ECONOMIC RESEARCH REPORTS

STRATEGIC BEHAVIOR IN TWO-SIDED FOREIGN EXCHANGE AUCTIONS

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RR # 95-05 **February 1995**

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February 20, 1995

Abstract

The market microstructure chosen for foreign exchange auctions can influence trading volumes and equilibrium exchange rates. With emerging markets and developing countries increasingly utilizing two-sided auctions, we show that the choice of the discrete "tâtonnement" mechanism creates incentives for strategic behavior among market participants. The theoretical arguments are supported empirically through analysis of detailed data from a rare example of a tâtonnement market, the Moscow Interbank Currency Exchange. Consistent with findings from experimental economics, new entrants altered strategic behavior mainly on the market's demand side, without comparable implications for the supply side. We also show that bids and offers were influenced by the opportunity cost of holding dollars, parallel market premia, and specific policy measures.

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I. Introduction

The type of market microstructure implemented for foreign exchange trading can influence the trade volumes and equilibrium exchange rates generated by the market. Although a variety of auction microstructures are possible for foreign exchange trade, in this paper we consider a mechanism for trading in a two-sided market, i.e. when the private sector participates on both the demand side and the supply side.[2] We are interested in two-sided markets because these are increasing popular in developing countries and countries with recent experiences of introducing currency convertibility. A particularly noteworthy type of microstructure is the "tâtonnement" auction, which is similar in structure to "call" or two-sided "batch" auctions sometimes used in securities trading.[3] The objective of our paper is to explore implications of this auction microstructure for foreign exchange trading outcomes, with a particular focus on the implications for strategic play by market participants. Methodologically, we will provide theoretical results, discuss relevant lessons from studies in experimental economics, and generate observations using detailed data from a rare example of a tâtonnement market at work, the Moscow Interbank Currency Exchange (MICEX).

Tâtonnement markets have a number of important features. First, as two-sided markets both buyers and sellers interact. Second, transactions occur under a "competitive" or "uniform" pricing rule, so that all winning bidders and suppliers of the traded good transact at a common price. Third, this market has discrete or "periodic" trading sessions in which trader's orders are accumulated for simultaneous execution at a predetermined time.

Tâtonnement markets bear some similarities to other bid-ask institutions, especially the double auction market. The fundamental differences between these two microstructures concern the timing of the trading sessions and the pricing rules indicating the conditions under which transactions between agents can occur. A double auction market works on a negotiated or "discriminatory" price basis, while a tâtonnement market works on a competitive price basis. Under a discriminatory pricing rule, any subset of agents that meet in the market place may strike a mutually beneficial transaction even if, from an aggregate standpoint, the agreed upon price would not yield a market equilibrium. The trading system of a double auction can

[2]In a one-sided market the government or Central Bank generally controls the supply of foreign exchange.
[3]Feldman and Mehra (1993) provide a recent typology of auction micro-structures.

yield a sequence of bilateral transactions at different prices. Indeed, trades can take place at "false prices," meaning that some units are traded at prices that would not clear the entire market. Double auction trading is generally continuous, as in some stock exchanges. By contrast, tâtonnement trading is discrete and only takes place at a single, market-clearing equilibrium price. These differences in trading arrangements also imply that under double auctions any message sent by a trader is binding. Under tâtonnement, if a market does not clear in a particular round, messages are not binding for subsequent rounds of trading.[4]

Unlike much of the market microstructure literature, our analysis will highlight strategic trading that occurs independently of informational asymmetries or imperfections. We show that, even under perfect information, the tâtonnement market mechanism may encourage strategic "under-revelation" of demands or supplies by participants who perceive that, because of their relative size, they have the ability to influence equilibrium prices and shift the surplus in their favor. The intuition behind the strategic behavior is straight-forward: if a participant in the market can understate his excess demand and can thereby lower the price on all units (of foreign exchange) that he purchases, the market surplus will shift in his favor. Likewise, if the market power is concentrated in the supply side of the market, supply will be understated and, through making supply scarcer, the participant will attempt to secure a higher price for his units supplied to the market. In Section II we show this result formally based on a typical trader's problem and a specific illustrative example. Our theoretical results further demonstrate that when new players enter a market alterations in the degree of under-revelation can be detected by analysis of slopes and intercepts of bid and order functions for foreign exchange.

The results we obtain underscore the importance of studying particular market microstructures for foreign exchange trade. The tâtonnement rules for trade present participants with a potentially stronger motive for market-power driven under-revelation compared with double auction rules. Since double auctions have a "discriminatory" pricing rule, where trades can take place at a number of different prices, market power is targeted at the marginal unit's price, rather than at the price of all units that the agent ultimately will trade. Our emphasis on the importance of market power rather than informational asymmetries complements an existing and emerging body of research on alternative market microstructures. Madhavan (1992) shows that periodic auctions (in securities markets) aggregate information

[4]As emphasized by Bronfman et al. (1994), this property is important for designing efficient trading rules.

efficiently. Also, in comparison with a continuous market, he argues that the periodic auction is more robust to problems of informational asymmetries. His arguments could clearly be applied in foreign exchange markets, where the counterpart to the periodic auction is the tâtonnement market we study, and the counterpart to the continuous auction is the double auction. Lyons (1993, 1995) pursues the link between alternative models of foreign exchange trading activity and market volumes under informational asymmetries. Unlike Lyons' work wherein the models and data pertain to continuous trading mechanisms, our work concentrates mainly on the periodic auction which is more pertinent for much less mature foreign exchange markets.

The "tâtonnement" mechanism has very seldom been observed in "real world" markets. Besides the "London Gold Fixing" market (Jarecki, 1976), to our knowledge there have not been any documented cases of other markets that work in the same fashion.[5] In Section III we examine bid and offer activity in a rare example of a two-sided "tâtonnement" micro-structure at work: the Moscow Interbank Currency Exchange (MICEX) established in Russia in 1991.[6] Our analysis of this foreign exchange market provides empirical support to the strategic under-revelation hypothesis in a two-sided market. Our examination of the specific case of the Russian market is intended to generate lessons regarding the implications of using tâtonnement markets for foreign exchange trade, and lessons well as for multi-unit auctions in general.

From the empirical analysis we conclude that early efforts of broadening access to the MICEX market had mixed effects on the monopolistic behavior exhibited in that market. New entrants may have eroded the monopsony power of purchasers of foreign exchange, but did not weaken the power of existing players on the supply side of the market. New entrants to the market had demand side competitive implications, but supply side effects were virtually absent. It is noteworthy that our empirical findings about which side of the market is influenced by new entrants are consistent with prior conclusions generated in experimental economics. Finally, we also study the implications for MICEX market outcomes of macroeconomic fundamentals which include the opportunity cost of holding dollars, black market exchange-rate premia, and a set of "events". This analysis confirms that Russian foreign exchange markets are indeed

[5]Walker (1972) and Morishima (1977, Chapter 2) provide conceptual and historical accounts of the Walrasian tatonnement. The near absence of tatonnement experiences also is underscored in Friedman's (1993) survey.
[6]According to Kovanen (1994), Romania has recently experimented with tatonnement foreign exchange auctions.

responsive to fundamentals and these should be included in any time series analysis of market microstructure themes. Section IV concludes and suggests directions for further research.

II. Analytical Issues: Market Structure, Trader Behavior, and Outcomes

Consider a market outside of the United States in which foreign exchange, which we refer to as dollars, is traded in exchange for domestic currency. The unit price of dollars, the nominal exchange rate, is defined in terms of domestic currency per dollar. The real exchange rate relevant for decision-making by traders is denoted by e, which is simply the nominal rate deflated by domestic prices. Let e_0 be the equilibrium exchange rate from the previous market session. At the opening of each trading session, market participants submit to the auctioneer preliminary applications indicating their quantities demanded (x^d) and supplied (x^s) at rate e_0. Since any agent i (i=1,...,n) may potentially be a buyer or a seller, we lose no generality by concentrating on each agent's excess demand $x_i = x_i^d - x_i^s$. Trader i's excess demand function is defined as $x_i(e)$, where $\partial x_i/\partial e < 0$.

The institutional structure of the foreign exchange market defines the rules by which excess demand is eliminated. If we define the initial aggregate excess demand function for foreign exchange as $X(e_0) = \sum_{i=1}^{n} x(e_0)$, the institutional structure determines the rule $f(X(e))$, where $f'>0$ and $f(0)=0$, by which the market-maker or "auctioneer" modifies the prevailing exchange rate.[7] The market reaches its equilibrium when the aggregate excess demand disappears, i.e., when $X(e^*)=0$ at the rate $e = e^*$.

