by central banks in these jurisdictions may have to use relatively larger intervention amounts to have an impact, in other words they would have to "buy credibility" for their signal of future monetary policy stance to be as effective as in a developed market context (Mussa 1981). On the other hand, central banks in developing countries enjoy certain benefits relative to their developed market counterparts such as information advantages over the market and the ability to intervene with larger amounts relative to the market given the size of turnover in these markets (Canales-Kriljenko, Guimaraes and Karacadag 2003). These factors may therefore give central banks in some developing countries an advantage over even some of their developed market counterparts in the use of the signaling channel, particularly where the size of the intervention amount is relative to the overall market is large given the small size of the market.

Under the portfolio balance channel, intervention work by generating rebalancing in terms of the currency composition of market participants' portfolios. This is based on the portfolio balance model of exchange rate determination (Sarno and Taylor 2001). The key assumptions of this framework are that domestic and foreign-currency denominated financial assets are imperfect substitutes and that investors are risk averse. Agents therefore demand a higher return on the asset whose outstanding stocks has increased to equalize risk-adjusted returns. Foreign exchange market interventions alter agents' relative supply of foreign and local securities and force rebalancing which generates changes in the exchange rate. In the case of un-sterilized interventions the corresponding contraction in the monetary base reinforces the impact of the intervention. The portfolio balance channel is thought to be more effective in developing countries where central bank credibility may be weak, where domestic and foreign currency debt are imperfect substitutes and where the central bank interventions are large relative to market turnover[1] (Canales-Kriljenko, Guimaraes and Karacadag 2003, Galati and Melick 2002).

The rapidly growing field on the microstructure of the foreign exchange market and the role of information asymmetry in financial markets has highlighted the existence of another channel through which intervention can affect the exchange rate. The microstructure approach to foreign exchange markets focus on order flow[2], information asymmetries, trading mechanisms, liquidity and the price discovery process (Lyons 2001, Seerattan 2004). Central bank intervention works in this framework by emitting information to the market which modifies expectations and generates huge order flows. These orders in turn may tend to increase short-term volatility (Guimaraes and Karacadag 2004). Central bank intervention is therefore a special form of order flow which causes agents to change their expectations on the future part of the exchange rate and net open positions that generates a cascade of order flows.

Intervention induced order flows may also increase volatility but this is dependant on the state of the market which depends on the amount of liquidity traders in the market and therefore the level of liquidity in the market. The relationship between volume and volatility in the microstructure setting is driven by agent heterogeneity and asymmetric information where informed traders gain at the expense of uninformed traders or customers who trade to eliminate exposure, especially when new information flow into the market. This is related to the mixture of distributions hypothesis (MDH) outlined by Easley and O'Hara (1992). In this framework volume and volatility in prices are related because both aggregates are driven by common dynamics as new information comes into the market during normal (liquidity trading) periods (Frankel and Froot 1990, Tauchen and Pitts 1983), however, during periods of market turmoil liquidity traders withdraw from the market and there is a negative relationship (Galati 2000). This implies that there are two types of regimes or market conditions in which central bank can intervene, a liquidity trading regime where most liquidity traders are involved and where the mean and variance of the exchange rate returns are relatively small and, an informed trading regime where many liquidity traders leave the market and where the mean and variance

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1 The converse is of course true in developed market economies where the volume of market turnover has been growing rapidly restricting the scope for intervention on the scale that would have an impact on the rate.

2 Order flow is transaction volumes that are *signed*. That is if you are the *active initiator* of a *sell* order this takes on a *negative sign* if you are the *active initiator* of a *buy* order it takes on a *positive sign*. The dealer in this case is on the *passive side* of the transactions. The important issue here is to identify the active initiator of the transaction. In this way, one can get an accurate picture of net buying or selling pressure in the market, where a negative sign and a positive sign indicates net selling and buying pressure respectively.

of exchange rate returns are relatively large. If the market is in the former regime central bank interventions would tend to increase volatility, as there is a positive relationship between volume and volatility in this regime. If the market is in the informed trading state central bank interventions will tend to reduce volatility, since there is a negative relationship between volume and volatility in this regime.

