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AN EXAMINATION OF THE BOLIVIAN EXPERIENCE

ABSTRACT

The Bolivian experience suggests that, even in highly indexed economies, exchange rate auctions can work. After introduction of its auction, the Bolsin, not only did the parallel market premium for dollars all but disappear in Bolivia, but the Boliviano exchange rate remained surprisingly stable. This paper examines how the Bolsin accomplished this. The empirical evidence from daily auction data suggests that credit for the Bolsin's success should be attributed largely to central bank policy at the auction rather than the auction as an institution.

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Exchange rate auction systems have recently been introduced in a number of developing countries[1]. Auctions would seem the ideal system for governments that appreciate the efficiency of the market mechanism, but are concerned about potential manipulation of their exchange rate in thin markets. Governments may also find auctions politically appealing relative to fixed or explicitly managed exchange rate systems in which authorities must take direct responsibility for unpopular adjustments of the exchange rate.

Do exchange rate auctions work? The evidence from the Bolivian experience suggests that they can. Bolivia introduced its exchange rate auction system, the Bolsin, as part of a larger stabilization program in late 1985. The program was one of the most successful stabilization experiences of the post-war period. The hyperinflation of 1985 was replaced by a relatively stable inflation rate that continues to average less than 20 percent per year. A key role in the stabilization was played by the exchange rate: unification of the official rate with the parallel rate, together with the stabilization of the official rate helped break inflation in an economy where most prices were (and still are) indexed to the dollar.

How did the Bolsin accomplish all this? Although the institutional features of the Bolsin did not change markedly over the period under examination, central bank policy at the Bolsin did. This paper examines the evolution of the Banco Central de Bolivia's policy toward the exchange rate and the responses of market participants at the Bolsin. The paper begins by briefly discussing the generic exchange rate policy objectives of developing countries. Section II describes the institutional features of the Bolsin. Section III examines the incentives of auction participants in the Bolsin and section IV examines the empirical relationships between market determined prices and the policy variables controlled by the Bolivian Central Bank. Section V describes other New Economic Program government policies introduced at the same time as the Bolsin and section VI presents conclusions.

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[1] In addition to Bolivia and Jamaica (84-89), the African countries that currently have (or previously had) established exchange rate auction markets include: Ghana, Guinea, Uganda (82-85), Zambia (85-87) and Sierra Leone (82-83).

I. Exchange Rate Policy Objectives

Flexible exchange rate systems have an advantage over fixed systems in that they grant the monetary authority an additional instrument of macroeconomic policy. The traditional prescription for countries in the midst of balance of payments crises is a devaluation of the domestic currency. To the extent that the devaluation increases the relative price of tradeables to non-tradeables, the devaluation encourages exports and import-substitutes, thereby relieving the balance of payments pressure.

For exchange rate policy to be effective, however, it is necessary that the nominal exchange rate change lead to a _real_ exchange rate change. If domestic prices rise proportionately with the devaluation, the real exchange rate remains unaffected and the stimulative effect of the devaluation is lost. Countries with a high degree of indexation may therefore benefit more from a stable nominal exchange rate regime than a flexible one.[2]

In the last stages of a hyperinflation, the domestic currency typically loses its attributes of a store of value and unit of account. Domestic prices effectively become fully indexed to a foreign currency. This was the Bolivian experience in 1985. The econometric evidence in Morales and Sachs (1990, Table 6.6) shows that by 1985 the depreciation of the Bolivian Peso in the parallel market fed through to domestic prices one for one (after controlling for past inflation and the depreciation of the official rate).

Figure 1 displays monthly Bolivian inflation rates since September 1985 alongside depreciations in the official and parallel exchange rates. After a brief spike in early 1986 the monthly inflation rate has never exceeded 5 percent and has averaged 1 percent from mid-1986 through early 1990. Regressions over this post-hyperinflation period of the monthly rate of inflation on past inflation, current depreciation and past depreciation indicate that the magnitude of the (pass-through) coefficient on past depreciation remained surprisingly large. For example, the pass-through

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[2] See Bresciani-Turroni (1937), Dornbusch (1986), Fischer (1986) and Sachs (1987) for further discussion of this point.

coefficient over the sample September 1988 through March 1990, which includes relatively stable rates of inflation[3] with one small spike of 3 percent, is .6 and statistically significant. Moreover, the magnitude of the pass-through coefficient over the full period is generally positively related to increases in the rate of currency depreciation. This result suggests that the Lucas critique operates: the more the Bolivian Central bank attempts to depreciate the nominal exchange rate, the higher will be the pass-through coefficient and the lower the ultimate real exchange rate depreciation.[4]

Developing countries like Bolivia, therefore, have little latitude to accomplish real devaluations using nominal exchange rate policy. Given this, if the country's main objective is to stabilize domestic prices, its exchange rate policy ought be to stabilize the nominal exchange rate. The problem with this policy in practice, however, is that stabilization often leads to overvaluation, the birth of a parallel market for foreign exchange, and an eventual reserve crisis. Some developing countries have recently established exchange rate auction systems in order to avoid overvaluation, at the expense of the stabilization objective. But as will be documented in the following sections, after the introduction of the Bolsin in Bolivia not only did the parallel market premium for dollars all but disappear, but the exchange rate also remained relatively stable. It is unsurprising that the Bolsin eliminated the parallel premium; what is controversial is whether the Bolsin can also be credited with stabilization.

