INTRODUCTION TO THE MARKET MICROSTRUCTURE LITERATURE APPLIED TO THE FOREIGN EXCHANGE MARKET

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Introduction

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In their forthcoming chapter for *The Handbook of International Economics*, Frankel and Rose (1994) review empirical and theoretical studies of exchange rate movements. The models used to explain the exchange rates between industrialized countries rely on macroeconomic fundamentals such as prices, money supplies, and trade-related national accounts. These factors are believed to account for the level of the exchange rate. An early paper which describes these relations is Mussa (1976). It was believed that macro forces drive the exchange rate process. Examples of these macro forces include the degree of price flexibility, changing risk factors due to the accumulation of changes to an economy, or the actions of the government to the influence macroeconomic factors. Models including dynamic factors began to appear after work by Dornbush (1976). The intelligent agents in these models are the foreign exchange traders, usually banks, who understand the dynamics of the exchange rate process and interpret the macroeconomic fundamentals. In most early models, these agents are often passive participants and are not modeled explicitly.

A straightforward interpretation of the fundamentals using time-series modeling of the exchange rate has failed to adequately explain the level of the exchange rate within sample or to forecast future movements. Adding dynamic elements has led to more complex models of price stickiness and overshooting or undershooting but these enhancements, while interesting as theoretical models, have not significantly improved upon the basic econometric models. A simple model using a random walk process as an explanation of the movement of the exchange rate has performed nearly as well as the more complex models. This is documented in the work of Meese and Rogoff (1983) as well as others. After their review of the existing empirical results from nearly all of the existing models, Frankel and Rose (1994) conclude that the existing structural models have little in their favor beyond theoretical coherence.

The failure of the existing theoretical structural models has turned the focus of

current research to the intelligent agent as participant, and often overriding influence on the path of the exchange rate. Agents can influence the exchange rate by forming expectations of the future level of the exchange rate, and by acting on these expectations as active participants in the foreign exchange market. Since the model of Mussa (1976), the presence of expectations has been recognized. This can be seen by the expression for the level of the exchange rate in the simple monetary model:

$$e_t = f_t + \beta E_t[de_t]/dt.$$

where e_t is the level of the exchange rate, f_t is the underlying fundamental, E_t is the expectation operator, and de_t/dt is the change in the level of the exchange rate over time.

The initial interpretation of the expectation term was that it was due to the dynamics of the model. If prices move slowly and the equilibrium relations are known, then there is an expectation of reaching an equilibrium sometime in the future.

A later interpretation, attributed to Dornbush (1978) and Frenkel (1981), stressed the role of expectations derived from new information available to agents. This represented a subtle shift in the interpretation of expectations. Expectations were present in the models but now these expectations are due to information related to the fundamentals. Earlier models assumed the fundamental was known, but these later models assume only that information about the fundamental is known.

This interpretation of expectations led to empirical work to measure factors which could affect the formation of expectations. Empirical studies reviewed by Frankel and Rose (1994) use innovations (shocks) in econometric time-series models to study how expectations might be affected by innovations to interest rate differentials, the money supply ratio, or changes in policy.

After the disappointing results from these studies, the expectations themselves were estimated. Survey data or official policy change announcements were used to test

the effect of changes in expectations. Frankel and Froot (1987) and Frankel and Chinn (1993) are examples of this line of research. Research of this kind is not unique to the study of foreign exchange. Much of the work on expectations has been directed to the understanding of market efficiency. This work also brings into focus the importance of the assumption of rational expectations underlying the models of foreign exchange determination.

While expectations have been incorporated into the monetary models of exchange rate determination since the mid-1970s, it has been difficult to explain how these expectations are formed or to observe these expectations. Perhaps more importantly, how these expectations are used by agents in the market has not been adequately addressed. The issue of how expectations are used has led to the development of the market microstructure literature. In this literature, attention is placed on the market institution and the activities of agents within the market institution. The formation of expectations by agents is modeled as a dynamic process where information is processed regarding the fundamentals of the market, and strategic interaction takes place among the agents in the market.

