- CHAPTER 2 -

LITERATURE REVIEW

2.0 Overview

Only in recent years researchers adopt high frequency data to study financial assets behavior. This is mainly because the data availability and techniques such as wavelet are enabled on computer software.

On the area of forex volatility, there have been some reasonable researches done but not much are on the behavioral of currency pairs. Furthermore, most previous research focuses on effect of forex volatility.

In this chapter, the literature review starts from the point where researchers realize the importance analysis using high frequency data and it moves to the factors that can be affected by or affect forex volatility.

2.1 Importance of High Frequency Data and its Application

The trading activities in financial markets operate in a continuous and high frequency basis. However, virtually all earlier researches especially in the early 90s are based on discrete sampling at lower and often much lower frequency. The advent of high-frequency (HF) data ended this disparity. In

some markets, second-by-second data is now available, allowing continuous observations of price, volume, trade size, and even depths.

One reason why data sets are traditionally low frequency and discrete were the cost of collection and analysis. In general, only those actions resulting in a legal obligation between individuals, e.g. a deal involving a purchase of shares for cash, were written down, and even then the resulting audit trails would normally be retained only a short time. The growth of information technology has brought a dramatic fall in the cost of gathering data as well as decreased the cost of the simultaneous transmission of 'news' to investors. This has changed the structure of markets. These structural changes in trading have important implications for both the availability and interpretation of high frequency data.

Another issue of importance is whether high frequency data bases will reveal limitations to the efficiency of markets, thereby providing a way of legally making an excess return from trading. Past researches have combined a search for nonlinear relationships, and the use of other predictive techniques, notably neural network to examine the potential profitability of trading rules.

Arbitrage opportunities are likely to be seized extremely quickly. Therefore only by looking at the highest frequency and continuous time series that one could observe temporal inter-relationships between markets connected by such inter-relationships.

2.2 Wavelet Analysis on Financial Assets

Early use of wavelet analysis in the area of finance and economics are for outlier detection (Greenblatt 1994), processing of non stationary data (Goffe 1994), examination of the time-frequency distribution (Ramsey 1995, Zhang 1996), study of the statistical self similarity of financial data (Ramsey and Usikov 1995), examination of relationship among key macroeconomic variables (Ramsey and Lampart 1998) and estimation of long-memory processes (Jensen 1998). However, it was Davidson (1998) who made one of the earlier revolutionary contributions by using wavelet analysis in a semi non parametric regression framework. This contribution provide an insight on how one can use wavelet analysis to easily handle inherent restrictions and utilize the well established statistical properties of semi non parametric regression to assess the output.

Foreign exchange market exhibits non linear dynamic structures, high degree of small amplitudes and fast, non informational, trading pattern and non periodic cycles. This characteristics are most probably induced by frequent international capital flows, national business cycles, changes in political regimes globally, country risk, unexpected information shocks in financial markets and diversification in investment strategies. (Jeyanthi 1997)

Unlike low frequency data, high frequency data have extremely high negative first-order auto-correlation in their return. Therefore the volatility estimate is always higher when high frequency data is used. Zhou (1996) explained that

this is due to the noise components in the data. Pan and Wong (1998) combine the wavelet analysis with regression and state space formulation to study the potential stochastic relationship between S&P 500 index price and its dividend yield.

Jeyanthi (1997) found that most forex pricing process is not stationary and their frequency characteristic is time dependant. In order to solve this issue, Jeyanthi applied wavelet multi-resolution analysis with Haar wavelets to analyze non stationary data (time dependent) and self-similarity (scale-dependence) of intra-day Asian currency spot exchange rate. Using this wavelet, Jeyanthi concluded that most Asian exchange rate, which includes Malaysian Ringgit, Philippines Pesos, Thai Baht and Taiwan Dollar, display changes in frequency in July 1997 when the Asian Financial Crisis began. However the exchange rate for Deutschmark, Yen and Singapore Dollar were not greatly affected by the financial crisis.

Studies made by Lo and MacKinley (1990), Stoll and Whaley (1990), Wahab and Lashgari (1993) and Shyy (1996) made studies to determine whether non synchronous trading was suitable as sole explanation for the lead-lag relationship. Findings from their studies concluded that non synchronous trading accounted only for part of the asymmetrical lead-lag relationship. Grunbichler (1994) suggested that automation system was one of the other contributing reasons as shown in a study where German DAX, which is utilizing automated system, led the spot index by twenty minutes.