II. Institutional Features of the Bolsin

Bolivia followed a unified, officially pegged exchange rate system from 1957 through 1982. During these years, the exchange rate remained remarkably stable, requiring only one devaluation, in October 1972. After 1982 the inflow of foreign capital was significantly reduced, but the government

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[3] The average monthly inflation rate over this period was one percent with a standard deviation of the same size.

[4] See Dominguez and Rodrik (1990) and Pastor (1990) for further discussion of the degree of post-hyperinflation pass-through of exchange rate changes onto domestic prices in Bolivia.

remained reluctant to devalue the Bolivian Peso. As a result, in March 1982 with international reserves at dangerously low levels, the system deteriorated into a dual exchange rate, with an overvalued and rationed official rate and a divergent parallel rate. On August 29, 1985, as part of the New Economic Policy stabilization program, an exchange rate auction system, the Bolsin, was introduced. The Bolsin's main responsibility initially was to reunify the official and parallel market exchange rates and allow free convertibility of foreign exchange. On the first auction day, the Peso/Dollar exchange rate depreciated by 1,600 percent from the previous day's official rate (Morales and Sachs (1990), pp. 240).

The Bolsin initially met twice a week; as of January 1986, the Bolsin meets five times a week. A five person committee (two voting and three non-voting advisory members) from the Banco Central de Bolivia (BCB) decide on both the reserve price (below which they will not sell dollars) and the quantity of dollars to be supplied on each auction day before the bids are unsealed. The reserve price and quantity decisions are not announced to market participants until after all bids are submitted. There are no restrictions on who can participate in the auction. Bidders must provide the BCB by a prespecified time[5]: (1) a sealed bid with the quantity of dollars demanded (bids must be in multiples of $5000) and a bid price, (2) a certified check in Bolivianos[6] or a cash deposit to cover the bid, (3) the bidder's name and signature,[7] (4) the name of the person(s) who will ultimately receive the dollars.

The Bolsin is a standard sealed bid auction; participants pay the price they bid. All participants that bid at or above the reserve price are deemed

[5] Initially the Bolsin met in the morning, so that bids were due at the BCB by 10:30 am. Currently the Bolsin meets in the afternoon and bids are due at the BCB by 4:30 pm.

[6] On January 1, 1987 the Boliviano was introduced as the standard accounting unit, worth 1 million Pesos, and nearly 50 U.S. cents.

[7] It is said to frequently be the case that auction participants fail to sign their bids; without a signature, bids are deemed invalid.

successful in the sense that they are eligible to purchase dollars at their bid price. If the quantity of dollars demanded at the auction is greater than the predetermined quantity of dollars supplied by the BCB, participants with bids at or above the reserve price receive a prorated fraction of the total amount demanded, with the largest rations going to those bids with the highest price.[8]

The official (ask) exchange rate is established after each auction as the weighted average of the reserve price and the bids that exceeded the reserve price.[9] It is at the official (bid)[10] rate that the BCB and other government agencies purchase dollars between auctions. The BCB's supply of dollars for the auctions comes from private and public sector export earnings. All (legal) export proceeds are required to be surrendered to the BCB at the official bid rate.[11] A portion of the foreign exchange obtained from export earnings is set aside for reduction of external arrears, debt obligations and reserves and the rest is offered for auction at the Bolsin.[12]

III. Auction Incentives

Auction theory offers predictions about bidder strategies and equilibrium outcomes of various selling schemes. A dominant bidding strategy, however, cannot be uniquely defined for the standard sealed bid auction (or a

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[8] The bidder with the highest bid price receives 100% of his demand or the total supply, whichever is smaller. The bidder with the next highest bid price receives 100% of his demand or the remaining supply, whichever is smaller, and so on. If more than one bidder bids the same price, each receives a fraction of their demand, where the fraction is calculated as the total supply of dollars remaining divided by the total quantity of dollars demanded in those bids (Banco Central de Bolivia (1986)).

[9] The weights are the quantities of dollars demanded at each bid price at or above the reserve price (BCB (1986)).

[10] The official bid rate was one point below the ask rate over the period examined.