The microstructure literature addresses the role of information in the market in relation to the formation of expectations. The primary question is how information is incorporated into market prices. Information is assumed to be dispersed among many agents in the market. To what extent does a single market clearing price incorporate the dispersed information? There are many theories as to how this is accomplished and many doubt that it is possible at all. Rational expectations is a key assumption in these models. Information is assumed to be the basis of price expectations, and agents are assumed to form these expectations rationally. When the information available to agents is known, it is possible to measure the information content of prices for various market institutions.

The paths of prices are then driven by the revelation of information and the degree of informativeness of prices. Knowing the path of the fundamentals is not enough if

prices do not fully reveal the fundamentals. An understanding of the information process in the foreign exchange market is key to understanding how the foreign exchange rate relates to the fundamentals. In what follows, literature on the informational process will be discussed generally. Much of the literature in this area is applicable to the foreign exchange market, although more work is needed to derive useful results. Once the informational process is understood, hopefully it will become clear how to attribute movements in the foreign exchange rate to both movements in the fundamentals and to movements that may be due to the informational process itself.

Information in markets

The effect of imperfect information on competitive markets gained attention in the early 1970s by researchers such as J.E. Stiglitz and J.R. Green. Some early papers were collected in the "Symposium on Economics of Information," in the *Review of Economic Studies* which followed a conference on the economics of information in 1975. The theme of these papers is that imperfect information changes the character of the competitive economy, and that prices may have a role in conveying information in addition to their role in clearing the market. The dual role of prices raises two main issues: 1) Will there always be incentives to gather information which is not already incorporated into price? 2) Under what conditions are prices informationally efficient?

The first of these issues is addressed by Grossman and Stiglitz (1976, 1980) and Grossman (1977). The focus of the work is how information is aggregated in the market, and how information passes from the informed to the uninformed agents in the market using prices. A trading model is developed where agents may trade risky and safe assets. When information about the risky asset can be acquired at a cost, there must be some incentive to become an informed trader and to trade against uninformed traders. If price

always reveals all information available, there is no incentive. If price does not reveal all information then there is an adverse selection problem for the uninformed trader when facing a better informed trader. It was shown that a market may shut down due to the adverse selection problem even when there might be gains from trade. Grossman and Stiglitz resolve this problem by adding noise to the price process in the form of supply uncertainty. Prices reveal some but not all available information and there is an incentive to gather costly information which is not completely revealed in prices.

The informational efficiency condition is considered by Green (1977). A price is informationally efficient if enough agents choose to be informed, and their information becomes incorporated into the market price. For an equilibrium to exist, the number of agents who choose to become informed must be fixed, otherwise prices cannot settle to an equilibrium. Green shows that the number of informed agents is generally not optimal when an equilibrium is reached, and in some situations of which he demonstrates an example, an equilibrium will not exist.

An equilibrium will not exist if prices are unable to transmit sufficient information for agents to make an optimal decision. In Green's words, the space of prices is not 'large' enough. He suggests that in these situations, other variables such as quantity variables may be used along with price, and agents' expectations may depend jointly on price and quantity in equilibrium. An alternative method of assuring an equilibrium is to restrict the functional form of the uncertainty in the model.

These explanations for the role of price are criticized by Hellwig (1980), who calls traders in the Grossman models, "schizophrenic," in that their private information will be incorporated into prices yet they use the information in prices to decide when to gather private information. However, in the absence of a Walrasian auctioneer who collects all private information, all traders cannot be price takers. Hellwig's alternative is to suggest that the value of private information depends on individual heterogeneous preferences. In addition, in a large market, equilibrium prices only reflect information

which relates to the common preferences of a large number of agents. To demonstrate these alternatives, Hellwig uses a version of the Grossman model where agents have varying degrees of risk aversion.

In a later paper, Hellwig (1982), it is shown that in a rational expectations, intertemporal model, when agents condition demands on past rather than current prices, and when market periods are short, the market will approximate full informational efficiency. This will be important in the model of Chapter One where the past price is used by traders in their estimate of the current price.