For each trader the problem of making decisions under tâtonnement rules depends on the particular market structure. If i is small enough with respect to the aggregate, and also believes that everybody else is, the noncooperative equilibrium of a tâtonnement market approaches the Walrasian outcome (Schmeidler 1980, Mas-Colell 1982, Novshek and Sonnenschein 1982). In this case, each agent cannot do any better than reveal his/her true excess demand at each price quoted by the auctioneer. Samuelson (1954) also showed that, when agents are very small with respect to the aggregate, the competitive process makes it unprofitable to depart from the rules of perfectly competitive behavior when everyone else continues to abide by these rules. Hence, in tâtonnement markets with a large number of

[7]See Morishima (1977) and Joyce (1984) for the technical aspects related to this function.

agents, one should expect Walrasian-like outcomes.

Unlike the purely competitive case, there is room for strategic behavior in tâtonnement markets with a small number of traders or where some large traders have market power. Vickrey (1961) points out that when agents perceive that their stated excess demands affect the direction and magnitude of price changes, they will have the incentive to understate these excess demands.[8] Hurwicz (1972) also observes that when an agent has positive measure it would pay for him to "falsify" his true preferences when everyone else follows the rules of perfect competition. In this case, a single agent finds it optimal to behave as a monopolist and under-reveal his/her true excess demand in equilibrium. The extent of this under-revelation should diminish as a market becomes more competitive and approaches the Walrasian case.

The intuition behind the strategic behavior under the discrete two-sided auction is straight-forward. If a participant in the market can understate his excess demand and can thereby lower the price on *all* units (of foreign exchange) that he purchases, the market surplus will shift in his favor. Likewise, if the market power is concentrated in the supply side of the market, supply will be understated and, through making supply scarcer, the participant will attempt to secure a higher price for his units supplied to the market.

The basic implications of strategic under-revelation can be illustrated graphically. Figures 1a and 1b depict basic FOREX currency supply and demand curves, illustrating both the Walrasian curves and the form of under-revelation when the respective sides of the market have concentrated power. The subscript s denotes strategic and the subscript w denotes Walrasian. In the resulting equilibrium, net gains from strategic play are the area A-B. If buyers (sellers) understate their true quantities demanded (supplied), the theory predicts that (a) the equilibrium price will be lower (higher) than the Walrasian price, and (b) the quantity transacted will be lower, regardless of which group behaves strategically. Hence, in the FOREX market concentration among buyers of foreign exchange will promote real exchange rate appreciation, while concentration among the sellers of foreign exchange will contribute to real exchange rate depreciation. Concentration on either side of the market contributes to overall thinness of the market.

[8]See also Smith et. al. (1982) and Shubik (1977).

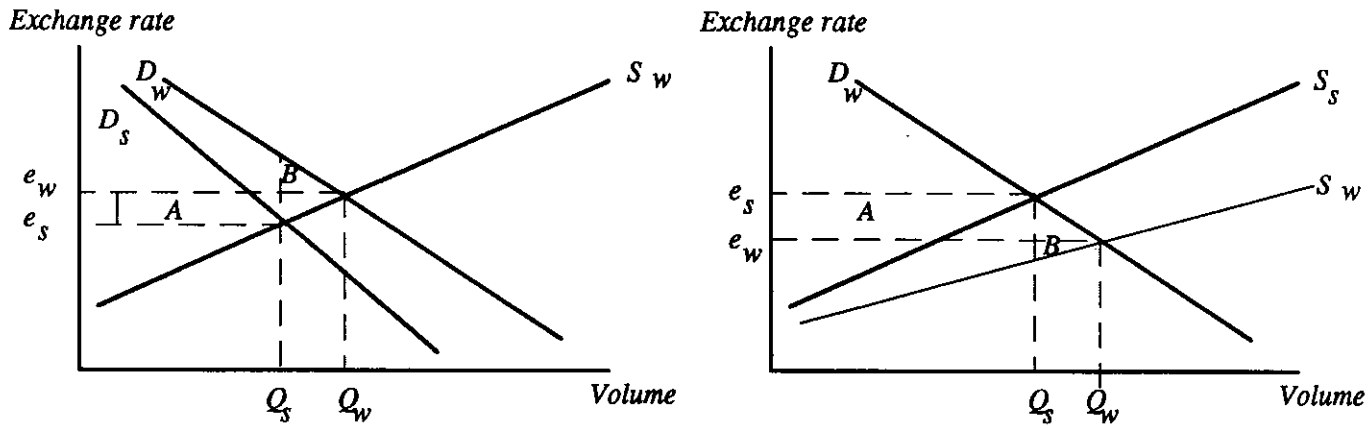


Figure 1a and 1b

IIA: A Typical Trader's Problem

In this section we present a typical trader's decision making problem when he submits his excess demand message in a tâtonnement market. Trader *i*'s objective is to maximize the net value of his foreign exchange trade,[9]

$$\underset{x_i}{\text{Max}} \quad V_i(x_i) - e\left(x_i + \sum_{j=1,\neq i}^{n} x_j\right)x_i \qquad (1)$$

where x_i is *i*'s quantity of foreign exchange, $V_i(x_i)$ is the value that trader *i* places on x_i,, $e(\cdot)>0$ is the exchange rate, and *j* indexes all traders other than *i*. x_i is positive for agents purchasing foreign exchange, and negative for agents selling foreign exchange. Because of the "competitive" pricing structure of a tâtonnement market, the excess demand message of a single trader is binding only in equilibrium, i.e. when all of the traders' messages are consistent and the market clears. For this reason, the equilibrium exchange rate $e(\cdot)$ is a function of the

[9]The specified problem is a static one, i.e. value maximization from a single meeting of the market where the trader calculates the value of foreign exchange based on its current price. This is most directly relevant when trading is dominated by transactions needs, i.e. for import- and export-based activities. Our objective in the theoretical formulation is mainly to motivate the under-revelation hypothesis and to identify a means for testing this hypothesis. Later we also discuss the implications of the dynamic behavior of agents. Madhavan (1992) shows that the rationale for under-revelation should prevail in dynamic environments.

stated excess demands of all market participants.

The necessary condition for a Nash equilibrium at (x_i^*, x_j^*) is [10]

$$V_i'(x_i^*) - e\left(x_i^* + \sum_{j=1,\neq i}^{n} x_j^*\right) - x_i^*\left[\partial e(\cdot)/\partial x_i^* + \sum_{j=1,\neq i}^{n}\left(\partial e(\cdot)/\partial x_j^*\right)\left(\partial x_j^*/\partial x_i^*\right)\right] = 0 \qquad (2)$$

Since no real time information is released when the sealed initial quantity bids and offers are submitted, traders cannot sequentially react to the actions of their opponents. Thus, the conjectural variation $\partial x_j^*/\partial x_i^*$ should equal zero for all j. This implies that Cournot behavior is a reasonable approximation to use in a trader's problem and the necessary condition (2) is rewritten accordingly as (2'):

$$V_i'(x_i^*) - e\left(x_i^* + \sum_{j=1,\neq i}^{n} x_j^*\right) - x_i^*\left[\partial e(\cdot)/\partial x_i^*\right] = 0 \qquad (2')$$

If agent i is a buyer of foreign exchange, then $V_i'(x_i^*) > e(\cdot)$, which means that i under-reveals the true marginal value of his bid quantity. This translates into bidding for fewer units than prescribed by his Walrasian demand. Analogously, if i is a seller of foreign exchange, $V_i'(x_i^*) < e(\cdot)$, so that sellers require a price higher than their marginal valuation of the units sold. In comparison with Walrasian behavior, at every exchange rate sellers offer fewer units of foreign exchange for sale at the auction.

The linkage between under-revelation and the structure of the market is straight-forward to illustrate. Condition (2) also can be expressed as

$$V_i'(x_i^*) = e(\cdot)\left[1 + \partial e(\cdot)/\partial x_i^* \cdot x_i^*/e(\cdot)\right] \qquad (3)$$

Let $s_i = x_i/\left(x_i + \sum x_j\right) = x_i/X$ denote i's market share. Then (3) becomes

$$V_i'(x_i^*) = e(\cdot)\left[1 + \frac{\partial e}{\partial X}\frac{X}{e}s_i\right] = e(\cdot)\left[1 + \frac{s_i}{\varepsilon}\right] \qquad (4)$$

[10] Smith et al. (1982) and Madhavan (1992) present formulations that result in related conclusions.

where ε is the price elasticity of the market's excess demand function. Clearly, as $s_i \to 0$, representing the competitive case, then $V_i' \to e(\cdot)$ and under-revelation disappears. Conversely, as the market share of a player increases, then under-revelation increases. The limiting case of $s_i = 1$ depicts the behavior of a monopolist or monopsonist.