[11] In order to stimulate surrender in the initial months of the auction, "those surrendering foreign exchange were able to obtain an exchange reimbursement certificate in an amount equivalent to 10 percent of the foreign exchange surrendered". (Quirk, Christensen, Huh and Sasaki (1987), pp 10).

[12] Unfortunately data on the daily reserve position of the BCB are not available.

Dutch auction) because the profit maximizing bid depends on the actions of other bidders. Vickrey (1961) shows that in the special case in which bids are independent and identically distributed random variables, a Nash equilibrium exists in which each bidder's strategy is to bid the same increasing function of his valuation. The resulting auction outcome is efficient because successful bids will be those from bidders with the highest valuation.

Exchange rate auctions generally involve bid quantities as well as prices, and there is reason to suspect that bidder valuations in exchange rate auctions are not strictly independent. Tenorio (1990) shows that multi-unit auctions are not guaranteed to be efficient, even when price-quantity bids are independent and identically distributed random variables. Hansen (1988) shows that in auctions with endogenous and unconstrained quantities, if demand is elastic, the average price of successful bids will be lower than in auctions where quantity is not a decision variable. Milgrom and Weber (1982) discuss the implications of one form of bidder dependence, affiliation: as bidder's valuation rises, the expected valuations of other bidders also rises. In such an environment, Milgrom and Weber show that sellers are better off if they reveal information that is related to bidder's estimates of value. In the case of an exchange rate auction, for example, the existence of affiliation would provide the central bank an incentive to reveal, in advance, the reserve price and the quantity of dollars to be supplied at the auction.[13]

Auction theory, therefore, suggests that the institutional features of the Bolsin may not be optimal in terms of maximizing the BCB's profits[14]. In

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[13] More generally, if bidders are affiliated, the optimal auction scheme (from the sellers point of view) is one where the price paid by each bidder is explicitly linked to the bids made by others.

[14] Another way to think about the Bolsin, given that exporters are forced to surrender their foreign exchange earnings, is that it serves as an export subsidy and an import tax. Exporters are forced to surrender their foreign exchange at the official bid rate, where the bid rate is one point below the official ask rate established as the weighted average of the reserve price and all bids above the reserve price at the last auction. Likewise, importers must purchase dollars either at the Bolsin or in the parallel market, typically at a rate higher than the official bid price. If this is the authority's objective,

the following section a model of bidder behavior at the Bolsin is presented to explore further the implications of these features for auction outcomes.

A. Bidder Incentives in the Bolsin

Bolivians interested in purchasing foreign exchange can either participate in the Bolsin or go to the legal parallel market. Recall that minimum bids at the Bolsin are for multiples of $5000. The parallel market is non-centralized and may, like the Bolsin, be subject to quantity constraints. There are no data available on the volume of transactions in the Bolivian parallel market. The parallel market price of dollars has generally been above the auction-determined official exchange rate, but as can be seen in Figure 2 the parallel market premium is small, averaging one percentage point.[15]

In order to explore bidder incentives at the Bolsin it is useful to simplify the problem to one in which the quantity of foreign exchange available in both the parallel market and the Bolsin is unconstrained. In this case the post-auction parallel market price of dollars provides a ceiling for auction bid prices. Assume that all market participants follow the same strategy. The post-auction parallel exchange rate is a function of the auction reserve price. Intuitively, if all bids at time t, B_t, are below the auction reserve price, R_t, then bidders should expect that the resultant demand for dollars in the parallel market will bid up the parallel price of dollars.[16] Let $E_t(P(R)_{t+1}|\Omega_t)$ denote the post-auction parallel exchange rate investors expect if the reserve price is R, conditional on all information available at time t, Ω_t. Let R_{t-1} denote the known auction reserve price from

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and not revenue maximization, it may not be optimal for the authorities to pre-announce reserve price changes.

[15] The spike in the parallel premium occurred on August 2, 1989, the day that the former leftist revolutionary, Jaime Paz Zamora, was declared the new President of Bolivia by congressional vote.

[16] This assumes that some of the unsatisfied demand for dollars at the auction will spillover into the parallel market. Alternatively, bidders may postpone dollar purchases until the following day's auction. Bids on the following day, however, would likewise be influenced by the reserve price.