These simple models have allowed many diverse informational issues to be considered. For example, Diamond and Verrecchia (1981) consider the implications of traders having disparate information rather than asymmetric information as in the Grossman and Stiglitz model. Subsequent research has focused on the strategic actions of the informed trader and market informational efficiency. Questions are raised as to why informed traders as "insiders" would continue to be price takers in the market, and how the efficiency of the market might be altered by alternative market structures. These questions are addressed in the next subsection on market structure and imperfect competition.

Market structure and imperfect competition

There are several well known early papers considering the effect of insiders on market competitiveness and the informational efficiency of prices. In Kyle (1985) trading is examined over time with a structure of three types of traders: a single risk-neutral insider, random noise traders, and competitive risk-neutral market makers. Using the concept of sequential equilibrium, Kyle shows how the insider may exploit monopoly power by using uninformed traders to hide their trading activities. This is to show that

insider information can in fact be valuable to an insider. As the time between trades becomes small, a continuous limit is reached, and the result of this model is that all private information is incorporated into prices gradually at a constant rate. Increased activity by noise traders has no effect on the rate in which information is revealed. This result on the effect of the noise traders, however, is reversed in Kyle (1989).

In his well known paper, Kyle (1989) provides two reasons for modeling the structure of speculative markets as not perfectly competitive. First, it is observed that there are often well-informed traders who are capable of taking large positions. Commodities, government securities, and equities are examples of this type of speculative markets. Foreign exchange is not mentioned by Kyle; however, it is generally believed that the majority of foreign exchange trading is interbank and not customer driven which may imply that trading is more likely to be informationally driven than liquidity driven.[1] The second reason given by Kyle is that models based on perfect competition do not have reasonable properties with respect to private information. This refers to the objections by Grossman and Stiglitz and Hellwig outlined above. This is principally due to the incentives for acquiring costly private information, and revealing this information to other traders.

Kyle (1989) suggests modeling markets using imperfect competition where informed traders maximize against an upward-sloping residual supply curve, and the quantity traded is restricted from corresponding competitive amounts. This reduces the amount of information which might otherwise be transmitted to the uninformed traders. In the Kyle model, an equilibrium exists where speculative traders have incentives to acquire costly information. The resulting oligopolistic equilibrium will differ from a perfectly competitive equilibrium although Kyle describes how a limiting sequence of

[1] The Federal Reserve Bank of New York prepares periodic studies of the turnover in the foreign exchange market. The most recent survey was taken in 1992, and the next survey is scheduled for late 1995. See references section.

imperfectly competitive equilibria will converge to a competitive one.

The model used is a one-period model following concepts introduced by Grossman and Stiglitz (1980) and Hellwig (1980), with the exception that traders know that their actions will influence the market clearing price. The model includes three types of traders: noise traders, informed speculators, and uninformed speculators. Utility is exponential and each informed speculator has the same degree of risk aversion and information precision. Trading in this model depends on each trader submitting a demand schedule to a fictitious Walrasian auctioneer who calculates a market clearing price. With these assumptions it is shown that an equilibrium exists where strategies are symmetric and linear. A key result of the paper is an existence proof which shows that the equilibrium linear strategies in this model exist, and that they dominate all non-linear alternatives.

Prices in the Kyle model do not reflect all available information. When noise traders are present, informed traders restrict the quantity traded from competitive levels. If noise trading activity is reduced, then markets become illiquid and overall trade is reduced. In the absence of noise traders, there is no trade. The result of the actions of the informed trader is that uninformed trading activity can influence the informativeness of prices. This result will be examined in other contexts in later papers. The proposition which is demonstrated in this paper is that the trading process itself determines how well prices reveal information. The trading process includes such factors as market structure, and the proportion of informed and uninformed traders in the market.

Another model in which the trading process reveals the information held by insiders is presented by Glosten and Milgrom (1985). The focus of this paper is the adverse selection problem for specialists trading with insiders. A specialist is a trader who is willing to post a bid and ask price at any time to any trader without knowing if this trader is informed or uninformed. A positive bid-ask spread compensates the specialist for the uncertainty as to the type of trader faced. Using a partial equilibrium

rational expectations model similar to Grossman (1976) the authors conclude that trading is informative in that due to trading, information will become incorporated into prices. This will in turn tend to decrease the size of the bid-ask spread and reduce the overall cost of trading. The difference between this model and the Kyle (1985) model is that in this model, the flexibility of the bid-ask spread will prevent the no-trade situation faced by informed traders in the absence of sufficient noise trading.