An Example:

For simplicity, consider a two-sided market where the supply side consists of a fringe of competitive agents and the demand side is composed of potentially strategic agents. This setup permits us to develop further insights into the behavior of market participants while avoiding issues of indeterminacies of equilibria that are associated with bilateral monopolies or oligopolies. Suppose that the competitive supply is represented by a linear function

$$e = cX, \quad c > 0 \tag{5}$$

Trader *i* is a net purchaser of foreign exchange, with valuation function:

$$V_i(x_i) = ax_i - bx_i^2, \quad x_i \le a/2b \quad a,b > 0 \tag{6}$$

If *i* is the sole trader on the demand side of the market, the resulting Nash equilibrium demand function is

$$x_i = \frac{a}{2b} - \frac{e}{b} \tag{7}$$

Suppose now that a second identical trader *j* joins the demand side of the market. Nash equilibrium market demand is given by:

$$X = x_i + x_j = \frac{a}{b} - \frac{3e}{2b} \tag{8}$$

By contrast, if both players were Walrasian (competitive) agents, the demands in the one and two-agent cases would be:

$$x_i = \frac{a}{2b} - \frac{e}{2b} \quad , \text{ and} \tag{9}$$

$$X = x_i + x_j = \frac{a}{b} - \frac{e}{b} \tag{10}$$

Setting demand equal to supply, the equilibrium quantities and exchange rates in each case are:

	monopsony	duopsony	one competitor	two competitors
quantity	$a / 2(b+c)$	$2a / (2b+3c)$	$a / (2b+c)$	$a / (b+c)$
exchange rate	$ca / 2(b+c)$	$2ca / (2b+3c)$	$ca / (2b+c)$	$ca / (b+c)$

The strategic under-revelations *SU* with one and two-players on the demand side of the market are given by, respectively:

$$SU(monopsony) = \frac{ac}{(2b+c)(2b+2c)}, \quad SU(duopsony) = \frac{ac}{(b+c)(2b+3c)} \tag{11}$$

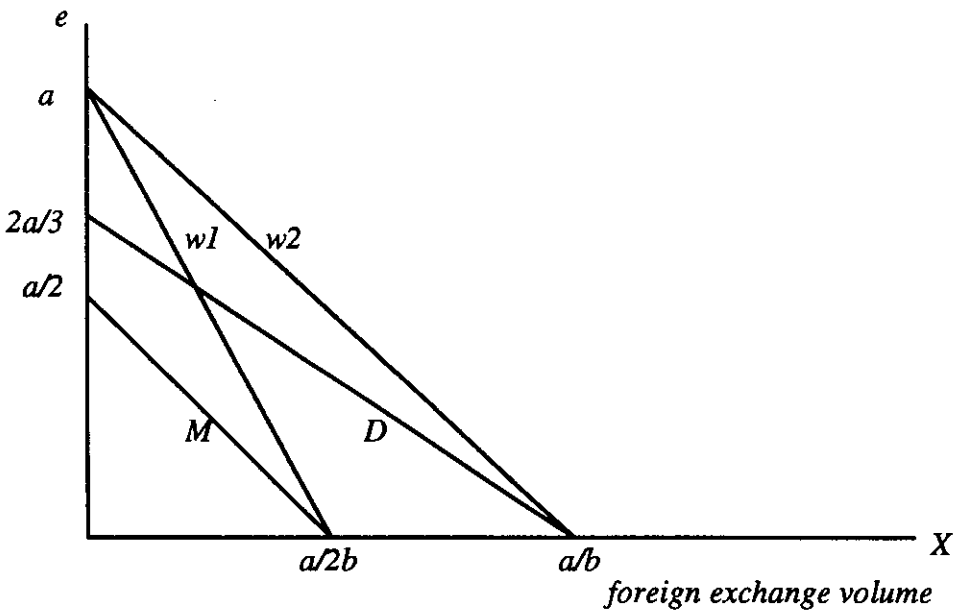
and, using (11), the difference between market under-revelations when there is a new entrant on the demand side is

$$SU(monopsony) - SU(duopsony) = \frac{ac^2}{2(b+c)(2b+c)(2b+3c)} \tag{12}$$

Since this expression is always positive, increased participation on the demand side of the market unambiguously leads to reduced under-revelation.

Plotting the market demand functions for these cases, as in Figure 2, illustrates additional insights concerning the impact of under-revelation on the slopes and intercepts of demand functions. These insights will be especially relevant for empirical analyses of under-revelation using actual market data. Observe from Figure 2 that, as conjectured, strategic demands (*M* and *D*) display under-revelation of quantities when compared with Walrasian demands (*w1* and *w2*). This under-revelation is stronger in the one agent case, where the stated demands are steeper. Our example also shows that the demand quantity intercepts are equal in the strategic and Walrasian cases, both in the context of one and two buying agents. Thus, in this setup, the *difference in the quantity intercepts* between the monopsony and duopsony structures are purely due to aggregation, i.e. they *reflect a pure volume effect. Decreased under-revelation* that results from increased participation must necessarily appear as a *reduction of the absolute*

value of the slope of the market demand function.[11]



M: Monopsony; D: Duopsony; w1: one Walrasian buyer; w2: two Walrasian buyers.

Figure 2

Finally, consider the market outcomes when a competitive player is added to a market where there already exists a concentration of market power. The results from this case, solved below, and combined with our previous results, show that the changes in the intercept of the demand function solely reflect changes in market volumes, while the changes in the slope of the demand function primarily reflect changes in strategic under-revelation.

When a non-strategic (Walrasian) agent indexed by "$-i$" is added to the demand side of a market which already previously contained a single strategic player, equilibrium demands satisfy

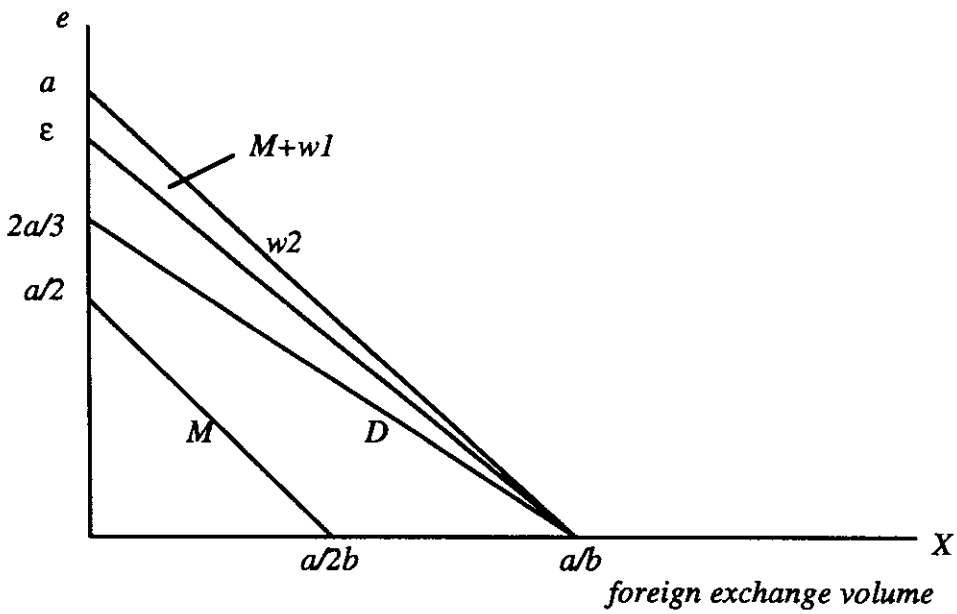
[11]Inclusion of a second trader with a smaller intercept or slope does not alter the results significantly. The difference in intercept reflects a pure volume effect whereas the slope differences subsume both volume and revelation effects. The only substantive difference between this example and the example provided in the text is that the Walrasian single agent will buy more at high prices than the two competitive agents. Since Walrasian demands only are intended to provide a benchmark and are unobservable in practice, testable hypotheses arising from the theory are unaltered.

$$2a - 2b(x_i + x_{-i}) - 2c(x_i + x_{-i}) - cx_i = 0 \qquad (13)$$

Without loss of generality, we can assume that $x_i = k(x_i + x_{-i})$, where k is agent i's share of the market quantity. Since i and $-i$ are identical in every respect, except for i's under-revealing behavior, $k \in (0,1/2)$. Thus, the equilibrium market demand is given by:

$$x_i + x_{-i} = \frac{a}{b} - \frac{(2+k)}{2b}e \quad , \quad k \in (0,1/2) \qquad (14)$$

The slope and intercept of this new market demand curve can now be compared with those of the previously discussed cases of monopsonist, duopsonist, and Walrasian agents. The exchange rate intercept for this case is $\varepsilon \in (4a/5, a)$.