2.3 Effect of Exchange Rate Stability and Volatility of Asset Pricing

Conditional volatilities of asset returns as well as their international correlations are important parameters for the day to day risk management in financial institutions and the pricing of contingent claims. Although it is often recognized that variances and covariance of returns evolve through time, their determinants are not yet well identified and documented. The theoretical literature does not offer strong predictions on the influence of exchange rate stability on the volatility of asset prices. A frequent argument is that, for a given set of random shocks, fixing the exchange rate induces higher volatility of interest rates, money supplies, prices and output (Frenkel and Mussa 1980; Artis and Taylor 1994; Flood and Rose, 1995). However this 'volatility transfer hypothesis' is theoretically not well grounded.

Real shocks of domestic origin, in aggregate demand or supply, have magnified effects on output and prices under a fixed exchange rate regime conversely, when domestic and foreign money demand shocks dominate, fixing the exchange rate dampens the volatility of asset prices' fundamentals; when foreign real shocks prevail, the net outcome is ambiguous (Henderson and McKibbin, 1993).

In addition, the degree of credibility of the peg matters. An imperfectly credible exchange rate may result in higher volatility of domestic interest rates and asset prices than what would be the case in a permanently fixed and credible regime (Flood and Hodrick, 1986). One may also argue that, if volatility in the

exchange market is due to uninformed ‘noise traders’ or ‘chartists’, it can be eliminated by fixing the exchange rate, without thereby in any way transferring uncertainty to other sectors of the economy (Krugman and Miller, 1993).

In contrast to the ambiguity of the theoretical analysis, a large body of empirical studies suggests that stabilizing the exchange rate reduces the volatility of asset prices. Flood and Rose (1995) and Rose (1995) conclude their investigation of various episodes of fixed and flexible exchange rates over the 1960 - 1991 period for OECD countries by noting that there is no evidence of a substantial tradeoff between exchange rate volatility and the volatility of macroeconomic fundamentals such as interest rates, money supplies, output, prices .

Baxter and Stockman (1989) are unable to find systematic differences in the volatility of real macroeconomic aggregates when they compare the pre-1973 and post-1973 periods for a sample of OECD and non-OECD countries. Artis and Taylor (1994) confirm this reduction in the conditional variances of nominal and real exchange rates over the 1979 to 1992 period and show that there is no simultaneous increase in the conditional variance of interest rates.

Theory only offers ambiguous conclusions, along two strands of arguments. The first argument is based on the fundamental approach of asset prices and suggests that credibly fixing the exchange rate increases cross-country correlations. In a credible peg, common fundamentals across countries have a maximum weight in the determination of asset returns. News about present

and future monetary policies therefore affects bond prices symmetrically. Only ‘portfolio shocks’ which bear on the respective credit risk premium required by investors are responsible for a less than perfect correlation between bond returns.

A strong synchronization of business cycles, the absence of disruptive exchange rate shocks on the countries’ tradable sectors and the symmetry in monetary policies also provide for a high correlation between stock market returns. On contrary, doubts about the credibility of the exchange rate and frequent revisions in the probability of realignment imply a high variability of interest differentials and therefore low correlations of asset returns.

The second argument is based on the contagion explanation of changes in asset prices. It suggests that international correlations increase, instead of decrease, when exchange markets are more volatile. Because of noise trading or herd behavior, contagion effects are highest in volatile markets when a large dispersion of expectations about the fundamentals induces investors to look at asset prices abroad for information about the likely trends in the domestic market (King and Wadhwani 1990).

International correlations are then higher in periods of increased market volatility. As credibly fixed exchange rates reduces uncertainty about fundamentals such as monetary policy, contagion effects become less likely and noise-induced correlations fall. The opposite becomes true when low

credibility of the exchange rate peg induces volatility spillovers between countries.

2.4 Effect of Exchange Rate Regime on Growth Per Capita Income

Two apparently opposite views in the literature exist when dealing with the effects of exchange rate regimes and volatility on growth of per capita income.

