Spreads in the Jamaican Foreign Exchange Market during Tranquil and Volatile Periods

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Annual Monetary Studies Conference

November 9-12, 2010

DRAFT: Not for Quotation

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Abstract

Bid-ask spreads in foreign exchange markets have profound effects on agents especially those in developing markets where spreads tend to be higher. High spreads can in fact negatively affect the willingness of agents to trade in the market, which in turn, hampers the liquidity, efficiency and development of the market. Additionally, since spreads appear to have different dynamics in volatile and tranquil periods in the market it would be interesting to decompose the spread in these different periods since the literature on the Caribbean has generally not reviewed this issue explicitly. In this context, this paper looks at the determinants of bid-ask spreads and the factors that drive the spread in the foreign exchange market in Jamaica, especially the links between trading volume and spreads during volatile and tranquil periods.

1.0 Introduction

At the beginning of the 1990s a number of Caribbean countries sought to liberalise their foreign exchange markets[1]. In Jamaica this involved the elimination of exchange controls, the removal of restrictions on both the current and capital transactions, the widening of the number of market players in the foreign exchange markets (brokers (inter-dealers), dealers and cambios) and the move from a fixed to a floating exchange rate regime. The reform of the foreign exchange market represented a fundamental change in the way the Jamaican foreign exchange market was organized. It meant that the way agents in the foreign exchange market behaved was now driven more by considerations such as the effective demand and supply of foreign exchange and less by rationing and proscribed spreads. Very importantly also the market was now increasingly driven by competition for the sale and purchase of foreign exchange which implies that bid-ask spreads should fall. These developments raise issues that center on the microstructure of this market how this impacts on the efficiency and liquidity of the market.

The issues that became important after the liberalisation of the Jamaican foreign exchange market is best addressed in the context of the market microstructure literature. These issues include trading infrastructure, decentralisation, the heterogeneity of agents in the market, the size and liquidity of the market, the efficiency of the clearing mechanism, the relationship between the spot and derivative market, how information flows affect the functioning of the market and, very importantly, how micro-structural features affect the bid-ask spreads in the market and the impact of these factors on the pricing efficiency, liquidity and stability of the market.

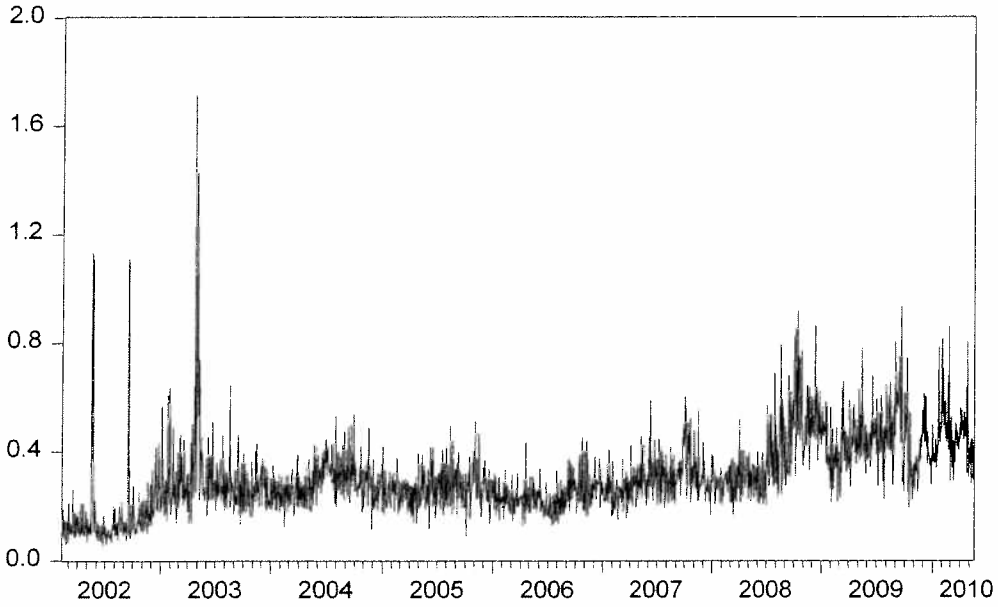
The size of foreign exchange markets in the Caribbean countries and the importance this market to the efficiency of economies in the region warrants a closer look at these markets. In particular, the bid-ask spreads in these markets could be considered an indicator of the transactional efficiency of the market which have a profound impact on returns to agents in the financial market and the economy in general. High spreads can in fact negatively affect the willingness of agents to trade in the market, which in turn, hampers the liquidity, efficiency and development of the market. High spreads can also signal increased risk averseness in foreign markets which can be a precursor to financial crisis and as such could act as an early warning of impending problems.