M: Monopsony; *D*: Duopsony;
M+w1: one Walrasian buyer plus one strategic buyer; *w2*: two Walrasian buyers.

Figure 3

As shown in Figure 3, an additional market participant has two potential effects. First, if the extra player is a strategic player, the resulting equilibrium reflects a reduction in under-revelation and appears as the duopsonist case, *D*. However, if, instead, the player is non-

strategic, the resulting equilibrium reflects demands that appear as the *M+w1* case. In this latter scenario, the rotation of the demand schedule reflects volume effects on the market, not changes in under-revelation or strategic behavior. In Figure 3 the *M+w1* equilibrium market demand is drawn for the mean value of k=1/4, which results in $\varepsilon = 9a/10$. Observe that, on average, the slope of *M+w1* is significantly closer to the purely competitive case *w2* than it is to the duopsony case. This shows that as new players enter the market changes in the slope of the market demand function are mainly due to underrevelation.

From our numerical example the change in (inverse) demand slope from *M* to *D* can be decomposed as follows:

Total Slope Change (from *M* to *D*)	$9b/18$
Slope Change from *M* to *M+w1* (volume)	$2b/18$
Slope Change from *M+w1* to D (under-revelation)	$7b/18$

Approximately 80 percent of the slope change is due to under-revelation or strategic effects, while only 20 percent of the slope change is due to addition of a competitive player to the market. Comparable examples based on changing some of the initial assumptions yield qualitatively similar results.

In sum, given data on demand and supply as functions of prices (real exchange rates), the simple theory that we presented distinguishes among the following cases. For the demand side of foreign exchange market: (i) diffusion of existing demand among more players changes competitive structure and under-revelation only. This does not imply an intercept effect but does imply a flatter demand curve (where slope refers to the change in volume brought about by a change in exchange rates); (ii) adding a (non-zero weight) competitive player to an already competitive market yields a positive volume effect and a steeper demand curve; and, (iii) when a competitive player is added to a market with non-competitive players, most of the impact will be in volume (and intercept); and (iv) when a non-competitive player is added to a market which already contains noncompetitive players, there will be a volume increase (intercept effect), and also a steeper demand curve. The slope change primarily reflects the reduction in demand under-revelation by strategic players. We conclude that when the demand curve becomes steeper with additional players, this mainly reflects a reduction in the degree of under-revelation in the market. Positive intercept effects are mainly due to pure increases in transaction volumes. Analogous conclusions can be presented for adding players to the supply

side of the foreign exchange market.

While our theoretical exposition has concentrated on a few simple examples for the tâtonnement auction, there are of course many other cases for which solutions can be considered. For example, variations may start with alternative utility specifications for the agents bidding for foreign exchange. Models could also work with alternative gaming strategies and information structures among the agents. Similar examples to those which we have just presented can be constructed for strategic suppliers competing against a fringe of Walrasian buyers. However, our problem becomes analytically complex when both sides of the market are strategic and the multiplicity of equilibria makes outcomes difficult to compare. While there are many ways in which the results can be modified, we expect that the basic insights from our simple example are qualitatively robust.

Below we perform an examination of activity in a rare example of a tâtonnement market at work, the Russian foreign exchange market. Based on our theoretical findings about the potential for strategic play in this market, one of our objectives will be to seek evidence of this activity. While anecdotal evidence abounds, more formal evidence can only be obtained by analysis of transaction data. In Section III we provide this analysis. In Section IV we relate our theoretical and empirical conclusions to results generated in experimental economics on similar and related market structures.

III. The Russian Foreign Exchange Market

The Russian foreign exchange market operates under tâtonnement rules. The main trading place is the Moscow Interbank Currency Exchange (MICEX), wherein both buyers and sellers of foreign exchange (FOREX) interact and the market is discretely cleared at each session. The clearing procedure is straight forward and similar to the formulation in Section II. The exchange rate quoted at the previous trading session is taken as the opening exchange rate for the day. Prior to each trading session currency dealers submit preliminary applications for selling and/or buying foreign currency. In these preliminary applications, foreign exchange cannot be purchased as a price lower than the opening rate, nor can it be sold at a price higher than the opening rate. If, given this price, there exists an imbalance between initial currency bids and offers, the exchange rate is adjusted in fixed increments by the auctioneer. Dealers then have the opportunity to revise their bids and offers. This process continues until desired volumes from both sides of the market are balanced. The number of banks participating in the

MICEX auctions as well as the volumes of foreign exchange transactions have risen dramatically since the inception of the current auction format in January 1992.[12]

In addition to the number of participants in the market, there are numerous other forces that can influence foreign exchange market activity. Since our analysis utilizes time series data we control for the effects of relevant changes in the rules, policies, and economic fundamentals that influence currency demands and supply. The fundamental determinants include: (a) the expected opportunity cost of holding rubles, represented by the domestic nominal interest rate net of the domestic rate of inflation, $i_t - \pi_t$;[13] (b) the profitability of leakages into black markets. Since auction and black market exchange rates are simultaneously determined, we proxy the profitability of leakages by the lagged black market premium, δ_{t-1};[14] and (c) a vector of zero-one dummy variables Z reflecting the actual policy changes summarized in Appendix Table 1, and relevant rumors and announcements summarized in Appendix Table 2. Policy measures which could have influenced demand or supply for foreign exchange include changes in bank licensing, regulation of foreign currency transactions, regulation of external trade activity, the foreign exchange surrender regime, and incentives transmitted through inter-related markets.[15]

Net foreign asset demands and the ruble - dollar exchange rate also are intricately related to goods prices and other asset prices. In our empirical analysis we include the secondary market exchange rate and the premium on "cash" activities as potentially important determinants of the relative attractiveness of "noncash" official markets such as MICEX.[16] Real

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[12]Foreign exchange auctions began in November 1989 in Russia (the USSR at that time) and were held weekly throughout most of 1991. While the MICEX was not the formal trading institution until January 1992, the largest players in this currency market participated in the earlier auctions. The interbank market met weekly from April 1991 through March 1992. The market then met bi-weekly until early June 1993 when trading expanded to four sessions per week, and further expanded to five sessions per week later in June 1993.

[13]We assume that the contemporaneous and expected inflation rates are equal. In calculating the annual inflation rates, January 1992 and the week of January 5, 1993 yield very high numbers since price reforms occurred at these dates. A dummy variable is added to the regressions to capture these high inflation/ price reform periods. The real interest rate is constructed using the interbank market interest rate. Since the real interest rate in Russia is negative throughout our sample period we use the negative of the real interest rate in regressions, i.e. inflation less the nominal interest rate, in order to take logarithms of this variable.

[14]This premium is constructed using cash exchange rates and "effective" MICEX exchange rates. The data appendix provides further details.

[15]Institutional details and further discussion of policy changes are provided in Goldberg and Tenorio (1995).

[16]In Russia there is a distinction between noncash account transactions, such as those channeled through MICEX, and cash transactions. Noncash or credit activities dominate those of large enterprises and official sector transactions. Cash operations prevail between individuals and small private agents.

interest rates in the domestic economy indicate the cost of borrowing in rubles for the purpose of purchasing foreign exchange (or indicate the opportunity cost of selling foreign exchange).[17] Changes in real rates alter the relative attractiveness of current and future transactions in foreign exchange. Due to these portfolio motives, real interest rates should be inversely related to both net foreign exchange demand at MICEX and the ruble-dollar exchange rate.[18]

Actual and expected inflation rates affect the real opportunity cost of holding rubles and are influenced by announcements about future monetary policy and price reforms. For example, if price reforms are expected to spur an increase in inflation, agents (including banks) will attempt to readjust their portfolio of assets toward foreign exchange. This is expected to cause an increase in the net demand for foreign exchange and an immediate depreciation of the ruble at MICEX. In our empirical work we consider the possibility that rumors to have independent effects, or may have effects already subsumed within movements in real interest rates and cash market premia.

Finally, a time series analysis of auction data would be incomplete without consideration of additional intertemporal features of trading decisions and outcomes. From a micro-market perspective, two main forces potentially link traders' behaviors and market outcomes across periods. The first force is due traders learning about their valuations of foreign exchange in relation to market valuations. The value of the dollar is neither exogenously given to each trader (the "private values" paradigm), nor is it common to all traders (the "common values" paradigm). Rather, a trader's value may be linked to both his (private) ability to use or "transform" dollars, as well as to economy-wide (common) considerations. Thus, in a FOREX auction, the currency traded falls within the category of "correlated values," which implies that a trader may learn about his value by observing signals within as well as outside of the market.