The first view is that costs of volatility argument (CVA), establishes that exchange rate volatility may be harmful for growth and thus provides indirect support to the creation of monetary unions (MUs) which eliminate part of this volatility (Buiter *et al.* 1998). According to this perspective, the elimination of exchange rate volatility is generally considered a beneficial effect, given the perception that unpredictable volatility can inflict damage and although the associated costs have not been quantified rigorously (Buiter *et al.* 1998, Devereux *et al.* 2003), many economists believe that exchange rate uncertainty reduces international trade, discourages investment and compounds the problems people face in insuring their human capital in incomplete asset markets. When exchange rate movements are an independent source of volatility and are also driven by speculative dynamics, anticipated entry into MUs may help small open economies to avoid negative macroeconomic effects of exchange rate volatility. De Grauwe and Schnabl (2004) empirical research support this hypothesis, finding a positive association between exchange rate stability and growth in Central and Eastern Europe for transition candidates in the last decade.

The second view, which is defined as advantage of flexibility argument (AFA), considers that terms of trade shocks are amplified in countries with more rigid exchange rate regimes and that, after controlling for other factors, countries with flexible exchange rate regimes grow faster (Edwards and Yeyati, 2003). This second approach traces back to Meade's (1951) argument that, in countries with fixed exchange rates and inflexible money wages, adjustment in the equilibrium real exchange rates arising from external shocks will occur through domestic nominal prices and domestic wages. In such cases shock absorption would be easier under flexible exchange rate regimes. Meade also recognizes that flexible exchange rates may not be of help in case of inflexible real wages, due to some indexation mechanisms. The advantage of flexibility effect also seems supported by empirical evidence. Edwards and Yeyati (2003) show that terms of trade shocks are amplified in countries with more rigid exchange rate regimes and that, after controlling for other factors, countries with flexible exchange rate regimes grow faster.

Bagella Becchetti Hasan (2005) pointed out that these apparently conflicting views of advantage of flexibility and cost of volatility can be easily reconciled when exchange rate volatility is properly measured with a multilateral trade weighted exchange rate and that the concurrence of both effects can be jointly tested in growth estimates. This is because, while the strong negative relationship between exchange rate flexibility and bilateral volatility with the dollar makes almost impossible that AFA and CVA may be jointly tested if volatility is measured with the latter, multilateral trade weighted exchange rate

volatility is much less correlated with exchange rate regimes and allows to measure separately the two issues.

A well known theoretical benchmark predicts a positive effect of volatility on investment (Caballero and Corbo 1989) under perfect competition, risk neutrality and symmetric costs of capital adjustment. The argument is that, under unfavorable exchange rate movements, firms will remain with excess capital investment. And when under favorable exchange rate movements, firms will happen to be with less capital than what is needed. With a convex profit function, potential losses for insufficient investment in good states are higher than potential costs for excess capacity in bad states and therefore firms will over invest when the exchange rate volatility is higher.

Serven (2003) shows that irreversibility must be accompanied by imperfect competition and decreasing returns to scale to change (from positive to negative) the sign of the relationship between uncertainty, investment and growth. Serven also shows, though, that irreversibility affects ex ante investment choices and that ex post firms may find themselves stuck with excessive capital. The direction of the link between investment and volatility definitely changes and becomes negative if risk aversion is considered. In a world in which irreversibility, imperfect competition and risk aversion matter, therefore it is to believe that the finding of a negative relationship between the exchange rate volatility and growth may not be excluded.

In spite of these considerations, few empirical research papers, have found significant effects of exchange rate volatility on levels and growth of per capita GDP. Baum *et al.* (2001) investigate the effects of permanent and transitory components of exchange rates on firm's profitability under imperfect information and show that the variances of these components have indeterminate effects on profit growth, but predictable effects on its volatility.

2.5 Conditions That May Cause Exchange Rate Volatility

Empirical studies indicate that nominal exchange rate changes are not fully passed through to goods prices. In fact, it appears that consumer prices are very unresponsive to nominal exchange rate changes.

An implication of this finding is that the ‘‘expenditure-switching’’ effect of exchange rate changes might be very small. A change in the nominal exchange rate might not lead to much substitution between domestically produced goods and internationally produced goods, because the relative prices of those goods do not change much for final users. If the exchange rate change has little effect on the behavior of final purchasers of goods, then it may take large changes in exchange rates to achieve equilibrium after some shock to fundamentals. For example, if there is a shock that reduces the supply of foreign goods, a very large home depreciation might be required in order to raise the relative price of foreign goods enough to reduce demand sufficiently. That is, low pass-through of exchange rates might imply high

exchange rate volatility in equilibrium (Krugman 1989, Betts and Devereux 1996).