Additionally, foreign exchange markets especially in emerging markets tend to experience episodic volatility, that is, there are periods of high volatility preceding and following normal periods of tranquility. The functioning of foreign exchange markets, especially the response of agents in the market to developments such as shocks and various policy measures appear to be very different during these different episodes (Seerattan and Spagnolo, 2009). The notion of two regimes also fits well with the market microstructure approach to exchange rates which has been increasingly seen as important in explaining the dynamics in foreign exchange markets (Evens and Lyons, 2002). In particular, there is a liquidity trading regime where uninformed or liquidity traders dominate trading and the market is characterized by exchange rate returns with relatively low mean and variance and low bid-ask spreads. In contrast, the more volatile informed trading state where informed traders such as market makers or central banks are active in the market is

[1] Guyana and Jamaica started the process of liberalization in 1990 while Trinidad and Tobago started its programme of liberalization a little later in 1993.

characterized by exchange rate returns that have relatively higher mean and variance, as well as, high bid-ask spreads. In these conditions, the response of agents to shocks and policy implementation may be very different because their risk averseness and expectations for the behavior of the market may be different in these two periods. Policymakers should therefore be interested in this issue because it complicates the measurement of the impact of policy implementation and can negatively affect the degree of effectiveness of policy instruments used in these markets. Moreover, a direct result of this observed regularity of two regimes in foreign exchange markets is that single equation estimates of the dynamics in these markets tend to be biased. Spreads have generally increased during periods of volatility in the foreign markets in the Caribbean and this was indeed the fact in Jamaica post 2008. In fact, there appears to be two regimes with lower spreads prior to 2008 and higher spreads thereafter, validating to some extent the idea that that spreads in the Jamaican foreign exchange market fit into a two-state process (see Figure 1). In spite of these facts, however, the study of the bid ask spreads in the foreign exchange market has not received the attention it deserves in the Caribbean.

Figure 1: Spreads in the Jamaican Foreign Exchange Market



In this context, this paper, using a Markov switching framework, attempts to determine whether the factors driving the spread in the Jamaican foreign exchange market have a differential impact during tranquil and volatile periods. The spread determination process is allowed to switch between two distributions, one corresponding to a relatively stable period and the other to a more volatile period. The advantage of such an approach is that it separates periods of low from periods of high volatility allowing the probabilistic structure of the transition from one regime to the next to be a function of variables driving the spread. Single regime models of the bid-ask spread in the foreign exchange market is likely to be dominated by inferences flowing from tranquil regime market conditions since this state usually predominates in markets and as such single regime estimates of these models (which are an average of the low and high volatility regimes) would be biased in favour of the low regime outcome. The Markov switching

framework by allowing for two or more regimes can therefore more adequately capture the micro-structural dynamics mentioned above.

The paper is structured as follows. Section 2 reviews the theory of market microstructure especially as it pertains to the determinants of the bid-ask spreads. Section 3 reviews the evolution of the microstructure of the Jamaican foreign exchange market. Section 4 presents some stylized facts on bid-ask spreads in the Jamaican foreign exchange market, as well as, the empirical results of the Markov Switching models of the spreads and, Section 5 concludes.

2.0 Market Microstructure Theory and the Bid-Ask Spreads in the Foreign Exchange Market

Microstructure therefore focuses on the mechanics of trading and how these affect the price formation process. The term market microstructure was first used by Garman (1976) to describe the transactions based nature of realistic exchange processes. The two main strands of the market microstructure literature include the inventory based and information economics based models. Much of the literature in both strands focuses on the problem facing intermediaries of determining market-clearing prices. The inventory-based models essentially looks at how price forms based on order flow and the market clearing protocol. There are three distinct approaches to inventory based models. The first strand of this research started by Garman (1976) is based on the impact order flow has on trading prices. The second strand looks at the dealer optimization problem (Stoll (1978), Ho and Stoll (1981)). The third strand is based on the impact multiple dealers has on liquidity and prices (Cohen, Maier, Schwartz and Whitcomb (1981)). The single unifying factor in these approaches is the uncertainty in order flow, which result in inventory and execution problems. This approach therefore boils down to how prices are set by dealers in different settings and how these prices change as we introduce different types of uncertainties.

An alternative approach to the market-clearing price is based on the impact of asymmetric information (Bagehot, 1971). This approach is based on the information dichotomy between informed and liquidity/uninformed traders (Copeland and Galai 1983); models where the superior information of informed traders mean that their trades could signal the underlying value of the asset and affect the behavior of prices and how prices respond to information flows (Glosten and Milgrom 1985, Easley and O'Hara 1987); models that looks at the strategic behaviour of traders that incorporate expectations about market-makers' pricing strategy (Kayle 1985); and models which look at the strategic behaviour of uninformed traders an prices (Admati and Pfleiderer 1988). The information-based approach has helped to improve our understanding of markets by focusing on the information implicit in market data and the Bayesian learning process that translates this information into prices. The information-based approach is especially useful because they allow for the examination of market dynamics and strategic behavior from informed and uninformed traders.

