Strategic Trading in a Two-Sided Foreign Exchange Auction

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Abstract

The market microstructure chosen for foreign exchange markets 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" auction creates incentives for strategic behavior among market participants. Theoretical predictions on strategic under-revelation of demand or supply positions are supported empirically using detailed data from a rare example of a tâtonnement market, the Moscow Interbank Currency Exchange. Our results suggest that market microstructures should be introduced alongside more traditional asset-market fundamentals in studies of foreign exchange market activity, especially in developing countries.

JEL Classification Codes: F3, F33, D44, O16, P5

Key Words: Foreign Exchange, Microstructure, Auction, Tatonnement, Russia

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I. Introduction

The microstructure of a foreign exchange market can influence trading volumes and equilibrium exchange rates. In recent years, a variety of auction-like mechanisms have been used for foreign exchange trade, especially in developing and transition economies. Two basic classes of auctions, one-sided and two-sided, have been used. In a one-sided auction, the monetary authority collects foreign exchange proceeds from exporters and after some official retention sells the balance to private foreign exchange users. In a two-sided auction, foreign exchange recipients and users meet in a central marketplace in discrete trading sessions.[2]

A noteworthy type of two-sided market is the "tâtonnement" auction, named after the analogous market-clearing mechanism proposed by Walras more than a century ago.[3] In this auction, buyers and sellers submit foreign exchange orders at a price announced by the auctioneer or market maker. The price then is adjusted in steps in the same direction as the aggregate excess demand. The market clears at the price where the aggregate excess demand vanishes. Since orders are executed only in equilibrium, the tâtonnement is a "competitive" price mechanism.[4] This mechanism is in contrast to alternative two-sided mechanisms like double auctions, where different traders may transact at different prices.[5]

Very little is known about the empirical properties of tâtonnement markets. Besides Jarecki's (1976) account of the London gold market, and some experimental work (Joyce 1984, Bronfman *et. al.* 1994), we are not aware of any other documented cases of markets working in a similar fashion. This near absence of tâtonnement experiences is underscored in the survey by Friedman (1993). As a result of this dearth of experiences, we may lack a good understanding of the implications of choosing this auction structure.

This paper is oriented toward generating some useful theoretical and empirical insights about trader behavior and outcomes in tâtonnement foreign exchange markets. First, we provide theoretical results on strategic behavior given the rules of this type of auction, and demonstrate

the results using a simple example. This exposition is innovative in that we are able to establish a testable theoretical relationship between strategic under-revelation and the slopes and intercepts of market bid and offer functions. Second, we present evidence from our examination of detailed data from a rare example of a tâtonnement market at work, the Moscow Interbank Currency Exchange (MICEX). We focus on the contribution to market activity of changes in market microstructures in addition to the more traditional foreign exchange fundamentals.

Our analysis highlights strategic trading that occurs independently of informational asymmetries or imperfections. The emphasis we place on the importance of market power rather than informational asymmetries complements an existing and emerging body of research on alternative foreign exchange market microstructures.[6] 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.[7]

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 offer functions for foreign exchange.

In the empirical section of our paper (Section III) we examine detailed bid and offer activity at the Moscow Interbank Currency Exchange (MICEX) established in Russia in 1991.[8] Our analysis of this foreign exchange market provides empirical support to the strategic under-revelation hypothesis for tâtonnement auctions. We conclude that early efforts of broadening access to the MICEX market had mixed effects on the price-setting behavior of traders. New

entrants may have eroded the monopsony power of purchasers of foreign exchange, but did not significantly weaken the power of existing players on the supply side of the market. This analysis also confirms that Russian foreign exchange markets are responsive to both macroeconomic and microeconomic fundamentals and a set of events. The results suggest that market microstructure considerations should be added to the set of issues addressed in studies of foreign exchange markets, particularly for developing countries. Indeed, in some instances microstructure changes may have greater effects on market outcomes than changes in traditional macroeconomic fundamentals. Section IV concludes and suggests directions for further research.