However, fully articulated equilibrium open-economy macroeconomic models with sticky nominal prices have found that exchange rate volatility is difficult to generate even when there is little exchange rate pass-through (Obstfeld and Rogoff 1995). While Obstfeld and Rogoff assume complete pass-through of exchange rates to prices because they assume that nominal prices are set in the currency of the producer, several studies have extended the Obstfeld–Rogoff framework to the local-currency pricing case.

Presence of these three factors (local currency pricing, heterogeneous international distribution of commodities, and 'noise traders' in foreign exchange markets) can potentially generate a high-frequency volatility of the exchange rate that is completely out of proportion to the underlying monetary shocks to the economy. Moreover, while exchange rate volatility is ultimately tied to volatility in the fundamental shocks to the economy, the exchange rate can display extremely high volatility without any implications for the volatility of other macroeconomic variables.

It was found that the volatility of consumption, GDP, the real interest rate, and the current account may be quite low (of the same order of magnitude as fundamentals), while at the same time the volatility of the exchange rate may be much, much higher. In this sense, the exchange rate becomes 'disconnected' from the real economy (Devereux and Engel 2002).

2.6 Causes on Intraday Volatility

A typical U-shaped pattern of intraday volatility, volume, and bid-ask spreads has been observed in several studies, including Baillie and Bollerslev (1991), Harvey and Huang (1991), Dacorogna *et al.* (1993), Cornett *et al.* (1995), Bollerslev and Ghysels (1996) and others. Moreover, instead of a U-shaped pattern, a doubly U-shaped pattern of intraday volatility is even found in markets associated with the opening and closing of the separate morning and afternoon trading sessions (Andersen *et al.* 2000, Tang and Lui 2002, Gau and Hua 2004, Gau 2005). In the high-frequency intraday exchange rates, substantial periodic clustering variation is often explained by information theory and inventory control theory.

Previous studies on information theory have shown how the arrival of public news affects the intraday volatility of exchange rates. However Berry and Howe (1994) found that public information arrives seasonally, and it exhibits a distinctively inverted U-shaped pattern across trading days. Chang and Taylor (2003) also claimed that public information is the major cause of the persistence of intraday exchange rate volatility.

Ederington and Lee (2001) pointed out that the traditional GARCH (1, 1) model tends to misestimate the persistence of high-frequency market volatility and found that the common U-shaped intraday volatility pattern disappears after controlling for announcement effects.

As for inventory theory, Flood (1994) and Lyons (1995) argued that dealers in a decentralized, continuous, open-bid, double-auction, interbank foreign exchange market tend to pass undesired positions along to another, thus creating temporary misallocations of currency inventories, which is often referred to as the hot-potato hypothesis. Furthermore, Hsieh and Kleidon (1996) found that a trader who must close out a position by the end of the day has an increasingly inelastic need to trade and will be more willing to accept a relatively poor price. In this study they find that dealers' inventory adjustments made to accommodate unexpected information risk raise volatility in the middle of regular trading days and at the regular market close.

Apart from the two theories described, a third source contributing to the intraday volatility of the exchange rate is likely the central bank's intervention. This is further elaborated in section 2.8.

2.7 Impact of Information on Exchange Rate Volatility

In a market microstructure, information is a variable that includes public and private component (O'hara 1995). Both public and private components are strongly related to currency market news announcements. The public component is made up of announcements which take place at scheduled times such as weekly reports or economic indicator announcements, or at random times such as a disasters and corporate fraud news.

Regarding private information, the most literature on the microstructure of exchange rates allows for two types of private information. First type is that some market participants could have access to yet unreleased information by central banks or government agencies (insider news). Second type is the notion of private information can be extended to include the so-called unrelated insider information such as private information that a dealer has regarding interim states of the market. For example, one dealer knows from pub chat that another dealer may keen on selling a large euro/dollar position, which should depress prices in the short run. The second type is the most probable type of private information event in the forex market, private information is strongly related to order flow between traders and their customers. (Degennaro and Shrieves 1997)

French and Roll (1986) focus on the distinction between volatility when markets are open versus closed by comparing stock return volatilities over weekends, stock exchange holidays and stock exchange trading days. They find that volatility is much greater during exchange trading hours and conclude that private information is the principal factor behind high trading-time variances.