In terms of the actual evidence on the various channels through which intervention affects the exchange rate empirical studies have found mixed evidence in evidence for the portfolio balance and signaling channels. Under the signaling channel (Dominguez and Frankel 1993a) estimated the impact of intervention on current and future exchange rate (using survey data), and found that intervention had a significant impact on expectations, especially if interventions are publicized. In terms of the portfolio balance effect, Obstfeld (1990) finds that the portfolio balance effects are significant but small. As a matter of fact the evidence on the portfolio balance effect was until recently that this channel was of limited use in intervention (Edison 1993). The exception to this was Dominguez and Frankel (1993b) who found a significant and large portfolio effect using survey data to measure exchange rate expectations and risk premiums.

Recent research that uses the framework of market microstructure and order flow (Evens and Lyons 2000, 2002) found that intervention had a significant impact on exchange rates (US$/DM and US$/yen) through the portfolio balance channel, with a 1 billion US$ intervention having an immediate 0.44% impact on the exchange rate with a permanent impact at 0.35%. Dominguez (1999) utilizes an even study approach with intra-daily data to capture microstructure elements in a model of central bank intervention in the foreign exchange market. The results indicate that intervention has a significant impact on both the US$/DM and US$/yen rates. The results of this study also indicate that the effectiveness of central bank interventions depends on the state of the market at the time the central bank intervention becomes known in the market and the microstructure of the foreign exchange market could play a significant role in determining the effectiveness of the central bank's intervention in this market.

Estimation Methodologies

Studies that attempt to measure the effectiveness of intervention in the foreign exchange market have focused almost exclusively on developed market economies. This in most cases reflect primarily the availability of data and the fact that many models of central bank interventions assume deep and sophisticated markets which are usually found in developed economies. A range of methodological approaches has been used to evaluate the effectiveness of intervention in the foreign exchange market over the years. The approaches have become more sophisticated over the years as more detailed data became available and with advances in empirical techniques. Excellent reviews of these approaches are available in Edison (1993) for studies done in the 1980s and Sarno and Taylor (2001) for studies done in the 1990s. Lyons (2001) and Guimaraes and Karacadag (2004) also add value to the literature by reviewing studies that focus on the microstructure approach and other more recent developments respectively in the literature. The main methodological approaches include OLS regression of mean, risk premium and order flow equations (Dominguez and Frankel 1993a and b, Evans and Lyons 2002), event studies of intervention episodes (Fatum 2000, Fatum and Hutchison 1993a and b, Hutchison 2003), unified approach to monetary policy and foreign exchange market intervention using structural VAR (kim 2003) and the GARCH framework for evaluating the impact of intervention on the level as well as the volatility of the exchange rate (Dominguez 1998, Murray et. al 1997 and Guimaraes and Karacadag 2004).

The approaches of course all have their strengths and weaknesses. The regression analyses all suffer from simultaneity problems, that is, the regression of exchange rate over intervention fails to separate the degree to which intervention responds to exchange rates rather than exchange rates responding to intervention. As a result the coefficient estimates can have the wrong sign or overstate the impact of intervention on the exchange rate. Moreover, in many of these early studies there was no data on intervention amounts and intervention was proxied by changes in external reserve which is a very imprecise way of measuring intervention (Neely (2001).

Event study approaches defines an event window to include one or more intervention episodes together with non-intervention days (to ensure there is a balanced sample in the event window). Exchange rate changes that occur in this event window are then compared to the pre-event window. The strength of this approach is that it focuses on the intervention episodes which tend to be very irregular and clustered in time and is therefore useful for highlighting the short term dynamics of intervention. The most serious weakness of this approach is that it offers no perspective on the long term effects of intervention. Studies using this approach (Fatum 2000, Fatum and Hutchison 2003a and 2003b) find that sterilized intervention has a significant impact on the bi-lateral exchange rate level (US$/Japanese yen and US$/deutsche mark) regardless of whether it is secret or publicized. Another event study Edison et. al. (2003) finds that the Reserve Bank of Australia’s interventions had a modest impact on the US$/Australian dollar but that these interventions tended also to increase exchange rate volatility.

Attempts to overcome the simultaneity problem by using the vector autoregression framework (VAR) have recently been made in which the impact of monetary policy and intervention on the exchange rate and the degree to which intervention reacts to exchange rate changes (Kim 2003). The results from this study find that intervention is effective in the US over the period 1973-1996, suggest that intervention in the US was sterilized over this period and that intervention has an impact on the exchange rate beyond the short term. The identifying restrictions used in these models allow the exchange rate to have an impact on intervention and can also measure the impact of conventional monetary policy on the exchange rate. The problem with this approach of course is the validity of the identifying restrictions used to identify structural shocks.