Second, traders may simply become more experienced at playing the game and at disentangling opponents' strategies after repeated market sessions. Experiments on repeated games usually show that even inexperienced agents can capture the gains from trade in early periods. However, repetitions may make strategic agents more aware of their price-setting power. Consequently, market participants may become more skilled at capturing their potential

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[17]Two key interest rate series operated in Russia during the period of our analysis. A government controlled fixed interest rate, the Central Bank refinance rate, is used for commercial bank borrowing from the Central Bank. Since new commercial banks rarely rely on CBR credits for their funds and instead rely more on interbank loans, the rate that we use in our analysis is the flexible interbank market interest rate.

[18]Goldberg and Karimov (1993) address this theme in greater detail.

surpluses over time. Dynamic behavior by such agents was confirmed in the results of Joyce's (1984) experiment using tâtonnement auctions: when players on the supply side of the market were segregated from players on the demand side so that more information accrued about each side's depth, the relative surplus of the more skilled group (the buyers) increased in successive repetitions.

Third, behavior across periods may simply be due to institutional delays which slow the implementation of desired behaviors by market participants. In each period there may be dampened effects of shocks from previous periods.

Estimating Equations and Data

The estimation period is January 1, 1992 through August 31, 1993. Our testing equation takes the form:

$$X_t^{initial} = \alpha_0 + \alpha_{0,j} Bdum_t^j + \left(\alpha_1 + \alpha_{2,j} Bdum_t^j\right) \cdot RER_{t-1} + \alpha_3 \cdot \left(-i_{t-1} + \pi_{t-1}\right) + \alpha_4 \cdot Z_t + \alpha_5 \cdot \delta_{t-1} + \alpha_6 \cdot X_{t-1}^{initial} + \varepsilon_t \quad (15)$$

where $X_t^{initial}$ is logarithm of initial bids for foreign exchange ($X_t^{d,initial}$) or the logarithm of initial offers of foreign exchange ($X_t^{s,initial}$).[19] Z represents a vector of events dummies.[20] The logarithm of the real exchange rate *RER* enters with both a constant coefficient and with an interactive dummy coefficient. The dummy variable vector $Bdum_t^j$[21] delineates discrete

[19]We do not use equilibrium trade volumes as the dependent variables because these quantities are more likely to be significantly distorted by CBR foreign exchange intervention activities than are the initial volumes data. In principle, intervention occurs only after the initial bids and offers are reported, however, in practice there is little concrete information about the procedures for intervention.

[20]Within this vector, dummy names refer to the specific events. The prefix "tx" refers to changes in export policy, "tm" to import policy, and "ar" to announcements of pending reforms. Particular reforms are indicated by a date suffix. Announcement dummies are equal to zero for three weeks following and inclusive of an announced policy initiative. The exception is the February 5, 1993 dummy, since this announced initiative was quickly retracted. *Rdum* and *Parliam* dummy variables are used in all regressions. *Rdum* is one during price reform periods of January 1992 and the first week of January 1993. This term is introduced into the regression equations to offset extreme values of annualized inflation that enter through the real interest rate term. *Parliam* is one during the parliamentary coup and zero otherwise.

[21]The perceived market structure is assumed to be identical to the actual market structure in any auction since more detailed information about perceptions is unavailable. In practice, once trading begins in a market, strategic interactions and deviations from Walrasian supply can occur in a variety of ways.

groupings of numbers of auction participants and changes in the regulation of auction participation: j=1 refers to bank participation rates of more than 41 banks; j=2 refers to participation by 52 or more banks; j=3 corresponds to June 30, 1993 onwards and delineates the tightening of regulation on bank capitalization in relation to foreign exchange holdings. The dates for which these dummy variables are zero and one are summarized in Table 1.

Table 1 Dates of Dummies for Numbers of Banks Participating in Auctions

bdum1=*bdum2*= *bdum3*=0	*bdum1*=1; *bdum2*=*bdum3*=0	*bdum1*=*bdum2*=1; *bdum3*=0	*bdum1*=*bdum2*= *bdum3*=1
1/3/92-7/24/92	7/28/92-10/2/92; 10/13/92-10/23/92; 11/3/92-12/4/92	10/6/92-10/27/92; 12/8/92-3/5/93; 3/16/93-7/2/93	7/6/93-11/16/93

The use of the *Bdum* vector in the estimating equation is intended to address the impact of potentially altering the competitive structure of the market by introducing new players or eliminating small undercapitalized players. When players are added to the market, as with *bdum1*=1 and *bdum2*=1, our theoretical exposition suggests the pattern of interpretation of the signs of intercept and interactive dummy variables shown in Table 2. The opposite sign pattern of coefficients could be observed with *bdum3*=1, since this variable is interpreted as representing a policy consistent with eliminating players rather than introducing additional ones.

Table 2 Strategic Under-revelation and Regression Coefficients

	Demand for Dollars		Supply of Dollars	
	intercept	slope	intercept	slope
diffusion of existing volumes: a change in competitive structure of the market only	$\alpha_{0,j} = 0$	$\alpha_{2,j} > 0$	$\alpha_{0,j} = 0$	$\alpha_{2,j} < 0$
no change in under-revelation	$\alpha_{0,j} > 0$	$\alpha_{2,j} < 0$ (weak)	$\alpha_{0,j} > 0$	$\alpha_{2,j} > 0$ (weak)
reduced under-revelation by strategic players	$\alpha_{0,j} > 0$	$\alpha_{2,j} < 0$ (strong)	$\alpha_{0,j} > 0$	$\alpha_{2,j} > 0$ (strong)

Finally, implementation of regressions using estimating equation (1) also nest the issues of dynamic responses and learning across foreign exchange auction sessions. In econometric terms, the presence of learning is likely to result in heteroskedastic errors. This would arise because the trader's accuracy of play may change over time and therefore could be systematically related to the error term. We check for heteroskedasticity and, if present, re-estimate the OLS regressions using White's (1982) correction methodology. We test for dynamic activity by examining whether inclusion of lagged dependent variables influence current values of the dependent variables. Likewise, we check for serially correlated residuals.

The data on initial foreign exchange bids, initial foreign exchange offers, net initial foreign exchange demand, and other series used in the regressions are described in Table 3. The means, standard deviations, minimum values, maximum values, and unit root features are summarized. In the early part of our sample period, January through March 1992, average weekly transaction volumes were US$11.30 million. By the summer of 1993, average weekly transaction volumes had elevated to US$266.34 million. Excess initial demand relative to market volumes was considerably higher in absolute terms in the early part of the sample but varied considerably over time. Both bid and offer data exhibited positive trends, but the net excess demand series had a trend insignificantly different from zero. None of the volume data or the real exchange rate series have unit roots.[22]

[22]Another issue which arose in testing and system specification concerns the choice of data frequency. The

Table 3 *Features of the Data*

	mean	std.dev.	maximum	minimum	unit root[3]	trend
initial bids[1]	46.68	28.37	146.56	2.47	reject	positive
initial offers[1]	43.25	25.01	135.7	4.35	reject	positive
real ex.rate	24.96	24.04	150.00	7.98	reject	negative
REER	20.66	15.23	106.00	7.98	reject	negative
cash premia[2]	9.50	10.88	31.84	-21.43	no reject	none

[1]: in millions of US dollars, data from Tuesday sessions

[2]: cash exchange rate divided by the noncash effective exchange rate

[3]: Augmented Dickey-Fuller tests. "Reject" implies rejection of unit root null.

The initial bid and offer data represent the activities of the private agents participating in both sides of the MICEX market. Included among these licensed banks are net providers of foreign currency to the interbank market, on balance reflecting the decisions of the exporters with whom they are associated. This contrasts with auction arrangements in many developing countries wherein the central bank controls the supply of foreign currency to the auction. The Central Bank of Russia also participates in the MICEX market. Through intervention activities, at times the Central Bank of Russia has pursued target (nominal) exchange rates, as in April through June 1992, or attempted to limit the volatility of exchange rates.[23] The auction

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frequency of auctions (and of exchange rate and trade volume data) changed during our sample period from weekly, to twice per week, and ultimately to daily sessions. However, the finest frequency in availability of the other variables entering in the regression equations, i.e. the interbank market interest rates and black market premia, is weekly. Two types of regressions were run to deal with this issue. First, we selected a particular day of the week, Tuesdays, and used this date as representative of trading volumes and activities for the week. Second, we constructed weekly weighted sums of order imbalances and weighted averages of initial session exchange rates. Each session within a week is weighted by the ratio of total session volume to the sum of volumes from all sessions during the week. The results are qualitatively similar for all variables except the exchange rate terms. However, since the Tuesday data are expected to yield more meaningful results than the weighted variables, we report only those regressions.