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

Consider a market external to the United States in which foreign exchange, which we refer to as dollars, is traded for domestic currency. The real exchange rate relevant for decision-making by traders is denoted by *e,* where an increase in *e* represents a real depreciation of the domestic currency against the dollar. Let e_0 be the exchange rate which cleared the market in the previous period. At the opening of the current trading session, market participants submit preliminary applications indicating the quantities demanded (x^d) or supplied (x^s) at the initial rate e_0.[9] 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 message is given by the function $x_i(e)$, where $\partial x_i / \partial e < 0$. This excess demand function will also depend on other exogenous fundamental forces in the economy which we will discuss further in Section III.

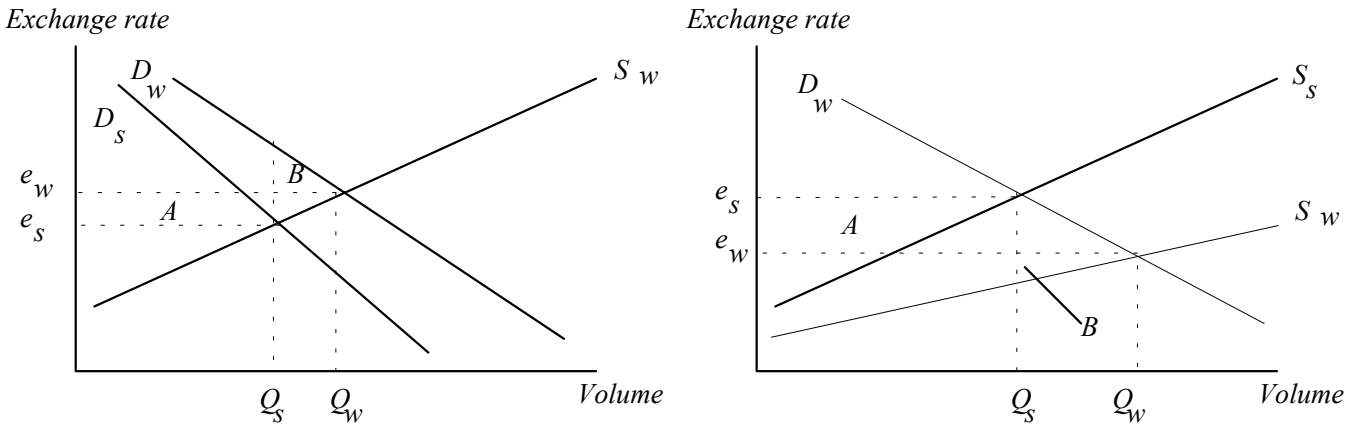
If we define the initial aggregate excess demand as $X(e_0) = \sum_{i=1}^{n} x(e_0)$, the tâtonnement process dictates that a market-maker or "auctioneer" use a rule $f(X(e))$, where $f' > 0$ and $f(0)=0$,[10] to modify the prevailing exchange rate until the excess demand vanishes and the market reaches its equilibrium, i.e., when $X(e^*) = 0$ at the rate $e = e^*$.

If agent *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 perfectly-competitive outcome (Roberts and Postlewaite, 1976). In this case, each agent cannot do any better than reveal 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.

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. 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. The extent of under-revelation diminishes as a market becomes more competitive and approaches the Walrasian case.

The basic implications of strategic under-revelation are illustrated graphically in Figures 1a and 1b. The figures show basic FOREX currency supply and demand curves, illustrating both the Walrasian curves (subscript *w*) and the curves which include under-revelation when the respective sides of the market have concentrated power (subscript *s* for strategic). Net gains from the strategic play are shown by the area A-B. If buyers (sellers) understate their true quantities demanded (supplied), the theory predicts that (i) the equilibrium price will be lower (higher) than the Walrasian price, and (ii) 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 unambiguously contributes to overall market thinness.

INSERT FIGURE 1



1a. *Strategic Demand* 1b. *Strategic Supply*

Figure 1

IIA: A Typical Trader's Problem

In this section we present a typical trader's decision making problem when submitting an excess demand message in a given round of a tâtonnement market. Trader *i*'s objective is to maximize the net value of his foreign exchange trade,[11]

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

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 purchasers and negative for sellers. The value function is associated with (*1*) purchasing foreign exchange for imports; or (*2*) selling foreign exchange from export proceeds.