Market microstructure theory decomposes the bid-ask spread into three components: The cost of dealer services related to order processing, the cost of information asymmetries to market makers (adverse selection) and the cost of holding inventory. In each of these cases trading volume plays a critical role.

Order processing microstructure models often assume that there is fixed cost in market making, these costs would for example be due to subscriptions to electronic information and trading systems, the costs of acquiring or training suitable personnel and and the costs associated with meeting certain prudential requirements. Demsetz (1968) actually characterized this as the costs of providing "predictable immediacy" for which agents in the market are willing to pay. The ability to execute either buy or sell transactions immediately suggests that this is inextricable linked to liquidity. In a busy market, a constant stream of agents willing to buy or sell creates 'predictable immediacy" or enhances the liquidity of the market as a by-product of their activities. Market makers by offering to execute transactions at prices (bid and ask prices) on both sides (buying or selling) facilitate this process and the fixed costs related to providing these services are reflected in the bid-ask spreads in the market. The level of fixed cost of market making that can be extracted from agents is, however, constrained by competition in the foreign exchange market. Competition from other market makers and dealers tend to force market makers to lower their spreads to avoid losing business. Hence fixed costs of market maker services and the level of competition (number of market makers and dealers) would tend to drive spreads in the market (Stoll 1978, Cohen, Maier, Schwartz and Whitcomb 1981, Black 1991). These costs have fallen drastically with the advent of electronic trading platforms, better information and greater competition in foreign exchange markets.

Information costs models are based on the arrival of new information or the presence of agents with better information than market makers and, the impact these factors have on the bid-ask spread. Bagehot (1971) was the first to examine bid-ask spreads in the framework of information-based models. His model was based on the existence of two types of agents in the market: liquidity traders (uninformed agents) who were willing to pay the costs of "predictable immediacy" and informed agents who possess inside information and can speculate at the expense of the market maker. The market maker cannot distinguish between these two types of agents and must therefore charge everyone a wider spread to compensate from losses arising from trading with the informed agents. This adverse selection type model basically posits that the arrival of new information is positively related to bid-ask spreads (Copeland and Galai 1983, Glosten and Milgrom 1985, Kyle 1985). The problem with this approach is that empirical estimation requires data on the rate of information arrival and the proportion of informed trading relative to overall trading, which are both unobservable. This problem has been addressed in the literature by using unpredictable foreign exchange trading volume as a proxy for information arrival (Easley and O'Hara 1992, Jorion 1996 and Hartmann 1998).

The bid-ask spread is also driven by inventory costs considerations. Barnea and Logue (1975) were the first to introduce the notion of inventory carrying costs which view market makers not only as providers of liquidity services but also as optimizers of their own portfolios. In this framework they try to choose the risk/return dynamics of their portfolios in such a way as to maximize their utility. Holding an inventory of foreign exchange may be risky because the holder is exposed to the market risk of depreciation in the value of the asset and because there are costs associated with holding inventory such as interest rate differentials and trading costs (Bessembinder 1994). The bid-ask spread is therefore regarded as a the premium for market makers as compensation for the risk they take on and the potential costs inherent in holding an open position in foreign exchange. The spread is therefore expected to increase with market risk and inventory holding costs.

In the simplest versions of the inventory costs model, the optimal inventory is zero and a constant spread is shifted up or down to equalize the probability of receiving a purchase order with the probability of receiving a sale order. The result is that the expected change in inventory is always equal to zero and inventory levels follow a random walk. An undesirable characteristic of the random walk model of inventory is that it inevitable leads to the bankruptcy of the market maker. This is so because capitalization requirements impose upper and lower bounds on inventories and since inventories follow a random walk, market makers will reach these bounds in a finite number of trades (Ross 1983).

The more advanced dynamic inventory optimization models deals with this weakness by arguing that market makers optimize their bid-ask prices over time in the face of order flow which follow a random walk, by adjusting bid and ask prices downwards (upwards) and increasing the spread when a positive (negative) inventory is accumulated (Stoll 1978, Amihud and Mendelson 1980, Sirri 1989). In these models, larger transaction sizes will push the market maker further away from his desired portfolio and thus widen the spread. On the other hand, if order flow is expected to come in many small independent orders, then by the scale effects increased (predictable) order flow would tend to decrease spreads. This implies therefore that unpredictable order flow increase spreads but predictable order flow decrease spreads.