[23]In the period of our estimation, attempts to manipulate exchange rates were conducted using foreign exchange sales and less frequently purchases. This contrasts with actions in 1990 and 1991 wherein participants in the auctions sometimes were persuaded by non-price means to limit their activities at particular sessions.

guidelines state that CBR intervention activity should occur *within* the trading session, *after* initial excess demands were observed. Although we cannot verify that these guidelines actually are followed, we also have no immediate means of determining if, when (within a session), and by how much the CBR intervened.

Two alternative real exchange rate specifications are utilized in our regressions: a real exchange rate (*RER*) and a real effective exchange rate (*REER*). "Effective" exchange rates are distinguished from observed market exchange rates in that they adjust for foreign exchange surrender (FXS) taxation imposed on exporters.[24] This adjustment is important mainly for the supply side of the market, since FXS taxes on exporters selling currency at the auctions have been as large as thirty percent of their earnings.

Since the adjustment for FXS taxes pertains mainly to exporters and the supply side of the equation, the relevant real exchange rate for tests on initial orders of foreign exchange is the effective exchange rate measure. The unadjusted real exchange rate is used for the initial bid equations. In the order imbalance (*net* initial foreign exchange demand) equations we try both exchange rate measures. When the relevant exchange rate variable is utilized in equation (1), it is the logarithm of the prior session's (t-1) closing exchange rate since, according to the rules of MICEX, this is the price relevant for initial market bids and offers.[25] The black market premium is constructed as the ratio of the black market exchange rate to the relevant real exchange rate series.

ESTIMATION RESULTS

Tables 4 and 5 report the results of various specifications of regressions of initial bids and initial offers after elimination of those events-dummy variables that were clearly statistically insignificant. In some regressions lagged volume data are included as explanatory variables with their coefficients interpreted as reflecting dynamic responses to impulses. Some regressions include a trend term, although this term has no true structural interpretation given our description of market fundamentals.[26]

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[24]See Goldberg (1993a).

[25]Real exchange rates are constructed by deflating the nominal exchange rates from the prior session by the current period's price level.

[26]Some regressions exclude the additive *Bdum3* term. The reason for this exclusion is the degree of colinearity between this additive term and the interactive *Bdum3* expression. These two series are highly correlated because variability in the real exchange rate is limited during the period in which *Bdum3* is defined equal to one.

<<Insert Table 4 and Table 5>>

Significance of Fundamental Variables for Foreign Exchange Demand and Supply: In equations of foreign exchange demands, both real interest rates and cash market premiums have the expected signs, although the statistical significance of these terms depends on the regression specification. Increasing real interest rates lower the demand for foreign exchange while increasing the cash market premia raise the demand for foreign exchange through legal channels. In periods of price reforms, the *RDUM* dummy shows that demand for foreign exchange is significantly less than that which the pure interest rate elasticities operating over temporarily high negative annualized real interest rates would predict. The real exchange rate enters with the expected sign and also is statistically significant: increasing the price of foreign exchange lowers the real demand for foreign exchange.

In Table 5, equations of foreign exchange offered indicate that the supply of foreign exchange at MICEX appears to be insensitive to real interest rates, although in periods of price reforms there is significantly less supply. Premiums of secondary market / cash exchange rates relative to MICEX exchange rates were expected to have a negative effect on supplies to the official auctions, however the effects of this fundamental variable take the wrong sign and are statistically significant. Likewise, the real exchange rate variable takes the wrong sign in the base period. The foreign exchange regime reform of 7/3/92 significantly increased currency supply at auction, while the prior announcement (on 5/6/92) of an intention to implement a controlled exchange rate significantly reduced foreign exchange sales.

Import and export policy measures generally did not have statistically significant effects on foreign exchange supply or demand. Among the few import tariff changes with statistically significant effects on foreign exchange demands, the direction of the effect was the opposite of that intended: "stiffer" tariffs were associated with increased rather than reduced foreign exchange demands. As documented by the World Bank (1993), this is most likely due to poor enforcement and increased differentiation.[27] Laws attempting to increase repatriation of foreign exchange earnings did not lead to significant increases in supply of foreign currency to the auctions. With the exception of the major reform of July 3, 1992, exporters did not modify their use of auctions in response to these laws.

[27]Another explanation is that the dummies are simply picking up time trends in demand. This explanation is unconvincing since the coefficients on the policy dummies do not uniformly enter with a positive sign.

Indication of dynamic market activity: On both sides of the market changes in fundamental variables have persistent effects on market activity. In addition to contemporaneous impacts, the autoregressive term shows an additional thirty percent response in one week, an additional nine percent response in two weeks, and in three weeks the effect is essentially dampened out with an additional three percent response. Overall it takes approximately one month for the effects of a one period policy impulse to be fully realized in the foreign exchange market.

Under-revelation and Strategic Considerations: On the demand side of the foreign exchange market the signs and significance patterns on the *bdum1* terms are consistent with reduced transaction volumes and heightened strategic play among market participants.[28] This result runs counter to our expectations regarding the effects of adding these new players to the market. A plausible explanation is that the dates of the *bdum1* =1 closely correspond to the introduction in early September 1992 of a set of restrictive import taxes. It is possible that this sharp increase in taxes reduced the activity of numerous players in the market, while simultaneously strengthening the relative positive of a smaller set of dominant players. It was not uncommon for dominant players in the market to negotiate less deleterious import taxes or even exemptions. On the demand side the new entrants indicated by *bdum2* terms lead to market outcomes strongly consistent with the reduced strategic play hypothesis. These additional players both added to total market demands and reduced the monopsony power of existing players. The signs and significance patterns on the *bdum3* terms, reflecting the impact on the demand side of the market of tightened bank capitalization requirements, suggest that these measures had little effect on foreign exchange demand.

On the supply side of the market we do not find evidence that new entrants reduced the exercise of market power by existing players. First, the basic exchange rate term has a negative sign. This may be due to the fact that during a significant portion of the January to July 1992 interval (when all interactive dummies are zero), the Central Bank of Russia announced and pursued a policy of heavy foreign exchange intervention to achieve gradual ruble appreciation. Foreign exchange round-tripping activities were reported to be rampant. Despite the fact that

[28]Recall that *bdum1* and *bdum2* represented expanded number of participants in the MICEX market, while *bdum3* reflects a tightening of capitalization requirements for bank activity, a policy initiative aimed at restricting the number of relatively small players in the foreign exchange market.

the ruble was appreciating, supply of dollars to the market increased on the expectation of further appreciation. Market participants later bought back their rubles at even lower prices (Goldberg, 1993). This activity ended in May 1992 after a steady loss of foreign exchange reserves resulting in a reinstituted floating exchange rate.

Given the background against which the number of participants in the auction was increased, the interactive *bdum1* term shows that elasticity of supply with respect to exchange rates was of the correct sign and highly significant. When the number of auction participants rose further, corresponding to the *bdum2* terms defined equal to one, the supply curve became flatter and offers of foreign exchange increased. This implies increased volumes but does not suggest a reductions in strategic under-revelation by existing suppliers. The coefficient on the *bdum3* dummy is consistent with reduced under-revelation of demand and does not support the hypothesis that the increased capitalization increased the concentration of market power on the supply side of the auction.

In sum, our empirical analysis supports two main conclusions. First, this foreign exchange market was responsive to macro-economic fundamentals and any related tests of microstructure hypotheses should account for this responsiveness. Second, most of the observed response to changing the number of market participants appeared on the demand side of the auction. In general, our results support the perception that the among the thirty-two banks which initially established MICEX, those acting on the supply side of the market retained power relatively unscathed by new entrants. This is consistent with the perception that the initial supply-side participants were representatives of the major raw materials and related exporting conglomerates in Russia, a dominant source of foreign exchange in Russia.

IV. Relationship to Results in Experimental Economics

In this section we address two main points. First, we consider the appropriateness of using the number of banks participating in the auction as an indicator of possible changes in the competitive structure of the auction. Second, we ask whether our results are general enough to provide useful lessons. In addressing both of these points, we appeal to lessons drawn from experimental economics. We believe that integrating these lessons into the study of foreign exchange market microstructures could be fruitful.