Dennert (1993) extends the Glosten and Milgrom and Kyle models to include several competing specialists. The bid-ask spread depends on the number of specialists in the market, and the degree of information sharing between specialists.

The unrealistic role of the Walrasian auctioneer is eliminated in Lyons (1991) in a model specific to foreign exchange trading. Each trader acts both as a speculator and an information clearing house in that information contained in customer orders given to the trader is transmitted to other traders through the trading process. Private price information in this model consists entirely of the trader's observed customer order flow. The change in the value of the fundamental asset traded in this model is related in some way to the average of all traders' information, although this is not made explicit. This results in traders having heterogeneous beliefs regarding the value of the asset. Traders attempt to extract information as to beliefs by observed trading volume between traders. Traders then form price expectations by optimizing according to their own private information signal and a signal extracted from observed volume. Lyons argues that traders underweight private information leading to informational inefficiencies in the resulting market price.

While the Lyon model has appealing characteristics, it does not explain the content of information. While information available to traders is responsible for price changes, information may not necessarily reflect the true value of an asset. The content of information in the Lyons model is composed of the size and frequency of customer orders. These customer orders are the driving force behind price changes, and customer

orders may be a misleading indicator of value.

Many researchers believe that volume generated either due to customer orders or trading is simply a characteristic of the trading process and not a direct determining factor to price changes. Certainly, volume has an effect on the informativeness of prices as is seen in the Kyle, Glosten and Milgrom, and Lyons models. It is an open question whether volume also drives the price process. A model in which volume influences prices might be considered the non-fundamental approach to price determination, and would be in contrast to approaches which assume that prices must always reflect some true value based on economic fundamentals.

There is ongoing debate as to which is the correct approach. Non-fundamental factors such as volume and institutional characteristics of the market certainly are of importance to the price process and cannot be ignored. It would seem unlikely that non-fundamental factors would dominate fundamental factors although this must be proven. Current theories which consider in more detail the importance of market institutional factors and the role of volume in the price process are explored in more detail in the next subsection.

The price process and volume

The importance of the trading institution's influence on the process of price formation and the informativeness of market prices has been extensively studied yet there remain many unresolved issues. Introductions to the characteristics of market institutions have been presented by Friedman (1993) in a survey of trading institutions and by Garman (1976) in an early comparison of dealership and auction markets and their effect on volume. While it is known that volume will differ across institutions, volume is also believed to be a key feature to the understanding of the informativeness of prices and the

statistical features of the price process in general. The reason for this specific interest in volume should become apparent in what follows.

A simple model of trading volume is presented by Karpoff (1986) where periods of increasing trading volume in a market are either due to traders interpreting information differently or due to diverse prior expectations. In this model, individual traders' demands are revised each period by a stochastic element. Traders are then matched randomly and the probability of trade is modeled as a binomial process. The resulting model allows a closed-form solution for expected transaction volume in both a continuous market formulation with transaction costs and a costless Walrasian call market. What is lacking in this model, however, is an explanation of how volume may be related to the price process itself.

From a strictly empirical approach, studies of equity and futures markets have clearly shown a positive correlation between volume and the absolute value of price changes. These studies are surveyed by Karpoff (1987). There are two popular theories to explain these empirical observations: the "sequential arrival of information" theory, and the "mixture of distributions" theory.

The "sequential arrival of information" theory attributed to Copeland (1976) describes a situation where traders receive information one trader at a time until all traders become informed. Trade occurs because each trader interprets this information differently. Some traders become "bulls" while others become "bears" and each trader subsequently trades based on these beliefs. Although when modeled this explanation will generate a positive correlation between volume and the absolute value of price changes, this theory contains a no short-sale restriction on the "bears," which may be responsible for the outcome of the model. This explanation has also been criticized in that traders do not learn from the market price. Traders must wait for exogenous information to arrive in order to become informed, rather than using market price to infer the arrival of information.