Because of the competitive pricing structure of this 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 stated excess demands of all market participants. The necessary condition for a Nash equilibrium at $\left(x_i^*, x_j^*\right)$ is

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

Our empirical analysis in Section III focuses on opening round (initial) excess demand messages. An important feature of this opening round is that no real time information is released when the bids and offers are submitted, which means that traders cannot sequentially react to the actions of their opponents within the round. Thus we can set the conjectural variation $\partial x_j^*/\partial x_i^*$ equal to zero for all *j*.[12] Accordingly, the necessary condition (2) is rewritten as:

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

If agent *i* is a buyer of foreign exchange, the third term in (2') is positive and $V_i'\left(x_i^*\right) > e(\cdot)$, which means that *i* under-reveals the true marginal value of his bid quantity and bids for fewer units than prescribed by his Walrasian demand. Analogously, if *i* is a seller of foreign exchange, $V_i'\left(x_i^*\right) < e(\cdot)$, 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. Manipulation of equation (2) yields:

$$V_i'\left(x_i^*\right) = e(\cdot)\left[1 + \frac{\partial e}{\partial X}\frac{X}{e}s_i\right] = e(\cdot)\left[1 + \frac{s_i}{\varepsilon}\right] \tag{3}$$

where ε is the price elasticity of the market's excess demand function and $s_i = x_i \Big/ \left(x_i + \sum_{j=1,\neq i}^{n} x_j\right) = x_i / X$ denote *i*'s market share. 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.[13]

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. In particular, we use the example to demonstrate the implications of under-revelation for the slopes and intercepts of demand and supply functions for foreign exchange.

Suppose that the competitive supply is represented by a linear function

$$e = cX, \quad c > 0 \tag{4}$$

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

$$V_i(x_i) = ax_i - bx_i^2, \quad x_i \le a/2b \quad a, b > 0 \tag{5}$$

If *i* is the sole trader on the demand side, the equilibrium demand function is

$$x_i = \frac{a}{2b} - \frac{e}{b} \tag{6}$$

If a second identical trader *j* joins the demand side, Nash equilibrium market demand is:

$$X = x_i + x_j = \frac{a}{b} - \frac{3e}{2b} \tag{7}$$

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

$$x_i = \frac{a}{2b} - \frac{e}{2b} \quad , \text{ and} \tag{8}$$

$$X = x_i + x_j = \frac{a}{b} - \frac{e}{b} \tag{9}$$

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

	monopsony	duopsony	one competitive player	two competitive players
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 strategic players on the demand side are:

$$SU(monopsony) = \frac{ac}{(2b + c)(2b + 2c)} \tag{10a}$$

$$SU(duopsony) = \frac{ac}{(b + c)(2b + 3c)} \tag{10b}$$

Subtracting (10b) from (10a),

$$SU(monopsony) - SU(duopsony) = \frac{ac^2}{2(b + c)(2b + c)(2b + 3c)} > 0 \tag{11}$$

which implies that increased participation on the demand side unambiguously leads to reduced under-revelation. Plotting the market demand functions for these cases provides additional insights on the impact of under-revelation on the slopes and intercepts of these functions.

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. This result is because the gains from under-revelation disappear as the price approaches zero. Thus, in this setup, the *difference in the quantity intercepts* between monopsony and duopsony 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.[14]