A priori it is not clear to what extent the raw number of banks is a good proxy for

market concentration.[29] The majority of related studies in experimental economics are on double auctions, but, with very few exceptions, these studies show that *convergence to a Walrasian outcome obtains regardless of the number of traders.*[30] In the double auction context Smith and Williams (1989) show that traders do not tend to exert monopoly pricing behavior or to restrict supply. Based on experiments over five monopoly markets and four duopoly markets, these results have been attributed to the sequential nature of transactions under the *discriminatory* pricing rule (but not the competitive pricing rule of the tâtonnement auction). By selling units at different prices, the buyers become informed that monopolists are able to make profitable trades at lower prices. In future auctions buyers response by withholding their purchases until prices fall and monopoly rents are dissipated. For double auctions, this type of result has led to the conclusion that the institutional features of markets are more important that traditional structural characteristics -- like the number of agents -- in determining which market outcomes will correspond to the predictions of the competitive model. Smith (1982) has termed this the "Hayek Hypothesis".

For experimental double auctions the only exception to the competitive outcomes result arises under conditions of *extreme concentrations of market power.* Holt, Langan and Villamil (1986) observe under-revelation when some traders are endowed with a large fraction of the total units supplied to the market. The exercise of monopoly power becomes even more pronounced as traders gain experience. This result also was confirmed in the experiments by Davis and Williams (1991).

It is not obvious that the general experimental conclusion of convergence to Walrasian outcomes regardless of numbers of players applies to outcomes under tâtonnement auctions. Because of the competitive or uniform pricing rules, tâtonnement markets do not permit the type of price discrimination observed in the double auctions. Monopolistic actions may remain feasible since withholding (of demand or supply) affects price and surplus for every unit traded. This latter result is not true under the discriminatory pricing of the double auction where withholding only influences the returns on sequential trades, and where market participants

[29]In the case of the Russian foreign exchange auctions, the only data available on market participation is data on the number of banks. This discussion is intended to aid in interpretation of these numbers.

[30]The original insight is due to Smith (1982). Davis and Holt (1993) provide a summary of related results. Holt et al. (1986) is the lone exception. They observe under-revelation when some traders are endowed with a large fraction of the total units, especially as traders gain experience. Davis and Williams (1991) find some support for the under-revelation hypothesis in the presence of market power.

learn more about the bounds of prices (i.e. exchange rates) acceptable to the monopolist.

These arguments underscore the importance for auction outcomes of the distribution of information about buyers and sellers in a market. The actual practice of under-revelation under alternative information conditions under tâtonnement was first tested by using a controlled experiment by Joyce (1984). He found that (a) both buyers and sellers tend to equally under-reveal when both groups are not segregated, and (b) buyers tend to under-reveal more --and reap larger gains from trade-- than sellers when both groups are segregated. Although this latter result remains an analytical puzzle, Joyce speculated that it could originate in the fact that experimental subjects tend to be more skilled acting as buyers than as sellers. Bronfman et al. (1994) also ran a set of experiments that allow for multi-unit demand conditions and find that traders under-reveal in most cases. Unlike Joyce, these experiments were not characterized by significant differences in under-revelation by net suppliers and net demanders.

Although our results and those of Joyce suggest that the demand side of the market exhibited more dynamics of strategic under-revelation, *a priori* clear it is not clear which side has a stronger incentive to behave strategically, especially in a market where any trader is potentially a buyer or a seller. It is even conceivable in this case that, depending on the information revealed during the tâtonnement process, traders holding dollar or ruble inventories may strategically change not just the magnitude but also the sign of their excess demands. Vickrey (1961) considered the simple case where traders have private values and the market is symmetric with respect to excess demands --that is where both the positive and negative excess demand schedules are the same. In this case both sides of the market will equally understate their excess demands, so that in equilibrium the price will be Walrasian but the quantity will be below the Walrasian level. Madhavan (1992) arrives at the same conclusion using a more general setup. On the other hand, if concentrated market participants swing between acting as buyers and sellers of foreign exchange, the potential for strategic market behavior can contribute to the volatility of real exchange rates.

Besides the experimental studies, very little is known about the empirical properties of tâtonnement markets. Jarecki's (1976) description of the institutional aspects of the "London Gold Fixing" market is the only noteworthy reference on the issue. In this market, five traders -- representing themselves and/or their clients-- meet twice daily and "fix" the price through tâtonnement. While the small number of traders and their inventory-holding abilities suggest that there is room for strategic behavior, the large number of clients that each may represent

during trading creates room for more competitive behavior. The market meets twice a day; there is frequent feedback between banks and clients during the fixing sessions; and the same agents have been meeting in the market for years. No hard evidence exists on how the confounding forces in this market affect price formation and trading volumes.

In sum, the experiments show that outcomes with under-revelation can be observed in tâtonnement markets where a few traders are well-informed and aware of their market power. Extreme concentrations of market power were not required for this result. This contrast between tâtonnement and double auctions suggests that a competitive price market provides more incentives for excess demand under-revelation that a negotiated price market. Because under tâtonnement all of the units are traded at the same price, traders can "move" the entire market up or down by understating their excess demands. This outcome is not possible in a double auction where each transaction is priced on a bilateral negotiation basis.[31] As a result of strategic behavior, in the experimental results tâtonnement usually results in more efficiency losses than in double auctions where there almost always is convergence to Walrasian outcomes.

V. Concluding Remarks

Lessons from market microstructure analysis can be quite important for foreign exchange markets. Especially for developing economies and newly emerging markets, the market-determined pricing of foreign exchange is crucial for efficient allocations of productive factors and reduced distortions in trade. This underscores the importance of understanding the effect on foreign exchange market outcomes of the institution used for foreign exchange trades. The tâtonnement market specifies uniform pricing of foreign exchange and discrete two-sided trading sessions.

As compared with the closest alternative two-sided auction structure, the double auction with discriminatory pricing rules, tâtonnement has greater potential for strategic interactions among market participants. Strategic play among market participants is likely to lead to lower elasticities of response of excess demand in relation to exchange rate movements and smaller quantities traded in the market. Thus, although the tâtonnement market has the advantage of presenting market participants with a single clear market-determined exchange rate, its

[31]In addition, it has been shown that as traders become more experienced and conscious of their price-setting attributes, the potential for engaging in strategic behavior increases. Joyce (1984), Holt et al. (1986).

disadvantage is the greater potential for agents to manipulate this rate. Because of the potential for strategic under-revelation, tâtonnement auctions may tend to be thinner than double auctions.

Other related themes are important to the comparison between tâtonnement and double auctions. Bulow and Klemperer (1994) and Madhavan (1992) show that markets that clear through a sequence of trades, as does the double auction, are more likely to result in higher price volatility than markets with periodic trading, like the tâtonnement. Both of these papers emphasize that suboptimal diffusion of information takes place in a sequential trade market. Indeed, Madhavan also shows that, in a periodic auction, informational asymmetries among players can present conditions for greater market efficiency at information aggregation than observed in the continuous double auction.

While there have been few empirical analyses of the implications of a particular FOREX auction format, evidence of "strategic quantity reduction" under uniform pricing rules has been confirmed elsewhere. Tenorio (1993a and 1993b) finds evidence in the one-sided foreign exchange auctions implemented in Zambia. Aron and Elbadawi (1993) find support for under-revelation in the Nigerian experience with one-sided auctions: banks generally did not bid for their full allowed quotas of foreign exchange in competitive auctions, while they did bid their full quotas in discriminatory auctions.

When strategic under-revelation occurs only on the bid side of the market, e.g. by importers and other purchasers of foreign exchange, volumes of foreign currency traded are reduced and the domestic currency becomes more appreciated in comparison with outcomes from a competitive Walrasian market. Given the added potential for strategic under-revelation on both sides of the market, volumes are even further limited than in the one-sided market. Relative to its closest alternative market microstructure, the double auction, foreign exchange trading activity can be relatively thin. Moreover, while there also are implications for market determined levels of exchange rates, these implications depend on the relative extent of under-revelation by purchasers and suppliers of foreign exchange.

Policy-makers considering alternative auction structures have recognized the importance of increasing competition and expanding access to thin markets (Quirk et al., 1987). These insights are born out by the theoretical and empirical results that we have provided in this paper. New entrants can reduce the concentration of market power and the ability of existing agents to manipulate prices.

In Russian markets the new entrants appeared to reduce strategic under-revelation mainly on the demand side of the market, while the supply side competitive structure remained intact. While we believe that the testing methodology that we present and the results are important, we also recognize that Russia's experience is purely suggestive and clearly not conclusive. This is especially true because the extensive changes in the regulatory environment over Russian trade and transactions during the period complicate empirical study. Nonetheless, the results are strongly suggestive despite the attendant econometric difficulties.