the last period's auction. As long as R_t is increasing over time, a rational bid, B_t, must lie between them:

$$R_{t-1} \le B_t \le E_t(P(R)_{t+1}|\Omega_t)$$

More generally an individual bidder's problem, assuming that there is no rationing, is to choose a bid price to minimize the expected cost of obtaining foreign exchange. Let F(R) be the cumulative probability density function for the reserve price, and f(R) its marginal density. The individual bidders problem is to minimize:

$$(1) \qquad B_t\int_0^{B_t} f(R)\,dR + \int_{B_t}^{\infty} E_t(P(R)_{t+1}|\Omega_t)\,f(R)\,dR$$

where the first term is the bid price times the probability that the bid is successful ($B_t \ge R_t$) and the second term is the expected price the bidder must pay in the parallel market if his bid is unsuccessful ($B_t < R_t$) times the probability that the bid will be unsuccessful. In a symmetric equilibrium all bids either win or lose, allowing us to express the expected post-auction parallel price in the range where all bids are unsuccessful (B_t, ∞) as $E_t(P_{t+1}|\Omega_t)$. The first-order condition corresponding to an interior solution to (1), given a symmetric equilibrium is:

$$(2) \qquad \int_0^{B_t} f(R)\,dR + B_t f(B) - E_t(P_{t+1}|\Omega_t)\,f(B) = 0$$

solving for B_t:

$$(3) \qquad B_t = E_t(P_{t+1}|\Omega_t) - \frac{F(B)}{f(B)}$$

The minimum bid is equal to the expected post-auction parallel market exchange rate, conditional on all bids being unsuccessful, minus the probability of the bid being successful over the change in the probability of the bid being successful with respect to changes in the bid price. Rearranging (3)

$$B_t + \frac{F(B)}{f(B)} = E_t(P_{t+1}|\Omega_t)$$

from which it is evident that a one unit increase in the expected post-auction parallel market exchange rate, $E_t(P_{t+1}|\Omega_t)$, generates a less than unit increase in the bid over the range in which F(B)/f(B) is increasing in B. This condition is guaranteed to hold if f'(B)<0; indeed if f'(B)<0 then

$$0 < \frac{dB}{dP_{t+1}} < \frac{1}{2}$$

Consider an example in which the cumulative density function takes the form:

$$F(B) = 0 \quad for \quad B_t < R_{t-1}$$

$$F(B) = a + b(B_t - R_{t-1}) \quad for \quad R_{t-1} \leq B_t \leq R_{t-1} + \frac{1-a}{b}$$

then substituting for F(B) in (3):

$$B_t + \frac{a + b(B_t - R_{t-1})}{b} = E_t(P_{t+1}|\Omega_t)$$

and rearranging:

$$B_t = \frac{1}{2}(R_{t-1} + E_t(P_{t+1}|\Omega_t)) - \frac{a}{2b}$$

The minimum bid is the average between the known reserve price from yesterday's auction and the expected post-auction parallel market exchange rate, conditional on all bids losing, minus the amount .5(a/b). a is the point density of the probability at R_{t-1} and b is the marginal density above R_{t-1}.

In this example, bidders will have an incentive to bid above the reserve price the lower is a, the higher is b, and the larger is the price differential between the reserve price and the expected post-auction parallel market exchange rate. More generally, bidders will bid above yesterday's reserve price the higher is uncertainty about today's reserve price.

If there is a positive probability that the quantity of foreign exchange demanded will exceed the predetermined quantity supplied on any given auction day, (recall that the BCB determines both a reserve price and quantity before each auction) bidders will have incentives to bid above the reserve price because the dollars allocated are prorated with those bidding the highest price receiving a larger percentage of the amount they demanded.[17] As long as each bidder is a small part of the market, the bidders problem when rationing is possible is similar to that described earlier except that the probability of success at the auction will now depend on the bid price being equal to or exceeding the market clearing price rather than simply the reserve price.[18]

B. The Relationship Between Bolsin Reserve Prices and Bids

The Banco Central de Bolivia maintains daily data on the Bolsin transactions. For each auction day, data on the reserve price, the minimum and maximum bid prices, the official exchange rate, the quantity of dollars supplied to the auction, the total and effective quantity of dollars demanded at the auction, and the number of successful and unsuccessful bids are available. The BCB also began to maintain a record of the parallel market price of dollars starting in January 1987. These daily data allow me to document the evolution of the BCB's policy variables (the reserve price and the supply of dollars) and the responses of market participants at the Bolsin over the five years the auction has been in existence.

Table 1 indicates that in the first year of the auction the Bolsin reserve price was changed frequently, every 1.8 days on average. The percentage of days on which the BCB changed the reserve price dropped dramatically in 1988 to just over 10% of all auction days. While the average number of days between reserve price changes increased over time, the standard

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[17] Table 2 indicates that after 1986, bidders with bids at or above the reserve price received 94% of their demand on average.

[18] The possibility of rationing may also provide bidders an incentive to overstate their demand because rations are a function of both the bid price and the quantity demanded. In the context of the model, I need to assume that receiving too many dollars is costly for bidders. Otherwise, subject to the liquidity constraint (bidders must provide a cash deposit (or certified check) in Bolivianos to cover their (inflated) bids), there would always exist an incentive to overstate demand. The empirical evidence presented in the sections to follow, however, suggests that rationing at or above the reserve price occurs infrequently.

deviation about the average decreased in relative magnitude over time. The data suggest that bidders, especially in the early years of the auction, could not predict with any degree of certainty when the BCB would next change the reserve price. In the context of the previous discussion of bidder incentives at the auction, market participants were more likely to bid above yesterday's reserve price in the first years of the auction.