Market makers (in most cases commercial banks) in the foreign market take positions in foreign currencies for a range of business activities in which they are engaged including loans to business customers and market making in derivatives. Since currency positions are taken for reasons other than market making, the identification of inventory carrying costs relevant to the provision of immediacy in the spot foreign exchange market is complicated. A bank can promise to provide immediacy to its clients by holding a liquid inventory of currencies and/or by purchasing liquidity from other market participants. Holding a currency imposes opportunity costs and the risk of depreciation in value. Opportunity costs arise because the interest rate which can be earned on highly liquid holdings of foreign currency is less than the rate that can be earned on holdings of less liquid securities. The alternative to maintaining liquid holdings of foreign currencies is to purchase these holding from other market participants or from correspondent banks for which there are costs (Bessembinder 1994). In the first case, market makers have to bid on the open market for the funds, the costs of which are proxied by the bid ask prices of the other market makers. In the second case, the costs are in the form of interest rate and closing costs. Moreover, these costs may increase over non-trading intervals such as weekends and public holidays because the opportunity costs increases as the inventory is held for more days and the risk of depreciation is greater since the bank cannot unbundle positions during these periods since the market is not open.

It is clear from the above review of the literature that the order processing costs, information asymmetry cost and inventory carryings costs strands of the market microstructure literature on the determinants of the bid-ask spread are inter-related. For example, in some cases it is very difficult to distinguish between order processing costs and inventory carrying costs. In the case of information asymmetry costs, spreads are likely to increase as new information come into the marketplace but the volatility that this causes also impact on inventory carrying costs. 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 positively related because both aggregates are driven by common dynamics as new information comes into the market during normal periods (Frankel and Froot 1990, Tauchen and Pitts 1983). However, during periods of market turmoil traders withdraw from the market and there is a negative relationship (Galati 2000). The greater volatility in the run up to non-trading periods is also driven by the greater sensitivity of prices to liquidity before non-trading periods as traders try to reduce their exposure to avoid high inventory cost over these periods (Lyons 1995).

Consolidating all the strands of the literature one can therefore argue that the main determinants of the spread include price risk proxied by the conditional volatility of the exchange rate, predictable volume and information arrivals sometimes proxied by unpredictable volume. Based on the theoretical review in section 2 it is clear that the critical determinants of the spread in the short term include trading volumes, forecasts of price risk (exchange rate risk) and the flow of new information into the market. One can therefore write the following model of bid-ask spread determination in the foreign exchange market as

$$sp=f(\sigma_P,x,I) \qquad (1)$$

where sp is the bid-ask spread, σ^P is predictable volatility of the exchange rate (a forecast of price risk), x is trading volume and I is the flow of new information into the market. The theoretical foundations of market microstructure posits that the $\partial f/\partial \sigma^P > 0$, $\partial f/\partial I > 0$ and that $\partial f/\partial x < 0$. The above positive relationship between bid-ask spreads and the forecast of price risk is driven by the need of market makers to cover for the possibility of the decline in asset value by charging a higher spread. The positive relationship between spreads and new information flows is related to the possibility of loss by the market maker from trading with better informed agents, the market makers therefore charges all agents a higher spread to cover these losses. The negative relationship between spreads and the expected or normal liquidity is driven by economies of scale in market making which enables the market maker to charge lower spreads and still increase his margin through volume (Easley and O'Hara 1992).

The problem with the above specification is that I is not observable. Many studies have dealt with this dilemma by leveraging the relationship between volumes and volatility in the mixture of distributions framework and proxied information arrivals as unpredictable volumes. They have done this by fitting ARIMA models of volume and using the forecasted series as predictable volumes and the residuals as unpredictable volumes (Bessembinder 1994, Hartmann 1999). This approach is data driven and in markets which are subject to high volatility these ARIMA models may be subject to huge errors and biases. In this study we therefore leverage the observation by some authors which view the central bank as an informed trader in the market in the context of direct central bank intervention in the market (Peiers 1997, Pasquariello 2002, and Payne 2003). In the context of Jamaica, the Central Bank may be viewed as the most important informed trader and a strong case could be made that its trades represent strong information

signals in the market given its critical role in this market and we therefore proxy information arrivals I in equation 1 by daily central bank intervention in the foreign exchange market. The specification for spreads represented by equation 1 now can be estimated as all the components are observable.

3.0 The Microstructure of the Foreign Exchange Markets in Jamaica

The basic microstructure of foreign exchange markets consists of a number of core elements. These include the major players in the market, the mechanisms for trading and the regulatory and management systems in place for the smooth operation of the market. The major players in the foreign exchange market include dealers who facilitate trade and who may double as market makers, central banks which structure the policy regime for the market and the public. The public includes individuals but also corporations and speculators that drive demand and supply in the markets. The mechanisms for trading are critically important to the operation of the market. The trading mechanism could be based on auctions or inter-bank markets, as well as on traditional and non-traditional price discovery mechanisms. Last, but by no means least, is the regulatory and management systems on which the market is based. These include systems such as internal risk management systems, the exchange rate regime and prudential standards on open positions. The market microstructure elements of the foreign exchange market in Jamaica are outlined below.