In closing, our view is that the study of foreign exchange markets can draw and build upon important lessons from market microstructure theory, experimental work, and related empirical analyses. This merging of lessons is an open area for research. Although a host of literature exists on tradeoffs related to the choice of exchange rate regimes, i.e. fixed versus flexible, and on the statistical properties of exchange rates, a comparable body of work is lacking relating to the interaction between exchange rate determination and the market microstructure used to implement foreign exchange trade.

Table 4 Initial Bids (Demand) for Dollars at MICEX, 1992-1993

$$X_t^{initial} = \alpha_0 + \alpha_{0,j} Bdum_t^j + \left(\alpha_1 + \alpha_{2,j} Bdum_t^j\right) \cdot RER_{t-1} + \alpha_3 \cdot \left(-i_{t-1} + \pi_{t-1}\right) + \alpha_4 \cdot Z_t + \alpha_5 \cdot \delta_{t-1} + \alpha_6 \cdot X_{t-1}^{initial} + \varepsilon_t$$

	(1)	(2)	(3)	(4)	(5)
lag-1(bid)		0.319***	0.347***		
		(0.095)	(0.089)		
bdum1	-4.328*	-7.031***	-7.634***	-7.344***	-4.658*
	(2.260)	(2.080)	(1.945)	(2.305)	(1.894)
bdum2	3.700*	6.283***	6.439***	6.909***	4.872*
	(2.078)	(2.278)	(2.009)	(2.167)	(1.926)
bdum3	3.961*	0.443			
	(2.395)	(1.531)			
Real ER	-0.817*	-1.508***	-1.975***	-1.878***	-1.167***
	(0.420)	(0.533)	(0.411)	(0.498)	(0.327)
bdum1*	1.445*	2.508***	2.747***	2.603***	1.564**
Real ER	(0.758)	(0.734)	(0.685)	(0.812)	(0.629)
bdum2*	-1.155*	-1.937***	-1.980***	-2.143***	-1.521**
Real ER	(0.677)	(0.723)	(0.640)	(0.699)	(0.626)
bdum3*	-1.462	-0.051	0.067	0.114	0.100
Real ER	(0.910)	(0.589)	(0.078)	(0.098)	(0.101)
- (i_{t-1}-π_{t-1})	0.010	0.047**	0.044*	0.016	0.019
	(0.023)	(0.047)	(0.025)	(0.025)	(0.025)
Cash prem-	1.720***	1.313***	0.190	0.844*	0.740
ium(#lags)	(0.629)(t-1)	(0.490)(t-1)	(0.526)(t-2)	(0.522)(t-2)	(0.527)(t-2)
log(trend)		-0.903**	-0.956***	-0.754*	
		(0.428)	(0.346)	(0.405)	
constant	6.058***	9.459***	10.946***	11.463***	7.045***
tm070392	0.533*	0.427***	0.400*	0.650**	0.567**
tm040193	0.278	0.294**	0.244*	0.275	0.100
ar050692	-0.863***	-0.981***	-0.953***	-1.075***	-1.109***
ar091592	0.455*	0.500***	0.555**	0.464*	0.462*
Rdum	-0.573**	-0.819***	-0.629***	-0.605**	-0.497**
Parliam	0.015	-0.017	-0.063	0.107	0.087
adj. R2	0.927	0.934	0.931	0.929	0.923
D.W./D.H.	1.959	0.319(DH)	0.567(DH)	1.859	1.845
ρ <1>	0.555***			0.385***	0.411***
SSR	7.571	6.911	7.155	7.741	8.079
hetero	reject	corrected	reject	reject	reject

standard errors in parentheses. *=10%,**=5%,***=1%signficance. <1> Cochrane-Orcutt or Beach-MacKinnon method used.

Table 5 Initial Offers (Supply) of Dollars at MICEX, 1992-1993

$$X_t^{initial} = \alpha_0 + \alpha_{0,j} Bdum_t^j + \left(\alpha_1 + \alpha_{2,j} Bdum_t^j\right) \cdot RER_{t-1} + \alpha_3 \cdot \left(-i_{t-1} + \pi_{t-1}\right) + \alpha_4 \cdot Z_t + \alpha_5 \cdot \delta_{t-1} + \alpha_6 \cdot X_{t-1}^{initial} + \varepsilon_t$$

	(1)	(2)	(3)	(4)	(5)
lag-1 (offer)	0.271*** (0.092)	0.304*** (0.095)	0.314*** (0.094)		
bdum1	-4.159*** (1.383)	-3.902*** (1.420)	-3.861*** (1.414)	-5.218*** (1.534)	-3.750** (1.820)
bdum2	4.392*** (1.480)	3.301* (1.713)	3.806** (1.544)	5.608*** (1.543)	4.384** (1.746)
bdum3		0.933 (1.352)			
Real EER	-0.531** (0.246)	-0.498* (0.252)	-0.501** (0.251)	-0.779*** (0.244)	-0.388 (0.358)
bdum1* Real EER	1.529*** (0.464)	1.440*** (0.476)	1.423*** (0.474)	1.925*** (0.510)	1.343** (0.641)
bdum2* Real EER	-1.396*** (0.491)	-1.022* (0.576)	-1.202** (0.513)	-1.776*** (0.510)	-1.407** (0.565)
bdum3* Real EER	0.293*** (0.069)	-0.057 (0.510)	0.291*** (0.071)	0.361*** (0.073)	0.335*** (0.076)
$-(i_{t-1}-\pi_{t-1})$	-0.007 (0.021)	0.001 (0.022)	0.002 (0.022)	-0.021 (0.020)	-0.016 (0.020)
(t-2)Cash premium	0.720* (0.370)	0.778** (0.390)	0.720* (0.379)	0.792** (0.393)	0.758** (0.392)
log(trend)					0.390 (0.265)
constant	3.970***	3.666***	3.651***	5.652***	3.409***
tx070392	0.290*	0.311*	0.305*	0.447**	0.329
ar050692	-0.696***	-0.699**	-0.693**	-0.737***	-0.743***
Rdum	-0.695***	-0.722***	-0.720***	-0.717***	-0.663***
Parliam	0.284	0.285	0.290	0.406*	0.397*
adj. R2	0.941	0.936	0.937	0.939	0.940
D.W./D.H (p-value)	0.978 (0.328)	0.7291 (0.466)	0.5953 (0.552)	1.982	1.990
SSR	5.567	5.738	5.773	5.704	5.556
hetero	reject	reject	reject	reject	reject
ρ	----	---	---	0.290***	0.316***

standard errors in parentheses. *=10%,**=5%,***=1%significance. Cash premium constructed using nominal effective exchange rates. For calculation of autoregressive residual, Beach-MacKinnon methodology is applied.

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Appendix 1

Appendix Table 1	**Discrete Events Influencing Supply and Demand for Currency at MICEX**
7/3/92	Increased taxation of exports (although exemptions are granted over time and presumably dampened the effectiveness of this initiative). Reduced effective taxation of exporters through foreign exchange surrender regime.
	Increased tariffs on imports.
	CBR gets reduced FXS revenues from exporters (although the CBR gradually regains these revenues in the last quarter of 1992 and first quarter of 1993 by delaying crediting accounts of exporters with rubles for surrendered foreign exchange.)
9/1/92	Increase in import tariffs
2/1/93	Increase in import tariffs
3/9/93 & 3/23/93	Laws tightening regulation of foreign exchange earnings from exporting and attempting to improve repatriation. Nonresidents admitted to currency exchange as seller; increased restrictions on who can purchase foreign exchange.
4/1/93	Increase in import tariffs
7/1/93	Foreign exchange surrender system altered: exporters to sell portion of foreign exchange earnings directly on MICEX instead of turning this over to the CBR. This could imply improved compensation terms for exporters (since CBR can't delay ruble account crediting). This also would imply reduced FOREX revenues of CBR (and reduced CBR ability to intervene in the FOREX market.)

Table 2	Announcements and Rumors
5/6/92	Government announces that ruble will be appreciated to 80R/$ on 7/1/92. Rumors also begin about CBR running out of reserves for defense of target exchange rates. This set of expectations triggers round-tripping foreign exchange activities by banks.
6/23/92	Rumors circulate about a pending monetary reform in Russia.
9/15/92	Government announces that energy price hikes will occur on 11/1/92.
1/19/93	Seventh Congress of People's Deputies adopts resolution which essentially calls for increased deficit spending. This resolution is not yet approved by the government.
2/5/93	CBR announcement that it may soon fix the ruble/dollar rate. Retraction few days later.
3/31/93	Rumors on CBR plans to restrict the import of foreign cash by banks from their correspondent accounts abroad.
7/12-19/93	Rumors circulate about government plan to swap money. Monetary reform occurs week of 7/24/93, whereby pre-1993 ruble notes are invalidated.