Ito and Roley (1987) investigate patterns of responses of yen-dollar rate to three specific types of news over the period January 1980 through September 1985. Using exchange rate quotes at the opening and closing of the Tokyo market and the 9 a.m., noon and 4.30 p.m. quotes in the New York market,

they document systematic responses of the yen-dollar rate to the surprise in money supply and industrial production in both the U.S. and Japan.

Baillie and DeGennaro (1989) show that the volatility decline when markets are closed is even more dramatic than French and Roll research observation. The volatility generating process in U.S. equities is virtually inactive during market closings. Jones *et al.* (1994) refine and extend this work by distinguishing between trading and non-trading periods occurring on business days when the equity markets are open.

Ederington and Lee (1993) investigate the effects of 19 regularly occurring macroeconomic news releases on the volatility of interest-rate and foreign exchange futures contracts in U.S. markets, attributing volatility persistence in these markets to private information arrival. Their time scale for U.S. dollar-deutsche mark futures is five minute intervals from market opening at 8.20 a.m. to closing.

Mitchell and Mulherin (1994) use explicit measures of public news arrival to analyze the impact of news on daily trading volume and the absolute value of market returns, but limit their conclusions to the relationship between news and market activity levels. Similarly, Berry and Howe (1994) relate the number of news items to equity market volume and volatility, finding that news arrivals systematically impact transaction volume, but not volatility.

During a three-month period ending in June 1989, Bollerslev and Domowitz (1993) examine the reaction of forex volatility, spread and spread volatility to market activity as measured by quote arrival rates 2. They do not find a significant relationship between quote arrival and volatility but do find that spread volatility increases with quote arrival.

Bollerslev and Melvin (1994) study the Deutsche mark - dollar relationship between bid-ask spreads and market volatility. They find that bid-ask spreads are directly related to conditional volatility and infer that forex dealers are compensated for the risk associated with their informational disadvantage.

2.8 Intervention in Exchange Market and its Effectiveness

The effects of central bank interventions in foreign exchange markets on exchange rate volatility have been the focus of a number of empirical studies such as those done by Aguilar and Nydahl (2000) and Dominguez (1998). Researchers have not only been interested in the magnitude of the effect of central bank interventions on exchange rate volatility, but also in the direction and sign of this effect.

The importance of collecting evidence on the sign of this effect stems from the fact that the exchange rate theories often applied in the intervention literature have clear-cut implications with respect to the sign of the effect of central bank interventions on exchange rate volatility. As an example, a model

frequently used in the literature to describe the intervention–volatility correlation is the asset-pricing model of exchange rate determination.

As shown in research by Dominguez (1998), this standard, forward-looking rational expectations exchange rate model implies that, due to its stabilizing effects on agents' exchange rate expectations, a credible central bank intervention should either dampen exchange rate volatility or should not affect exchange rate volatility at all. If, in contrast, interventions are not credible, or the monetary authorities send out ambiguous signals, central bank interventions should amplify exchange rate volatility.

In the 1980s and early 1990s, attention focused on the effect of sterilized intervention on the level of the exchange rate and on the channels through which it works. The results on the effectiveness of intervention are mixed and depend on which exchange rate is analyzed, the sample period studied and the intervention strategy that was used. In an influential paper, Dominguez and Frankel (1993) use daily and weekly official and press report data on intervention directed at the yen/dollar and mark/dollar exchange rates between 1984 and 1990. They find that intervention had a significant impact on the exchange rate, especially when it was publicly announced and coordinated. Further studies have not provided a unanimous confirmation of Dominguez and Frankel's finding because of contradicting results by each paper.

There papers that support or concluded intervention is effective. Catte *et al.* (1994) confirm that intervention influences exchange rates particularly for coordinated interventions by using a case study approach for the yen/dollar and mark/dollar exchange rates during the period 1985-1991. Fatum (2000) and Fatum and Hutchison (2002) argue in favor of an event study approach to examine the effect of intervention on exchange rate changes, as methods relying on time series data do not capture the sporadic occurrence of intervention.