The lower half of Table 1 indicates that while the average size of reserve price changes increased over time, the relative magnitudes of the corresponding standard deviations decreased over time. These data suggest that there was more uncertainty about the size of reserve price movements in the first years of the auction. In 1988 and 1990 all the reserve changes were of the same absolute size, one point.

Table 2 presents summary statistics describing the relationship between the reserve price, bids and auction outcomes over time. The fraction of minimum bids below the reserve price (therefore the number of auctions at which some percentage of the bidders were unsuccessful) declined from just over half of all bids in the first year to less than one-quarter of all bids in 1990. At the same time, the fraction of minimum bids equal to the reserve price doubled from 37% to 79% over the five years. The number of auctions at which the maximum bid was equal to the reserve price also increased dramatically, from 2% to 65%.

The second panel of Table 2 reports that the ratio of the quantity of dollars demanded to those supplied at the auction rose over the five year period, regardless of bid price. Figure 3 shows that the quantity of dollars supplied at the Bolsin fluctuated widely over the course of the five years. The largest quantity of dollars supplied to the Bolsin was 15 million and the lowest was 2 million. The average daily supply of dollars offered at the auction was 5.4 million with a standard deviation of 1.7 million.[19]

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[19] A regression of the daily supply of dollars offered at the Bolsin on monthly dummies provides evidence of a seasonal pattern. The supply of dollars at the Bolsin is significantly higher in the months of December and January relative to any other month. The yearly total sum of dollars offered at the Bolsin peaked at 1.5 billion dollars in 1987, and was lowest in 1988 when the

The third panel of Table 2 shows the unsurprising regularity that the percentage of the total demand awarded at each auction was highest when bids were either equal to or above the reserve price. However, even when the minimum bid was above the reserve price it did not follow that all demand was awarded. In total there were 107 days (out of a total of 1107 days) in which the quantity of dollars demanded was greater than the quantity supplied, and 97% of these days were ones where the minimum bid price was equal to or above the reserve. It is on these days that the quantity of dollars sold to bidders would have been prorated on the basis of their bid price. Figure 4 shows the daily quantity of dollars demanded at the Bolsin over the five year period. The average daily demand was 2.9 million (well below the average daily supply of 5.4 million) with a standard deviation of 1.8.[20] Over the full period, the average effective demand was 79 percent with a standard deviation of 32 percent.

Table 3 summarizes bidder behavior in reaction to a reserve price change. The Table shows that on days when the reserve price was increased, the maximum bid price was never below the reserve price in the first year, but in 1988 it was below the reserve price 51% of the time. This indicates that on half of the days on which the central bank decided to change the reserve price in 1988, none of the auction participants received dollars at the auction. In Figures 5 through 9 reserve price changes are highlighted with darkened squares on all days when the reserve price was greater than the maximum bid. Across all five years the probability that the minimum bid price was below the reserve price on the day of a reserve price increase was very high (approximately 95%). This suggests that in all five years the BCB could predict that some auction participants would be unsuccessful at the auction on

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yearly total was 1.1 billion dollars.

20 A regression of demand on monthly dummies indicated a seasonal pattern similar to that found for the supply of dollars. Demand was significantly higher in December and January relative of any other month.

days in which they decided to change the reserve price.[21]

On days when the reserve price is increased, both the minimum and maximum bids on the <u>following day</u> likewise increased well over half the time.[22] Likewise, on days when the reserve price increased the post-auction parallel market exchange rate increased 57 percent of the time and decreased 5 percent of the time. The average size of these parallel market changes was one point with a standard deviation of a half a point.

The evidence presented in the first three tables and Figures 5 to 9 suggest that the BCB's exchange rate targets became more transparent in the later years of the sample period. As the timing and size of reserve price changes became more predictable, an increasing fraction of the bids were set equal to the previous day's reserve price and the range between the minimum and maximum bids decreased.

IV. Market Forecasts of and Reactions to BCB Policy

While the institutional features of the Bolsin did not change markedly over the period under examination, the data presented in the previous section suggests that both central bank policy and bidding behavior at the Bolsin did. This section presents econometric tests of this hypothesis.