A second theory, attributed to Clark (1973) and Epps and Epps (1976), known as "the mixture of distributions hypothesis," argues that speculative prices are drawn from a set of distributions of differing variances. This causes the leptokurtotic feature observed in empirical studies of price changes. Variations in transaction volume cause the variance of associated transaction price changes to differ. Similarly, volume may be used as a replacement for the measurement of transaction time as described in Clark (1973). Variance of price changes measured over transaction volume appear to be closer to being Normally distributed than when variance is measured over time. Since volume is positively related to the variance of price changes, this theory supports the observed positive correlation between volume and the absolute value of price changes.

Both of the above arguments assume an exogenous source of information, and volume variations correlated with price changes are the ultimate result. The source of trading volume variations, however, may not necessarily be due to the arrival of information. Admati and Pfleiderer (1988) demonstrate how strategic interaction among traders might produce particular patterns of low and high concentrations of trading volume. These patterns occur even though information acquisition is modeled as endogenous. Using a variation of the Kyle (1985) and Glosten and Milgrom (1985) models, informed ("information") and uninformed ("liquidity") traders submit orders to a market maker who sets market clearing prices. Unlike the Kyle and Glosten and Milgrom models, liquidity traders may be non-discretionary or discretionary. This allows the authors to examine the concentration of trading within a period or over several periods. They find that discretionary liquidity trading is found to be concentrated rather than dispersed over time, and informed traders typically trade more intensely during periods of high concentration.

Discretionary traders' activities are based on arbitrary restrictions as to the timing of their trades. They attempt to minimize the cost of trading with respect to liquidity constraints and do not speculate on price changes. Periods of concentrated volume are

driven by the liquidity demand of the discretionary trader. Increased volume due to discretionary trading, however, also allows for the possibility of an increase in the profitability of the acquisition of costly information by informational traders. In this sense, information creation is endogenous and prices are more informative in periods of increased amounts of discretionary liquidity trading.

As it has been shown that variations in volume may occur without new information, it seems that prices too may change based on information which was public in previous periods. This is commonly known as the technical analysis of prices. Grundy and McNichols (1989) and Brown and Jennings (1989) both show this possibility using similar models. Multiperiod noisy rational expectations models are used which are based on the models of Grossman and Stiglitz (1980), Hellwig (1980), and Diamond and Verrecchia (1981). Information arrives in the first period and trade occurs. Supply uncertainty does not allow price in the the first period to be fully revealing. In a second period without changes in supply, trade still takes place even though new information may not have arrived. This is because rational traders use price history as well as the current price to form their demands. In the Grundy and McNichols (1989) model, all traders receive correlated signals in each period. In the Brown and Jennings (1989) model, signals are private and traders continue to use previous prices even when supply changes in each period.

The empirical observation relating volume and absolute price changes is salvaged somewhat by Blume, Easley, and O'Hara (1994). While volume itself may not be directly related to new information, and price changes may be related to previous public information, Blume, Easley and O'Hara (1994) argue that the combination of volume and technical analysis will be useful in determining the informational content of price changes. This is again shown in a noisy rational expectations model similar to the model of Grossman and Stiglitz (1980). Informed and uninformed traders are given signals as to the value of a risky asset. The informed traders have all the information available in

the market in that they know the distributions from which their signals were drawn and the distribution of the uninformed traders' signals. The uninformed only know the distribution of their own signal. Observing volume and past prices is useful to the uninformed trader in determining the precision of the signal given to the informed trader.

What appears to be lacking at this stage is a model that allows for the reintroduction of a meaningful fundamental that can be found behind the machinery of institutionally driven volume and price movements. The movement of this fundamental would reflect economic factors which affect the asset being traded. In the Blume, Easley, and O'Hara model, the fundamental is constant over time. It would be helpful to allow the fundamental to follow a time series process which is not well understood by the trader in the model. The influence of the fundamental could then be compared to the influence derived from the institutional factors, and the fundamental's effect on the resulting price process could be evaluated. The model presented in Chapter One is a start in this direction.

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