Jamaica liberalised its foreign exchange market substantially during the 1990s. In this period, exchange controls were eliminated in 1990, the exchange rate regime changed from a fixed to a floating regime in 1991 and the number of dealers increased in 1994 as cambios and merchant banks were included. The institutional structure of the market in 2001 consisted of 15 authorised dealers and 136 cambios (which include about 88 bureaux de change). The non-financial firms and individuals which underlie the demand and supply conditions in the market is fairly heterogeneous and the supply of foreign exchange is fairly evenly distributed among sources such as export of goods and services, remittances, direct investment flows, private portfolio flows and official loan inflows. There are some dominant players in the market who can have a significant impact on the market from the supply side. The Jamaican dollar is not a vehicle currency so shortages of foreign currencies cannot be filled by selling Jamaican dollars to foreign banks. If a particular market-making bank is short it must either enter the local market to bid for supplies or it must borrow foreign currency from a foreign correspondent bank.

Cambios are only permitted to buy and sell foreign exchange and there are limits of US$250,000 on cheques and drafts and US$10, 000 on cash transactions. These combios are licensed by and monitored by the Bank of Jamaica (BOJ) to ensure compliance with the BOJ's operational guidelines and the Money laundering Act. Cambios are also required to report to the Director of Public Prosecution any cash transaction greater than or equal to US$8,000. Cambios currently sell 5% of their gross daily purchases of foreign exchange to the BOJ by mutual agreement. The major difference between cambios and authorised dealers is that they are not permitted to grant loans or take deposits. There are approximately 88 bureaux de change in operation which exist primarily to facilitate the exchange of currency for hotel guests. These institutions sell 10% of their gross daily purchases to the BOJ.

The authorised dealers in the market consist of all commercial banks, merchant banks and the two largest building societies. These authorised dealers are engaged in all types of foreign exchange transactions, they buy and sell, intermediate and make a market in foreign exchange by posting bid and ask quotes for foreign exchange. No limits are placed on the value of transactions, however, under the Money laundering Act, these financial institutions are required to report to the Director of Public Prosecution any cash transaction at or above US$50,000. The authorised dealers, though not statutory bound, have also agreed to sell 5% of their daily gross purchases of foreign exchange to the BOJ. These institutions are monitored and regulated by the BOJ under the Financial Institutions Act and the Building Societies Act.

The commercial banks also make up the inter-bank market on which the system is based and which facilitates price discovery and trading. The information transmission mechanisms in the market were relatively unsophisticated consisting of informal contacts and telephone calls until 2001 when EGATE an electronic bulletin board was set up by the BOJ. Authorised dealers lists two-way bid and ask quotations which are posted on the system so price discovery is much more efficient. Dealers now have better information on prices so trading is done on a more informed basis. The system is based on an inter-bank market where indicative bid and ask quotes are set and where demand and supply and the intervention strategy of the BOJ determines prices. When spot transactions (transactions settled within 2 business days) between dealers and the public and between the two categories of dealers are executed different spot rates are realised. The official exchange rate is computed as a weighted average of all trades. A forward market for foreign exchange to hedge foreign exchange rate risk has also been in existence in Jamaica for several years but the volume of transaction and price data is not readily available.

The BOJ undertakes market surveillance, collects and disseminated information on the foreign exchange market and intervenes directly in the market to control volatility. It information dissemination function is an important part of the market microstructure as it helps the price discovery process in the market, especially since private mechanisms for price discovery are not well developed. The BOJ intervenes in the market directly to prevent excessive price (exchange rate) fluctuations by selling (buying) foreign exchange through authorised dealers and cambios since these institutions dominate the market and can affect liquidity condition and the rate very quickly. The rate at which the bank intervenes usually mirrors the weighted average buying or selling rates in the market.

4.0 Empirical Methodology: The Short-Term Determinants of Bid-Ask Spreads in the Jamaican Foreign Exchange Market

4.1 Data Dynamics

This study focuses on the short-term dynamics of bid-ask spreads in the foreign exchange market of Jamaica. The data used in this study comprise daily data on the bid-ask spread measured as the difference between the daily weighted average bid and ask prices for United States dollars $sp_t=ask_t-bid_t$ and exchange rate returns which are defined as $ger_t=100*log(er_t/er_{t-1})$ where er_t denotes the exchange rate which is measured as the midpoint between the bid and ask prices for United states dollars. The data on exchange rate returns are used to generate estimates of the

conditional variance of exchange rate returns using a GARCH (1,1) model which is then used as a proxy for market price risk. The data used also includes daily changes in trading volumes, with trading volume measured as the sum of daily sales and purchases of US dollars and Central Bank intervention measured as daily purchases or sales of US dollars by the BOJ. Daily changes in trading volume is used as a proxy for daily increases or decreases in market liquidity while central bank intervention is used as a proxy for informed trading in the market which signals new information arrival in the market. The data covers the period February 7, 2002 to September 27, 2010 resulting in 2158 observations after non-trading days such as weekends and public holidays were eliminated. The descriptive statistics presented in Table 1 indicate that these variables exhibit the usual properties of financial time series such as volatility clustering, non-normality, skewness and excess kurtosis.