In part A I employ the Granger-causality regression methodology[23] to test whether the Bolsin policy variables (the reserve price and the supply of dollars offered at the auctions) are exogenous with respect to the previous day's auction bids or parallel market prices. In the context of the reserve price, the test asks whether we can best predict movements in the reserve

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[21] One possible explanation for why the BCB does not preannounce reserve price changes is that this policy allows the BCB to limit sales of dollars on a random basis and thereby build up dollar reserves. Discussions with BCB officials suggest that there were occasions during the five year period when there was a temporary shortage of dollars available for sale at the Bolsin due to the lumpy nature of export receipts. Daily data on the BCB's dollar reserves are not publicly available to test this hypothesis.

[22] In the first two years, on the day following a reserve price increase, both the minimum and maximum bids sometimes decreased (appreciated) on the following day. This behavior was rational at the time because reserve price changes likewise changed direction on a number of occasions during this period.

[23] See Granger (1969).

price using just past movements in the reserve price or whether we can improve the predictions by also including the past history of bid prices or other public information. Part B presents one-step ahead forecasts of the BCB's reserve price using a vector autoregressive model with Bayesian priors over the five year period to explicitly test for time-variation in bidders' ability to predict reserve price movements. In Part C empirical predictions about bid prices and demand at the Bolsin (suggested by the model in Section IIIA) are tested using multivariate regressions.

A. The Granger-Causality Tests

X is said to Granger-cause Y if forecasts of Y can be improved by using past observations of X in addition to past observations of Y.[24] In regression format Granger's (1969) test is specified as:

$$Y_t = \alpha_0 + \alpha_1 T + \sum_{j=1}^{n} \alpha_{2j} Y_{t-j} + \sum_{j=1}^{n} \alpha_{3j} X_{t-j} + v_t$$

$$H_0 : \sum_{j=1}^{n} \alpha_{3j} = 0$$

where T is a time trend and n, the number of lags included in each bivariate Granger-causality test, is determined for each regression using the Akaike Information Criterion.[25]

Table 4 summarizes the results of bivariate Granger-causality tests on six variables of interest and a time trend over the full sample[26] and five

[24] Alternative causality tests using Sims (1972) methodology (regress X on past, present, and future Y and test the leads of Y) and the Geweke, Meese, and Dent (1982) serial correlation correction provided qualitatively identical results as the Granger tests and are therefore not included.

[25] See Akaike (1969). The Akaike Information Criterion (AIC) selects the lag length that minimizes $(R + 2k\sigma^2)/M$, where R is the residual sum of squares, k is the number of regressors and M is the number of observations.

[26] The Granger-causality tests are in levels because univariate unit roots tests on each variable included in the VAR model indicate that the coefficient on the first lag of the dependent variable is significantly different from one. Moreover, bivariate causality tests on first-differences provide similar results (qualitatively) as the tests on levels presented in Table 4.

subsamples.[27] The six (X) variables included are: the log of the reserve price, the log of the maximum and minimum bids, the log of the parallel market exchange rate, the quantity of dollars supplied at the auction and the quantity of dollars demanded in the auction. I also include the ratio of effective to total demand and the fraction of the total supply demanded at each auction as additional explanatory variables.

Looking first at what influenced the reserve price over the five subperiods (the first column of each matrix in Table 4), I find that except in the first subperiod the past history of both minimum and maximum bids does not improve the forecasts of reserve price movements. Reserve price movements were independent of auction bids as well as the parallel market for all the subperiods that begin after March 1986. In the last subperiod (VI) the past history of the supply of dollars offered at the auction does improve the forecast of the reserve price.

Granger-causality tests on the minimum and maximum bid prices, the parallel market rate and the quantity of dollars demanded at the Bolsin, indicate that the past history of reserve prices improved forecasts of each of these variables. Auction and parallel market participants changed their bid prices and demand for dollars in reaction to reserve price movements, but reserve price movements did not, after early 1986, react to bids or the parallel market. The demand and supply variables, and particularly the two measures of rationing generally improved the forecasts of bids over all the

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[27] Chow tests of a number of potential regime shifts dates indicate that the five year sample ought be divided into five subsamples. The first subperiod begins on September 2, 1985 (the first day for which Bolsin data are available) and ends on March 21, 1986. As can be seen in Figure 5, this period includes the last traces of the hyperinflation. The second subperiod runs from March 24, 1986 through January 30, 1987. The BCB kept the base rate virtually constant relative to the dollar over this ten month period. The third subperiod runs from February 2, 1987 through July, 14 1988. Over this subperiod the base price was increased in steps; on average the base was devalued one point every four auction days. The fourth subperiod runs from July 15, 1988 through December 1, 1988. As can be seen in the second half of Figure 8, dollar prices were relatively flat over this period. Moreover, for the first time since early 1986, the Boliviano appreciated relative to the Dollar on two occasions over this subperiod. The fifth subperiod runs from December 2, 1988 to August 1, 1989. Figure 4 shows that there was a steep devaluation of the Boliviano in August of 1989, just after the Presidential elections. The final subperiod runs from August 16, 1989 through May 1990.

subperiods. The supply of dollars available at the auction was exogenous in all but the first and fifth subperiods. In the rest of the subperiods none of the variables improved on forecasts made only with information on past supply.