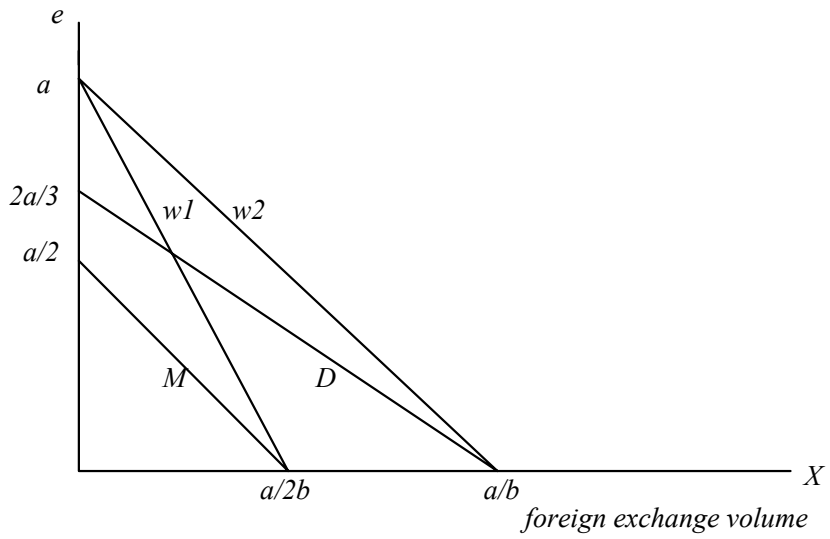
INSERT FIGURE 2

How are the volume and under-revelation effects reflected in the slope of the market demand functions? Consider the following case: a non-strategic (Walrasian) agent indexed by "-*i*" is added to the demand side which already contained a single strategic player. Then stated demands should satisfy

$$2a - 2b\left(x_i + x_{-i}\right) - 2c\left(x_i + x_{-i}\right) - cx_i = 0 \tag{12}$$

Without loss of generality, we can assume that $x_i = k\left(x_i + x_{-i}\right)$, 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, $k \in \left(0,1/2\right)$, and market demand is given by:

$$x_i + x_{-i} = \frac{a}{b} - \frac{(2+k)}{2b}e \quad , \quad k \in \left(0,1/2\right) \tag{13}$$



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

Figure 2

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 $\hat{e} \in (4a/5, a)$. As shown in Figure 3, an additional participant has two potential effects. First, if the extra player is strategic, the resulting equilibrium reflects a relative reduction in under-revelation and appears as *D*, the duopsonist case.

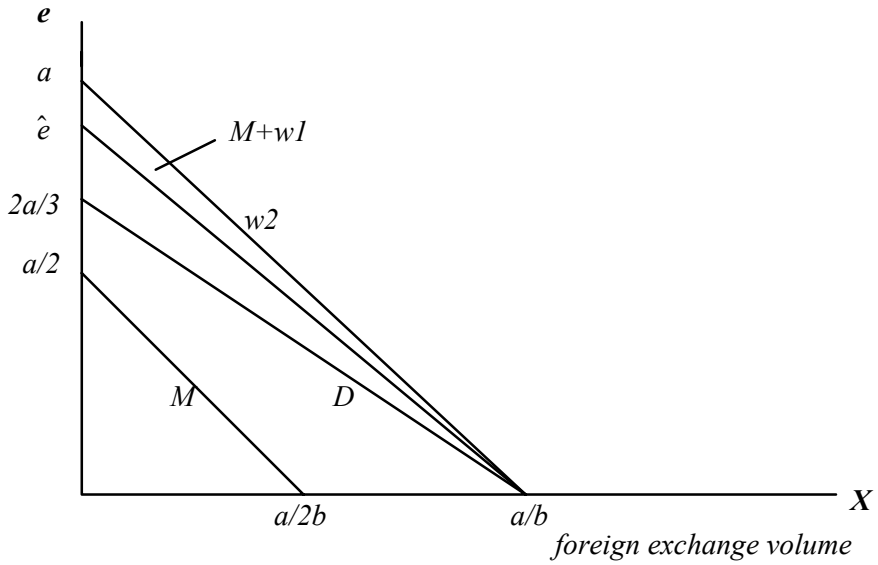
INSERT FIGURE 3

However, if the player is non-strategic, the resulting equilibrium reflects demands that appear as the *M*+*w1* case. In this latter scenario, the rotation of demand 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 $\hat{e}$=9a/10. Observe that, on average, the slope of *M*+*w1* is substantially 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 under-revelation.