Most recently attempts have been made to study the impact of intervention on the level exchange rate and the volatility of the rate in a unified framework using the generalized autoregressive conditional heteroskedascity (GARCH). Studies that utilized this approach (Dominquez 1998 and Guimaraes and Karacadag 2004) have found some evidence that intervention has an impact on the level of exchange rate, as well as on its volatility, but this is only interventions that involve sales of foreign exchange. This approach has the advantage that it is computationally simple and allows the simultaneous assessment of the impact of intervention on the exchange rate as well as its volatility. This is important since central banks not only have a target rate or band as its objective but is also interested in controlling volatility. GARCH models also provide good forecasts of volatility and have a proven track record in modeling the volatility of exchange rates (Anderson and Bollerslev 1998). Its weakness of course in using this framework to measure the impact of intervention on exchange rate and its volatility is that simultaneity problems could impact on the accuracy of the model parameters. Very importantly also, it assumes a linear relationship between intervention and the mean and variance of exchange rates which means it cannot account for different intervention outcomes in different environments.

Markov switching models can have also been used recently to study the effectiveness of intervention (Beine et al. 2003, Taylor 2004). These studies have been able to explain some of the puzzles in the dynamic of intervention, in particular the general finding of most studies in the GARCH framework that volatility tend to increase after intervention was called into question as they showed that intervention could decrease volatility if it was done in a high volatility environment. Intervention was also found to increase volatility if the market was in a low volatility state, a finding that corroborated earlier studies using GARCH type specifications. The fact that single regime models found increased volatility was attributed to the fact that low volatility conditions usually predominates in markets and as such single regime estimates (which are really an average of the low and high volatility regimes) would be biased in favour of the low regime outcome, which is, that volatility increased after intervention.

Section 3: Empirical Methodology

Markov Switching Framework

Let $y_t = 100 * Log(er / er_{t-1})$ where er denotes the number of units of the local currency per unit foreign currency. Consider a simple mean/variance-switching model:

$$y_t = u_{s_t} + \varepsilon_t \quad \text{where } \varepsilon_t \sim N\left(0, \sigma^2_{s_t}\right)$$

where μ_{s_t} and $\sigma^2_{s_t}$ are the state dependent mean and variance of y_t. The unobserved state variable s_t is expected to follow a two-state markov process that can take on the values of 1 for a stable regime or 2 for a volatile regime. That is, a stable "liquidity trading" state where μ_1 and σ^2_1 are relatively low and a volatile "informed trading" state where μ_2 and σ^2_2 are relatively high. If the transition probabilities are assumed to depend on lagged values of intervention I_{t-1}, then the transition probabilities can be defined as:

$$p_t^{11} = \Pr ob(s_t = 1 / s_{t-1} = 1, I_{t-1}),$$
$$p_t^{22} = \Pr ob(s_t = 2 / s_{t-1} = 2, I_{t-1}).$$

Clearly $p_t^{12} = (1 - p_t^{11}(I_{t-1}))$ and $p_t^{21} = (1 - p_t^{22}(I_{t-1}))$

The functions for the time varying transition probabilities (TVTP) can therefore be specified as follows:

$$p_t^{11}(I_{t-1}) = \frac{\exp\{\alpha_0 + \alpha_1 I_{t-1}\}}{1 + \exp\{\alpha_0 + \alpha_1 I_{t-1}\}},$$

$$p_t^{22}(I_{t-1}) = \frac{\exp\{\beta_0 + \beta_1 I_{t-1}\}}{1 + \exp\{\beta_0 + \beta_1 I_{t-1}\}}.$$

This time varying specification of course collapses to the fixed transition probability (FTP) model if $\alpha_1 = \beta_1 = 0$. Under the market microstructure framework we would expect that intervention would decrease the probability of remaining in the low state (p_t^{11}) since intervention in the stable state is expected to increase volatility. Likewise intervention is expected to decrease the probability of remaining in the high state (p_t^{22}) since intervention when the market is in a volatile state helps to reduce volatility. This implies that $\alpha_1 < 0$ and/or $\beta_1 < 0$.

For comparison the fixed transition probability (FTP) model is also estimated to serve as a benchmark for the time varying transition probability (TVTP) model. The maximum likelihood estimates of the parameters of these models are estimated using the Berndt, Hall, Hall and Hausman (BHHH) algorithm.

Data and Descriptive Statistics

This study covers daily data on the foreign exchange market and intervention over the period October 1, 2001 to September 28, 2006, generating a 1250 observation. The study utilizes daily data on central bank intervention in terms of both buying and selling operations. The data set used also included daily data on the weighted average buying rate and weighted average selling rate. The exchange rate (*er*) is the midpoint between the buying and selling rate.