To summarize, the Granger-causality tests show that the reserve price was exogenously determined after March 1986. Likewise the tests indicate that the second Bolsin policy instrument, the supply of dollars offered at each auction, was exogenous after 1986 except in subperiod V. Market variables, including bid prices, parallel market rates and demand at the Bolsin were all influenced by past reserve price movements.

B. Forecasting BCB Reserve Price Movements

In this section I present one-step ahead forecasts of the BCB's reserve price using a vector autoregressive (VAR) model with Bayesian priors to explicitly test for time-variation in bidders' ability to predict reserve price movements. I examine VAR model predictions rather than the actual bid prices in order to separate out the influence of the probability of rationing on bidder's behavior. The VAR model includes a constant and ten lags of the logged reserve price, the logged minimum and maximum bids, the logged parallel price and the quantity of dollars supplied. I impose the Bayesian prior that the mean on all coefficients except the first own lag in each equation is zero; the first own lag is given a mean of one. The prior on the out lags is that they follow a harmonic decay pattern. Model results with 5 and 15 lags, and no priors imposed were quite similar suggesting that the forecasts are not sensitive to the exact specification of the model.

The VAR model was estimated through period t and a dynamic 1-period ahead forecast is then generated using the model. This procedure was repeated daily over the five years that data are available from the Bolsin. The percentage forecast errors for the reserve price are presented in Figure 10. The mean percentage forecast error fell from -.2 in the first year of the Bolsin to .002 in the last year. Likewise, the standard deviation about the mean fell from 1.68 to .15.

The VAR forecasts confirm the hypothesis that BCB policy became more transparent in the latter years of the auction. Although the reserve price was found to be exogenous with respect to past bids and the parallel market price after the first year of the auction, forecasts based on the past history of reserve changes (and other known information) perform better than forecasts in the first year when information from past auctions was statistically significant.

C. Bid Prices and Demand for Dollars in the Bolsin

The Granger-causality test results shown in Table 4 indicate that both the past history of BCB policy variables and other market information improved forecasts of bid prices and the quantity of dollars demanded at the auction. Further, results from the VAR forecasts indicate that the past history of reserve price movements became more informative in the latter years of the auction. In this section I examine bidder behavior over time at the Bolsin directly in the context of a multivariate regression.

Market participants in Bolivia have an incentive to bid at the Bolsin rather than purchase dollars in the parallel market because the average dollar price of successful bids (the official rate) is typically one percent lower than the parallel market price. (This can be seen in Figure 2). As described earlier, the expected post-auction parallel market exchange rate acts as an upper bound on bid prices. Further, participants are more likely to bid above yesterday's reserve price the higher is uncertainty about today's reserve price, the higher is the expected post-auction parallel exchange rate relative to the official price, and the higher is the probability of rationing. Bids, moreover, involve both a price and a quantity. The quantity of dollars demanded at the Bolsin should be influenced by the same factors that influence the bid price.

Tables 5 and 6 present coefficient estimates from regressions of the bid premium and the quantity of dollars demanded at the Bolsin on past changes in the reserve price, the parallel market rate, the parallel premium over the official exchange rate, and past rationing (proxied by the ratio of effective demand to total demand). The regression specifications are:

$$B_t^j - R_{t-1} = \alpha_0 + \sum \alpha_{1k}(R_{t-k}-R_{t-k-1}) + \sum \alpha_{2k}(P_{t-k}-P_{t-k-1}) + \alpha_3(P_{t-1}-O_{t-1})$$

$$+ \sum \alpha_{4k}D^e_{t-k} + \sum \alpha_{5k}(B^j_{t-k}-R_{t-k-1}) + e_t$$

$$D_t = \sum \beta_{0i}M_{it} + \sum \beta_{1k}(R_{t-k}-R_{t-k-1}) + \sum \beta_{2k}(P_{t-k}-P_{t-k-1}) + \beta_3(P_{t-1}-O_{t-1})$$

$$+ \sum \beta_{4k}D^e_{t-k} + \sum \beta_{5k}D_{t-k} + e_t$$

where B_t^j is the maximum bid (j=1) and the minimum bid (j=2), R_t is the log of the Bolsin reserve price, P_t is the log of the parallel rate, O_t is the log of the official rate, D_t^e is the ratio of effective demand to total demand for dollars, D_t is the demand for dollars and M_{it} is the month i dummy variable. The null hypotheses are that $\alpha_1=\alpha_2=\alpha_3=\alpha_4=0$ and $\beta_1=\beta_2=\beta_3=\beta_4=0$.