Fatum (2000) uses a non-parametric estimation technique to show that during the months following the Plaza agreement, intervention by the Federal Reserve and the Bundesbank was effective, especially when it was coordinated. Using similar techniques, Fatum and Hutchison (2002, in press) find evidence supporting the effectiveness of intervention in the mark/dollar and yen/dollar markets. Ito (2003) presents evidence based on Japanese Ministry of Finance data that intervention in the yen/dollar market in the second half of the 1990s was effective. Dominguez (2003) concludes that G3 intervention was often successful with regard to both short and longer-term exchange rate movements.

On the other hand, there are research papers that do not support the conclusion that intervention is effective. Humpage (1988) concludes that intervention was unable to influence the dollar's level. Baillie and Osterberg (1997) find that over the period August 1985 to March 1990, Federal Reserve intervention did not influence the mark/dollar or yen/dollar exchange rates.

Dominguez (1993) argues that the impact on exchange rate volatility depends on how central banks conduct intervention. Looking at daily and weekly data for 1985-1991, Dominguez finds that intervention that is officially announced reduces volatility, while intervention that is not detected by the market increases volatility. Extending her study Dominguez (2003) finds evidence of a significant impact of intervention on exchange rate volatility both at the intra-day and the daily frequency, although little lasting effect.

Bonser-Neal and Tanner (1996) studied the effect of intervention on implied volatility. They use data on implied volatilities from exchange traded options from 1985 to 1991 together with official data on intervention by the Federal Reserve and the Bundesbank. They also recover data on perceived intervention by the Bank of Japan from newspaper articles. They find that intervention had a different impact on volatility over different time periods. Between February 1987 and December 1989 (the ‘‘Louvre period’’), intervention increased implied volatility, while there is less evidence that intervention reduced exchange rate volatility between 1990 and 1991. Over the period 1985-1991 as a whole, there is no evidence that central bank intervention reduced exchange rate volatility.

Murray *et al.* (1997) investigate the effect of different intervention strategies by the Bank of Canada on implied volatility of the Canadian/US dollar exchange rate. In contrast to Dominguez (1993) results, they find that intervention that was expected or unexpected had no effect on implied volatility.

Dominguez (1998) looks at the effect of intervention on both GARCH volatility and implied volatility and finds that the effect depends on both the sample period and the intervention strategy. One of her interesting results is that intervention can lead to an increase in volatility even if market participants do not perceive it.

Frenkel *et al.* (2002) looks at the period 1991 to 2001 and finds that the Bank of Japan regularly intervened in response to deviations of the yen/dollar rate from a short-term and a long-term target. By contrast, their results suggest that the Federal Reserve intervened only occasionally to accompany the Bank of Japan's intervention. Almekinders and Eijffinger (1996) present evidence that, from 1987-1989, the Federal Reserve intervened with the intention of lowering exchange rate uncertainty. Baillie and Osterberg (1997) conclude that intervention is motivated by increases in spot rather than forward market volatility.

Based on the literatures mentioned above, there is no unanimity among empirical studies on the size and strength of the effect of intervention on the level and higher moments of exchange rates. Findings vary by time period, data source, and estimation method. In particular, studies that include the Plaza and Louvre time periods are more likely to find that intervention has a significant effect on the mean or the variance of the exchange rate. Reviews of all of these studies, and commentaries by policy makers involved in intervention, do suggest a consensus view that is official intervention can be effective if the intervention is publicly announced and concerted and provided

that it is consistent with the underlying stance of monetary and fiscal policy (Sarno and Taylor 2001).

2.9 Spread Theory

Finance theory identifies order processing cost, inventory holding cost and information cost of market making as the source of bid–ask spreads:

Order processing cost models assume the existence of some fixed costs of market making or of providing ‘‘immediacy’’ for the exchange of ownership titles (Demsetz 1968). These costs may come, for example, from the need to acquire trading know how and a name in the market, as well as from subscriptions to electronic information and trading systems.

At a given spread, when a dealer expects that trading volume will increase in the next trading period, assuming all conditions unchanged, the expected profit goes up as well. However, inter-dealer competition will force the dealer to narrow his spread to avoid losing business to competitors undercutting him. Hence predictable volume should reduce spreads through an order processing cost effect (Black 1991, Hartmann 1994, 1998).