Table 1: Descriptive Statistics

Statistic	Exchange Rate Returns	Intervention	Total Volume	Spread
Mean	0.027456	-2.582491	72.74076	0.308870
Median	0.012036	0.000000	69.62649	0.282400
Maximum	3.084906	40.97000	176.3169	1.712600
Minimum	-6.827581	-34.60347	14.77025	0.055400
Std. Dev.	0.274156	6.203787	22.26193	0.143725
Skewness	-7.107067	-2.047823	0.688269	2.064688
Kurtosis	214.0726	8.476360	3.371172	13.17304
Jarque-Bera	4022236.	4202.990	182.6823	10833.76
Probability	0.000000	0.000000	0.000000	0.000000
Observations	2157	2157	2157	2157

4.2 Empirical Methodology

Studies that attempt to model the bid-ask spreads in foreign exchange markets implicitly assume a linear relationship between spreads and its determinants such as price volatility, volume and information arrivals. This may not be relevant or appropriate in practice in studies on foreign exchange markets as many studies have argued that price behaviour in this market generally evolves in a non-linear way (Sarno and Taylor, 2001). A number of non-linear exchange rate models have therefore emerged to better capture the exchange rates data generating process. These include, non-parametric procedures (Diebold and Nason, 1990), chaos models (Hsieh, 1991) and regime switching models such as smooth transition autoregressive (STAR) models (Sarantis, 1999) and Markov switching (MS) models (Engle and Hamilton, 1990).

Regime switching models in particular 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). Markov Switching models can therefore better capture the sharp changes in market regimes that sometimes occur and seem more appropriate than STAR models in this context. These models, by allowing for more than one regime in the evaluating the determinants of spreads, would tend to be superior to single regime type approaches in the sense that they can

explicitly account for different outcomes depending on the state of the market. It therefore allows us to account explicitly for the initial state of the market, a critical factor determining the accuracy of the spread decompositions. This corrects a methodological flaw in studies which use linear formulations, that is, these frameworks do not allow for this duality and therefore cannot capture the complex dynamics in foreign exchange markets.

The notion of two regimes also fits well with the market microstructure approach to exchange rates. The market microstructure channel has also been increasingly seen as important in explaining the dynamics in foreign exchange markets (Evens and Lyons, 2002). In particular, the Markov switching framework can more adequately capture the micro-structural dynamics of a liquidity trading regime where uninformed or liquidity traders dominate trading and the market is characterized by exchange rate returns with relatively low mean, variance and spreads. The more volatile informed trading state, where informed traders such as market makers or central banks are active in the market, is characterized by exchange rate returns that have relatively higher mean, variance and spreads. The dynamics of spread behavior and determination in these two market regimes is likely to create situations in which different types of agents predominate in each market regime and these agents are likely to respond differently to policy initiatives and shocks in the market.

4.3 The Models

This section describes the models used. We first present a simple linear model of the spread which serves as a benchmark for the regime switching models. The fixed transition Markov switching (FTP) model is then introduced and finally the extension to the time varying Markov switching (TVTP) model is presented where the determinants of the spread are considered.

4.3.1 The Linear Benchmark Model

A simple linear model of the spread in the following form is used for comparative purposes:

$$sp_t=\alpha+\beta PR_t+\delta I_t+\phi\Delta V_t+\varepsilon_t, \qquad \varepsilon_t\sim N(0,\sigma^2), \quad t\in T \tag{2}$$

Where PR is price risk (conditional variance of exchange rate returns), I is central bank intervention and ΔV is the change in trading volume.

4.3.2 Fixed Transition Markov Switching Model

The regime switching model considered in this section allows for shifts in mean and variance separating tranquil from volatile periods. sp_t is modeled as being conditionally normal, where the mean and variance both depend on the operative regime, and is given by:

$$sp_t=\mu(s_t)+\sigma(s_t)\varepsilon_t, \qquad \varepsilon_t\sim i.i.d.N(0,1), \quad t\in T. \tag{3}$$

$$\mu(s_t)=\sum_{i=1}^{2}\mu^{(i)}1\{s_t=1\}, \qquad \sigma(s_t)=\sum_{i=1}^{2}\sigma^{(i)}1\{s_t=1\}. \tag{4}$$

where $\mu^{(i)}$ and $\sigma^{(i)}$ (i = 1, 2) are real constants and s_t are random variables in $S = \{1, 2\}$ that indicates the state that the system is in at date *t*. A stable "liquidity trading" regime where μ_1 and σ_1^2 are relatively low (regime 1) and a volatile "informed trading" regime where μ_2 and σ_2^2 are relatively high (regime 2). Throughout, the regime indicator $\{s_t\}$ is assumed to form a homogeneous Markov chain on *S* with the fixed transition probabilities matrix defined as:

$$p^{ij} = \Pr(s_t = i / s_{t-1} = j), \qquad i, j \in S \tag{5}$$

where each column sums to unity and all elements are non-negative. p^{11} and p^{22} represent the probability of remaining in regime 1 and 2 respectively. It is also assumed that $\{\varepsilon_t\}$ and $\{s_t\}$ are independent. We shall refer to the two state order Markov switching model with fixed transition probabilities defined by (3)-(5) as FTP. The FTP generalizes the standard linear model (1) by allowing the mean and variance of innovation $\{\varepsilon_t\}$ to vary between two states according to a hidden Markov chain $\{s_t\}$. The probability law that governs these regime changes is flexible enough to allow for a wide variety of different shifts, depending on the values of the transition probabilities. For instance, values of $p^{ij}(i = S)$, not close to unity, imply that structural parameters are subject to frequent changes, whereas values near unity suggest that regime transitions are not likely to occur. The density function has two components, one for each regime, and the log-likelihood function is constructed as a probability weighted sum of these two components. The parameter vector $v = (\mu_1, \mu_2, \sigma_1^2, \sigma_2^2, p^{11}, p^{22})$ is estimated by maximum likelihood (Hamilton, 1989).

4.3.3 Time Varying Markov Switching Model

Finally, to study the intervention dynamics we relax the assumption of fixed transition probabilities by allowing the transition probabilities to depend on price risk, intervention and changes in trading volume (Filardo, 1994; Diebold *et al.*, 1994). Therefore, the transition probabilities are defined as:

$$p_t^{11} = Prob(s_t = 1 / s_{t-1} = 1, I_t, PR_t, \Delta V_t), \tag{6}$$

$$p_t^{22} = Prob(s_t = 2 / s_{t-1} = 2, I_t, PR_t, \Delta V_t). \tag{7}$$

The probability to switch from the tranquil to the volatile regime is given by $p_t^{12} = (1 - p_t^{11}(I_t, PR_t, \Delta V_t))$ whereas the probability to switch from the volatile to the tranquil regime is measured by $p_t^{21} = (1 - p_t^{22}(I_t, PR_t, \Delta V_t))$. The functions of the transition probabilities are as follows:

$$p_t^{11} = \frac{\exp\{\alpha_1 + \beta_1 I_t + \delta_1 PR_t + \phi_1 \Delta V_t\}}{1 + \exp\{\alpha_1 + \beta_1 I_t + \delta_1 R_t + \phi_1 \Delta V\}}, \tag{8}$$

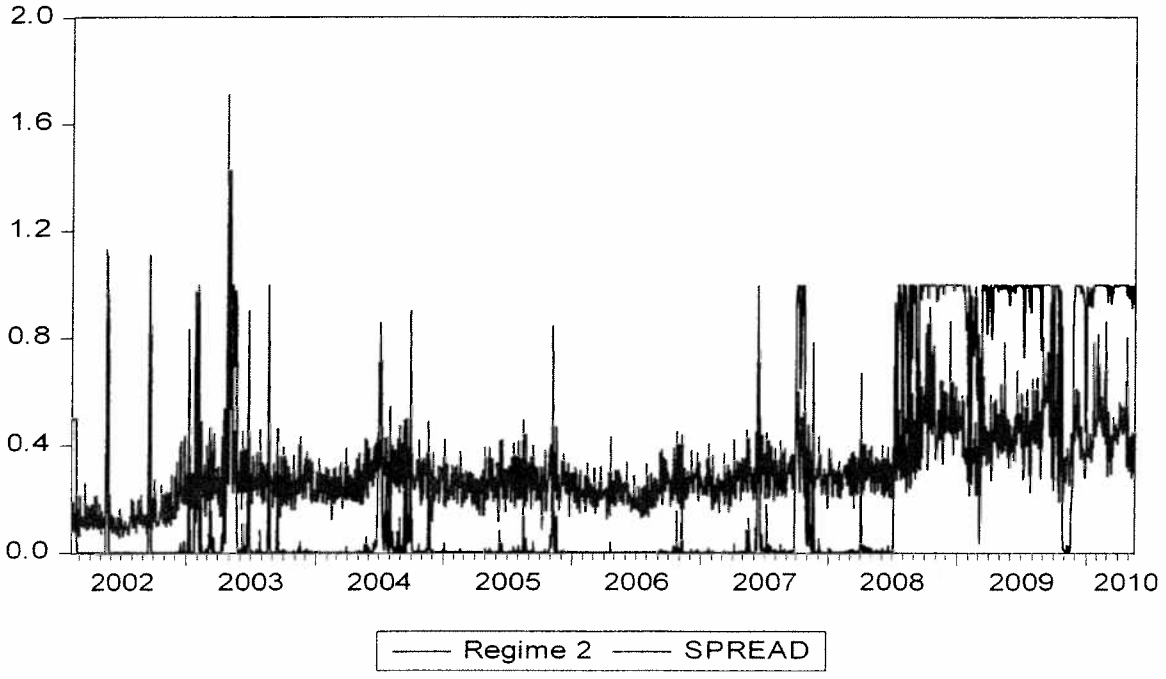
$$p_t^{22} = \frac{\exp\{\ \alpha_2 + \beta_2 I_t + \delta_2 PR_t + \phi_2 \Delta V\ \}}{1 + \exp\{\ \alpha_2 + \beta_2 I_t + \delta_2 R_t + \phi_2 \Delta V\ \}}. \quad (9)$$