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 a pure volume effect. Comparable examples based on changing some of the initial assumptions yield qualitatively similar results. If the supply side of the market for foreign exchange were instead modeled as containing a mix of strategic and competitive players, analogous results about the intercepts and slopes of the market supply function would arise. These types of relationships between numbers of market participants and foreign exchange bids and offers in Russia will be examined alongside more standard asset market fundamentals in the next section.



M: Monopsony. *D*: Duopsony.

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

Figure 3

III. Analysis of the Russian tâtonnement foreign exchange market

A. Description of Russia's foreign exchange auction: The main trading place is the Moscow Interbank Currency Exchange (MICEX), wherein both buyers and sellers of foreign exchange (FOREX) interact and the market discretely clears at each session using tâtonnement rules. 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.[15] From the arguments presented in Section II, we expect that the number of auction participants could have a significant effect on the slopes and intercepts of market demand and supply.

The auction clearing procedure is as follows: 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 applications, foreign exchange cannot be purchased as a price lower than the opening rate or sold at a price higher than the opening rate. If 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.

B. The Valuation of Foreign Exchange Bids and Offers: Bids and offers for foreign exchange at the auctions depend on the economic fundamentals which influence agent valuation functions.[16] These 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, $i_t - \pi_t$;[17] (b) the profitability of leakages into black markets, represented by the black market premium, δ_{t-1};[18] and (c) a vector of zero-one dummy variables Z_t reflecting both actual and anticipated policy changes, summarized in Appendix Tables 1 and 2.[19] 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.

Intertemporal Considerations: In addition to the aforementioned fundamentals which introduce dynamic considerations into agent decisions, three other intertemporal considerations associated with learning and institutional delays arise from micro-market perspectives. First, traders can learn about their valuations of foreign exchange relative 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 become more experienced at playing the game and at disentangling opponents' strategies after repeated sessions. Repetitions also may make strategic agents more aware of their price-setting power and become more skilled at capturing potential surpluses over time. Dynamic behavior by such agents was confirmed in the results of Joyce's (1984) experimental work on 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, trading may simply be linked across periods because of 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. We will deal with these issues in our econometric work by adjusting for heteroskedasticity and serial correlation of residuals. These problems may arise because the trader's accuracy of play may change over time and be systematically related to the error term. We also account for dynamic activity by examining whether inclusion of lagged dependent variables influence current values of the dependent variables.

C. Estimating Equations and Data: The estimation period is January 1, 1992 through August 31, 1993. Our testing equations for supply and demand at the auction take the form:

$$X_t^{initial} = \alpha_0 + \alpha_{0,j} bdum_t^j + \left(\alpha_1 + \alpha_{2,j} bdum_t^j\right) \cdot RER_{t-1} + \alpha_3 \cdot \left(-i_{t-1} + \pi_{t-1}\right) + \alpha_4 \cdot Z_t + \alpha_5 \cdot \delta_{t-1} + \alpha_6 \cdot X_{t-1}^{initial} + \mu_t \quad (14)$$

where $X_t^{initial}$ is either the logarithm of initial bids ($X_t^{d,initial}$) or offers for foreign exchange ($X_t^{s,initial}$).[20] Z_t represents a vector of events dummies, described in Appendix Tables 1 and 2.[21] The logarithm of the real exchange rate RER_t enters with both a constant coefficient and with an interactive dummy coefficient. The dummy variable vector $bdum_t^j$ delineates discrete 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.[22] The dates for which these dummy variables are zero and one are summarized in Table 1.

INSERT TABLE 1

Introducing new players or eliminating small under-capitalized players could alter the competitive structure of the market and effect on the slopes and intercepts of the estimated bid and offer functions for foreign exchange. Table 2 summarizes the expected sign pattern of effects on respective parameters of the estimating equation. Recall that the addition of players occurs incrementally with *bdum1*=1 and again with *bdum2*=1, while *bdum3*=1 reflects the potential elimination of (undercapitalized) players from the auction so that coefficients would be expected to have opposite sign patterns from those expressed in the table.