In contrast, the effect of trading volume on inventory holding costs is ambiguous, depending, for example, on transaction sizes. Inventory cost models, like Stoll (1978), Ho and Stoll (1981) and others, view dealers not only as providers of liquidity services but also as optimizers of their own

securities portfolio. In this framework they try to choose the return-risk efficient portfolio, which maximizes their (or their shareholders') utility. However, since providing closeness (standing ready to trade in a security at any time desired by customers) implies being pushed away from this portfolio, they announce bid and ask prices which assure that their positions are not too far from the optimal portfolio and provide revenues compensating for the remaining utility losses. On average, larger transactions will push the dealer further away from his desired portfolio, such that (assuming all other factors are held constant) the larger the transaction sizes in the order flow expected, the larger the spreads.

However, if trading volume is expected to come in many small, statistically independent orders, then by the law of large numbers increased (predictable) volume could also decrease spreads through an opposite inventory cost effect. Since additionally larger volume is not necessarily driven by larger transaction sizes (dealers may decompose one large transaction into several smaller ones of ‘‘standard’’ size for example or transaction frequency may increase) and quoted spreads are only binding up to a certain maximum transaction size, it is unlikely that inventory cost effects can be identified through daily volumes and spreads.

Information cost models suggest a relation between bid–ask spreads and information arrival or the presence of agents with better information than dealers in the market (Copeland and Galai 1983, Glosten and Milgrom 1985, Kyle 1985). If new information has arrived, such that dealers risk getting into

transactions with ‘‘insiders’’, then they will widen spreads in order to deter some of the informed traders or to earn higher mark-ups from liquidity-motivated traders, whose demand elasticity is rather low.

Therefore, the more important the information arrival during a trading period, the higher the dealers’ information costs, the larger their spreads. However, a major obstacle to the empirical implementation of these models is that the rate of information arrival or the share of information trading in overall trading is unobservable. The use of unpredictable forex volume as a solution to this problem is proposed further below.

2.10 Foreign Exchange Trading Pattern

Numerous studies have shown that the intraday pattern of bid-ask spread follows a U-shaped pattern (Ahn and Chueng 1999, Chan *et al.* 1995, McInish and Wood 1992). These results suggest that there may be a market order submission strategy that would benefit from the intraday variation of spread. Bid-ask spread are widest at the opening and continually declines throughout the rest of the day. Therefore, market order traders who postpone their execution toward the closing period should save on transaction costs.

However, delayed trading has three disadvantages. First, the price might move in an unfavorable way. Second, information value could sharply diminish because private information becomes public knowledge. Third, trades near the close face competition from inelastic institutional investors,

such as index funds. Nevertheless, if trading is postponed for only a short period, less than 30 minutes, investors might be able to benefit from the decreasing intraday spread pattern while limiting the adverse effects of delayed transactions.

Several studies have examined the optimal execution problem and attempted to develop an optimal execution strategy. For instance, Kissell and Glantz (2003) offer an overview of a number of quantitative execution methods and describe a comprehensive top-down approach to evaluating trading costs and optimizing execution.

Bertsimas and Lo (1998) propose a static price impact function to minimize the expected cost of executing a given order. They show that when the price follows an arithmetic random walk with linear price impact in the trade size the common strategy of breaking up large trades into a number of smaller trades of equal size is an optimal strategy.

Almgren and Chriss (2000) incorporate the risk considerations in a similar static price impact function and discrete-time setting using a mean-variance function and assert that the market impact of trading is the most important aspect of execution. Subramanian and Jarrow (2001) investigate the optimal liquidation problem for an investor with a power utility function given a constant execution lag and arbitrary price impact function in a setting without the economies of scale in trading condition. They argue that the

optimal liquidation value of the portfolio is characterized in terms of the solution of the above problem and the incorporation of liquidity risk.

2.11 Summary

Past research work based on the literature findings shows that not much attention was given to analyze the high frequency data that presents in a forex market, even though researchers have shown that traditional model such as GARCH has limitations. These limitations prevent the understanding that is close to the actual events.

Anyhow, using traditional methods, there are various studies made to study the forex market behavior when various economic factors are introduced to the market. However, there are some areas of the research which doesn't provide unanimous view, such as the effectiveness of the intervention (by government or central banks). This is how puzzling the forex market is where its behavior model is very much dynamic.

In this thesis, three currency pairs will be the scope of study. Minute by minute forex market data on every Monday between the time of one hour before and after 1pm GMT is used. This high frequency data is analyzed using wavelet methods to study the currency pair correlation and correlation of currency pair combinations.

This study provides an insight of the "Monday effect" for these three currency pair, which may help investors to capitalize or strategize.