Over the period covered by this study the Bank of Jamaica intervened on approximately 257 days or 21% of the time the period. The intervention operations amounts were generally relatively small (up to US$26 million per day) and intervention volumes did not change much in the short term which helped to develop stable expectations in the market. The vast majority of the intervention operations were selling operations indicating the pressures on the market was generally on the down side.

Table 1 presents descriptive statistics for the log first difference of the exchange rate and daily intervention volume. The results of the unit root tests indicate that all variables used in the analysis are stationary at levels. The descriptive statistics also show that the variables display many of the idiosyncratic features of financial time series such as fat tails and skewness, as well as volatility clustering.

Table 1: Descriptive Statistics for Jamaica

Variables	Descriptive Statistics				
	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera
Log 1st Diff. ER	0.039754	0.536339	-2.754728	85.67822	213991.7 0.00
Inter. Selling	2.598398	5.036210	1.721265	4.688515	458.8279 0.00

Source: Bank of Jamaica and authors calculation.
Note: Sample size 1250.

Estimation Results

The parameter estimates with standard errors and values of the likelihood function are presented in Table 2.

Table 2: Estimation Results

Model	Parameters and Test Statistics									
	μ_1	μ_2	σ_1	σ_2	α_0	α_1	β_0	B_1	p^{11}	P^{22}	LogLk
FTP	0.014 (4.7)[1]	0.183 (1.3)	0.103 (61.1)[1]	1.396 (34.1)[1]	7.645 (3.2)[1]		2.584 (41.1)[1]		0.99	0.93	698.5
TVTP	0.016 (498.5)[1]	0.144 (1.2)	0.101 (57.8)[1]	1.368 (35.6)[1]	5.234 (5.7)[1]	-0.339 (-3.2)[1]	3.77 (14.8)[1]	-0.56 (-0.4)	0.99	0.97	693.4

Notes: Significance levels of 1%, 5% and 10% is indicated by 1, 2 and 3 respectively.
The t statistics of the maximum likelihood estimates are in parentheses.
Loglk refers to log-likelihood at maximum.

Lagged values of intervention are used instead of contemporaneous intervention to deal with the simultaneity bias inherent in studies of this nature as in Beine et. al.(2003). It is clear from the results that the FTP and TVTP models both do a good job of identifying the tranquil and volatile regimes. It is also apparent that the models capture volatility regime rather than mean regimes as is norm in studies of exchange rates using regime switching models. The variance and the intercept in the volatile regime are substantially higher than that in the tranquil regime. The estimates of the mean and variance are also fairly similar across the FTP and the TVTP models which suggest that the specification is robust.

The probabilities for the FTP and TVTP models indicate that the low volatility regime is more persistent, with the probability of staying in that regime being higher than staying in the high regime. This reflects the persistence or volatility clustering normally found in financial time series. It appears therefore that the two regime framework is appropriate for studying the dynamics of intervention.

The TVTP model allows us to assess the impact of intervention when the market is tranquil and when it is volatile. It therefore allows us to account explicitly for the initial state of the market. B_1 is the parameter which measures the impact of intervention on the transition probability in the high regime while α_1 measures the impact in the low regime. According to the microstructure framework, interventions in the high regime are likely to be more successful since it is usually clear to the market the policy direction the central bank needs to take in the market. Intervention in the low regime is, however, problematic since the signal from the central bank is not as unambiguous. The results indicate that B_1 has the correct sign but is insignificant. In terms of the tranquil regime, α_1 is negative and significant indicating that interventions decrease the probability of staying in the low regime. This means that intervention in this regime is destabilizing.

4. Conclusions and Policy Implications

The results of our attempt to measure the effectiveness of central bank intervention in a two regime model has generated a number of conclusions that potentially have serious implications for intervention policy in the foreign exchange markets. The results indicate that intervention sales are not really effective in helping to move the market when the market is in a volatile state and can even generate a perverse result of increasing volatility if the intervention operations are done in a tranquil period (to supply foreign exchange to the market).

The market microstructure literature also provides a framework to explain why this may occur. In this regard policy tools designed to build confidence, stabilize expectations and harmonize the policy mix may be more relevant and effective. In particular, an intervention in a tranquil period inevitable leads to some volatility, at least in the short run, as agents in the market readjust their positions and the resultant trades impact on prices.

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