INSERT TABLE 2

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

Table 2 Strategic Under-revelation and Regression Coefficients

Implications of new entrants into the tatonnement auction market	Demand for Dollars Effects on Estimated:		Supply of Dollars Effects on Estimated:	
	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)

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 exchange rate	24.96	24.04	150.00	7.98	reject	negative
real effective exchange rate	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 auction 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 data on initial foreign exchange bids, initial foreign exchange offers, cash premia, and two alternative real exchange rate 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. Both bid and offer data exhibited positive trends. None of the volume data or the real exchange rate series have unit roots.[23]

INSERT TABLE 3

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. 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.[24] The auction 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.

Periods of exchange rate targeting complicate the interpretation of estimated regression parameters. The main period of targeted exchange rates within our sample, April through June 1992, falls within the interval before our *bdum1* variable is equal to one. At this time, the CBR had effectively announced that a gradual nominal and real appreciation of the ruble would occur. Thus, we would expect that *bdum1* might capture the effects of removing an anticipated appreciation along with the increase in number of auction licenses in Spring 1992. If an ruble appreciation signaled that further appreciations were forthcoming, the sign on the exchange rate

term in the supply equation could be the negative rather than positive, as would otherwise be expected.

Two alternative real exchange rate specifications are utilized in our regressions: a real exchange rate (RER_t) and a real effective exchange rate ($REER_t$). "Effective" exchange rates are distinguished from observed market exchange rates in that they adjust for foreign exchange surrender (FXS) taxation imposed on exporters. This adjustment is important mainly for the supply side of the market and is therefore only used in tests of initial offers of foreign exchange.[25]

D. Estimation results: Tables 4 and 5 report the results of various regressions of microeconomic and macroeconomic fundamentals on initial bids and initial offers after elimination of those events-dummy variables that were clearly statistically insignificant. In some regressions, lagged volume data also are included as explanatory variables.[26] Some regressions include a time trend, although this term has no true structural interpretation given our description of market fundamentals.[27]

INSERT TABLE 4

INSERT TABLE 5

Significance of Fundamental Variables for Foreign Exchange Demand and Supply: On the bid side of the market (i.e. foreign exchange demand), both real interest rates and cash market premia 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, the offer side, reflecting foreign exchange supply, is insensitive to real interest rates. Nonetheless, the response to exogenous fundamentals does provide evidence that the suppliers of foreign exchange are forward looking: in periods of price reforms there is significantly less supply. Premia 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. 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 tariff differentiation.[28] 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.

Indication of dynamic micro-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: The estimated parameters on the additive and multiplicative bank dummy variables provide mixed evidence of strategic under-revelation

in Russia's foreign exchange auctions. In general, the results are consistent with our priors and any significant departures from the expected sign patterns on the microstructure terms have clear explanations.

On the demand side of the MICEX market, the signs and significance patterns on the *bdum1* intercept and slope terms suggest that the added market participants were associated with reduced transaction volumes (negative intercept value) and heightened strategic play (positive multiplicative slope value).[29] This result runs counter to our expectations regarding the effects of adding new players to the market. We attribute this result to the close correspondence between the dates for which *bdum1* =1 and 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 position of a smaller set of dominant players.[30] The additional market participants indicated by *bdum2* have coefficients strongly consistent with reduced strategic play. The interpretation is that these additional players both added to total market demand and reduced the monopsony power of existing players.[31] The signs and significance of the coefficients on the *bdum3* intercept and slope terms suggest that the tightened bank capitalization requirements 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, as we had anticipated, the basic exchange rate term has a negative sign because during a significant portion of the January to July 1992 interval (when all interactive dummies are zero), real appreciations of the ruble signaled pending further appreciations due to the objectives of the Central Bank of Russia. Sales increased as the ruble appreciated because 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 re-instituted floating exchange rate.