The time varying specification of course collapses to the fixed transition probability (FTP) model if $\beta_1=\beta_2=\delta_1=\delta_2=\phi_1=\phi_2=0$. The two-state Markov switching framework is open-ended and compatible with any view of the impact of price risk, intervention and changes in trading volume on the spread. In fact it is also compatible with the view that these variables have no impact in either regime.

4.3 Model and Estimation

All the variables used in the empirical models were stationary at levels using the standard tests. The null hypothesis of linearity against the alternative of Markov regime switching must be tested but this cannot be done directly using a standard likelihood ratio (LR) test since standard regularity conditions for likelihood-based inferences are violated under the null hypothesis of linearity. We use an appropriate test procedure proposed by Hansen (1992). The three-pattern method (TPM) and the Akaike (AIC) selection procedures are also used since Psaradakis and Spagnolo (2003) show that these procedures are successful in choosing the correct state dimension. These test statistics are not reported for brevity but they all confirm that the data generating process for spreads in Jamaica can best be described by a two-state regime-switching specification. Figure 2 shows that the filter probabilities successfully separate the tranquil from the volatile regime (where a volatile regime has been labeled as regime 2).

Figure 2: Spreads and the Smooth Probability of the Volatile Regime



The parameter estimates with t-statistics and values of the likelihood function for Jamaica are presented in Table 2. The estimated results confirm that the regime switching models capture the

spread dynamics better than the simple linear model based on the value of the likelihood function. The mean and variance in the volatile regime is approximately twice that in the tranquil regime and is usually the case in the simple linear model the estimates seem to be an average of the volatile and tranquil regime and therefore measures the impact of spread determinant inaccurately.

Table 2: Estimated Models for Jamaica

	Linear Model	FTP	TVTP
μ	0.313 (98.88)		
μ_1		0.255 (127.34)	0.255 (128.45)
μ_2		0.473 (51.22)	0.476 (51.55)
σ	0.143 (4.88)		
σ_1		0.081 (54.13)	0.081 (54.60)
σ_2		0.164 (62.38)	0.164 (56.51)
α_1		5.008 (18.87)	5.943 (13.60)
α_2		3.979 (11.23)	5.014 (4.88)
β	0.003 (6.75)		
β_1			1.319 (4.27)
β_2			1.106 (1.73)
δ	0.059 (12.24)		
δ_1			-3.449 (-3.73)
δ_2			0.031 (0.06)
ϕ	-0.001 (-8.86)		
ϕ_1			6.437 (2.30)
ϕ_2			2.161 (1.21)
p^{11}		0.99 (18.87)	

p^{22}		0.98 (11.23)	
LogLik	-1263.9	-1884.8	-1895.9

The linear model results appear to conform to our a priori expectations but these parameters may be inaccurate. In terms of the TVTP model there are some interesting results. The flow of new information into the market caused by central bank intervention when the market in a tranquil state increases the probability of remaining in that regime, that is, in a low spread regime but if the central bank intervenes when the market is volatile and spreads are high then it sustains the high spreads so the traditional dynamics seem to work only in the volatile regime. In terms of price risk if the market is volatile increased price risks have no impact but increased price risks in the tranquil regime reduces the probability of remaining in that regime which means that the price risk contribute to increasing volatility and spreads. In terms of the changes in trading volume, changes in trading volume has no significant effect on spreads in the volatile regime but increases in volume increases the probability of the market remaining in the tranquil low spread regime. These initial findings are in tune with our a priori expectations.

5.0 Conclusions

These preliminary results confirm our expectation that spreads in the foreign exchange market generally evolve as a two state process. The results show that the FTP model accurately separates the time period under review into two regimes a tranquil regime and a volatile regime. The results also show that the traditional result of studies looking at the decomposition of the bid-ask spreads are accurate but they occur in different market regimes. That is, the information price risk and effects on spreads is operative only when the market is calm while the information arrival impact operates when the market is volatile. This implies that informed trading and signaling, as well as liquidity injections on the part of the Central Bank in the market may work to reduce spreads but generally but ironically only when the market is relatively calm.

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