Given the background against which the number of participants in the auction was increased, the *bdum1* slope 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, i.e. when *bdum2* equals 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 coefficients on the *bdum3* terms are 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. Moreover, any econometric modeling of exchange rates may be flawed if it neglects the effects of interim variations in market microstructure. Second, most of the observed response to changing the number of market participants appeared on the demand side of the auction, suggesting that 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. Concluding Remarks

Market determination of exchange rates contributes to the efficient allocation of productive factors and to reduced distortions in trade, especially for developing and emerging market economies. The numerous real consequences of exchange rates underscore the importance of understanding the implications of particular market microstructures for foreign exchange trade.

In this paper we have studied some of the properties of trader's behaviors in a two-sided tâtonnement auction. We have shown that this auction presents participants with a potentially

strong motive to under-reveal demand or supply curves. Thus, although the tâtonnement market has the advantage of presenting participants with a single clear market-determined exchange rate, its disadvantage is the potential for agents to manipulate this rate. Because of the potential for strategic under-revelation, the choice of this trading mechanism may result in overall market thinness. In the case of the Russian foreign exchange market, we find that 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.

The generality of this demand-side result can only be assessed in terms of evidence from actual auctions and from experimental work. 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 (1993) finds evidence in the one-sided foreign exchange auctions implemented in Zambia. Aron and Elbadawi (1993) find support for under-revelation in the Nigerian foreign exchange 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.

Experimental evidence derived mainly on double auctions with discriminatory pricing rules generally concludes that there will be convergence to Walrasian outcomes, regardless of the number of participants in the market.[32] However, these results may not apply to tâtonnement auctions where the competitive or uniform pricing rules do not permit the type of price discrimination observed in the double auctions. With uniform pricing, monopolistic actions may remain feasible since withholding (of demand or supply) affects price and surplus for every unit traded. This latter result does not extend to double auctions where withholding only influences the returns on sequential trades and market participants learn more about the bounds of prices acceptable to their trading counterparts.[33]

Tâtonnement markets have been subjected to relatively few experiments. Evidence of under-revelation behavior has been presented, but this actual practice has been linked to the

presence of information asymmetries among experiment participants. A controlled experiment by Joyce (1984) 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.[34] 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.

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 borne 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.

Finally, the choice of foreign exchange market microstructure also may have important implications for market efficiency and volatility. The studies by 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 batch trading, like tâtonnement. Because the diffusion of information is not optimal in a sequential trade market, it follows that greater market efficiency is attained under batch trading.

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 on the interaction between exchange rate determination and the market microstructure used to implement foreign exchange trades.

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ENDNOTES

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[2]Feldman and Mehra (1993) provide a recent typology of auction micro-structures.

[3]Walker (1972) and Morishima (1977, Chapter 2) provide conceptual and historical accounts of the Walrasian tâtonnement.

[4]The same competitive price rule is observed in "call" or two-sided "batch" auctions used in securities trading. In a basic (black box) call market, used to open daily trading at the New York Stock Exchange, orders accumulate and the specialist sets a single market-clearing price at which all executed orders transact. Alternatively, in an open book call or Wunsch auction, used at the Arizona Stock Exchange, orders accumulate for simultaneous execution at a pre-established time. At any point before this clearing time traders have full information about the outstanding market supply and demand functions. Although the uniform price rule applies to both batch trading systems and tâtonnement, the resulting equilibrium prices will not necessarily be competitive (see Section II). In addition, whereas excess demand messages are sequential under tâtonnement, they are simultaneous under batch trading.

[5] In a (continuous) double auction, traders' messages consist of bids and asks for units of the good, and of acceptances of the current best bid or ask. Trades consist of the bilateral transactions arising from the acceptance of the best bid or ask. See Friedman (1993) for further institutional details.

[6]Lyons (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.

[7]The term "under-revelation" is used to describe the reporting of a quantity that is lower than the Walrasian quantity for every quoted price. Alternative terms are "shading" or "strategic quantity reductions". See Friedman and Ostroy (1995) and Tenorio (1995).

[8]According to Kovanen (1994), Romania has recently experimented with tâtonnement foreign exchange auctions.

[9]Time subscripts are omitted. These subscripts are introduced in Appendix A for the dynamic trading problem and in the empirical work of Section III.

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

[11]In Appendix A we extend the objective and valuation functions to include intertemporal considerations. As shown in the present section, the specified problem is most directly relevant when trading is dominated by transactions needs, i.e. for import- and export-based activities.

[12] In fact, no real time information about bids and offers is released during any round. The only information released at the end of any round is whether or not the market cleared. If the market did not clear, all excess demand messages from that previous round are not binding, i.e. they will not affect *i*'s payoff in the current round. However, if *i* reacts to the opponent's conjectured actions from a previous round, the conjectured variations in rounds other than the initial round may differ from zero.

[13]Appendix A shows that under-revelation also arises if a speculative motive is present. Agents with market power recognize that their speculative actions alter the price of foreign exchange in a direction which reducing to some degree the profitability of this speculation and raising the cost of all units of foreign exchange purchased today. This recognition of market power leads the agent to purchase less foreign exchange today than would be the case in the absence of market power. Our results that strategic under-revelation also arises in a dynamic setting accord with the general discussion by Madhavan (1992).

[14]Inclusion of a second trader with a smaller intercept or slope does not alter the results significantly. The only difference between this case 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 provide a benchmark and are unobservable in practice, testable hypotheses are unaltered.

[15]For a more detailed discussion of this market, see Goldberg (1993) and Goldberg and Tenorio (1995a). 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.

[16]In contrast to our treatment of the role of market microstructure in influencing foreign exchange bids and offers, we do not offer a comparable exposition of the macroeconomic influences. This subject has been addressed extensively elsewhere. For example, see Obstfeld and Stockman (1984).

[17]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. 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]Since auction and black market exchange rates are simultaneously determined, we proxy the profitability of leakages by the lagged black market premium. This premium is constructed using cash exchange rates and "effective" MICEX exchange rates. The data appendix provides further details. Goldberg and Karimov (1995a, 1995b) provide a more thorough examination of the economic importance of black markets for foreign exchange.

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

[20]We do not use equilibrium trade volumes as the dependent variables because these quantities are likely to be significantly distorted by CBR foreign exchange intervention. 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.

[21]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.

[20]We use dummy variables for tiers of the number of banks rather than an explicit series on the number of banks for a variety of reasons. First, there were occasional dates where the market structure was viewed as basically stable but the number of banks per se was not reported. Second, the number of banks could be stable at the same time that the composition of banks and the structure of strategic play in the market may have changed. The dummy variable approach is less prone to problems arising from these issues. Moreover, the form of the estimating equation may be more arbitrary if the number of banks integer variable were explicitly introduced. One would not want to constrain early entrants into the market to have the same effect on the slopes and intercepts of market demand, for example, as the later entrants. A broad range of nonlinear specifications would be required, and the results may not have clear interpretations.

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

Tuesday data are expected to yield more meaningful results than the weighted variables, we report only those regression results.

[24]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.

[25]FXS taxes on exporters selling currency at the auctions have been as large as thirty percent of their earnings. See Goldberg (1993). 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. Real exchange rates are constructed by deflating the nominal exchange rates from the prior session by the current period's price level. The black market premium is constructed as the ratio of the black market exchange rate to the relevant real exchange rate series.

[26]While we interpret their coefficients as reflecting dynamic responses to impulses, other interpretations also are possible

[27]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.

[28]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.

[29]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.

[30] It was not uncommon for dominant players in the market to negotiate less deleterious import taxes or even exemptions.

[31] Referring back to Table 2, the additive *bdum2* intercept term is positive and significant and the multiplicative slope term is consistently negative and significant. We do not explicitly distinguish among alternative hypotheses about *why* these new players influence market activity. For example, in addition to our strategic play hypothesis, these players may have different demand elasticities than existing players or may have different information sets.

[32] See Goldberg and Tenorio (1995b) for a more extensive discussion of relevant experimental studies.

[33] Friedman and Ostroy (1995) experimentally analyze traders' behaviors in continuous double auctions and a batch procedure analogous to tâtonnement called the "quantities-only clearing house" or CHQ auction. Their results show that while double auctions were remarkably efficient, the CHQ auction induced consistent under-revelation.

[34] 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.