Tables 5a and 5b show that in the first subperiod only the lagged dependent variable is statistically significant in the maximum and minimum bid premium regressions. In the latter subperiods the coefficients on past changes in the reserve price are always positive and generally significant, especially in the maximum bid premium regressions. Past changes in the parallel market rate and the parallel market premium are sometimes significant and always positive. The rationing variable is generally not significant.

In Table 6 the chi-squared test of the null hypothesis that $\beta_1=\beta_2=\beta_3=\beta_4=0$ is rejected at the .01 level for all the subperiods. The coefficient estimates in the demand regressions indicate that in all but the first two and last subperiods past changes in the reserve price are positive and highly significant. The parallel market premium is never significant, but changes in the parallel market rate are significant except in the fifth subperiod. The coefficient on past rationing is significantly positive only in the first two subperiods. The coefficient on the lagged dependent variable is always significant and explains about half of demand in the current period for the latter subperiods.

The results in Tables 5 and 6 provide further confirmation that participants at the Bolsin increased the price and quantity of dollars demanded in their bids as a function of past changes in BCB reserve prices and changes in the parallel market after the first year. The regressions provide little evidence that past rationing influenced bid behavior.

V. Other Government Policies Enacted in the New Economic Program

Along with the establishment of the Bolsin, Bolivia's New Economic Program launched by President Victor Paz Estenssoro in August 1985, also included policies that would liberalize trade and capital accounts and reduce the government deficit and monetary growth. Tariffs were immediately set at 10 percent plus 10 percent of the prevailing tariff. In August 1986, tariffs on all imports were set at an uniform flat rate of 20 percent.[28] Public sector salaries, spending and investment were immediately frozen and gasoline prices were allowed to rise tenfold to world levels. Over the longer term, government outlays were reduced by drastically cutting public sector employment[29] and eliminating public sector wage indexation.[30] On the revenue side, a value-added tax was enacted into legislation in mid-1986 and became operational a year later.

In order to encourage repatriation of flight capital, the Banco Central de Bolivia legalized dollar deposits and did not accommodate the increase in demand for Bolivianos in the aftermath of the hyperinflation. In late 1985 through 1986 real Boliviano interest rates were quite volatile; lending rates rose on two occasions above 20 percent per month, and fell below -60% per month on one occasion. (The wide fluctuations of the real interest rate can be seen in the first third of Figure 11.) Figure 12 shows the movements in the real Bolivian monetary base, M1, M2 and M3. Real money stock movements,

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[28] In March 1988 tariffs on capital goods were reduced to 10 percent, in an effort to stimulate investment. See Larrazabal and Montano (1990) for further discussion of NEP tariff policy.

[29] Employment in the government's mining company, COMIBAL, fell by over 75 percent between 1985 and 1987.

[30] See Pastor (1990) for an interesting discussion of how the New Economic Program shifted the balance of power from labor.

like real interest rate movements, were relatively erratic in late 1985. By early 1986, however, all measures of the real money stock began on upward growth paths. In late 1986 real M1 and M2 fell below the real monetary base, while real M3 rose well above.[31] These data suggest that Bolivians held relatively few bolivianos for transactions purposes and dollar deposits constituted over 75 percent of total time and savings deposits by early 1988.[32]

Although real interest rates stabilized after mid-1987, monthly real interest rates remained relatively high. After April 1987, the average monthly real lending rate was 3 percent with a standard deviation of 2 percent. Overall, these data suggest that the BCB was slow to remonetize. And five years after the hyperinflation, the Bolivian economy remains highly dollarized.

VI. Conclusions

The empirical evidence presented in sections III and IV suggest that the Bolsin started off as a classic auction - which served to unify the official and parallel markets. Granger-causality tests indicate that in the first seven months of the Bolsin, the past history of auction bids and parallel market movements influenced BCB reserve price and supply decisions. But VAR forecasts indicate that reserve price changes were relatively unpredictable. Bids in this period were often above the previous day's reserve price reflecting the uncertainty about future reserve price changes.

By mid 1987, empirical evidence suggests that the reserve price was exogenous with respect to past auction bids and the parallel market, but reserve price movements were more predictable on the basis of their own history. Both maximum and minimum bids converged toward the previous day's

[31] The average money multiplier using M1, M2 and M3 in the numerator was 0.81, 1.09 and 2.22, respectively, between January 1987 and October 1989. I am grateful to Stephen Schwartz for pointing out that reserves can exceed deposits (M1) when M2 or M3 liabilities are issued to support reserves.

[32] Roughly 85 percent of these dollar deposits were for less than 90 day maturities.

reserve price over this period. Boliviano exchange rate movements after 1988 closely resembled a crawling peg system.

Since domestic prices are so closely linked to the exchange rate, Bolivia will have great difficulty maintaining domestic price stability unless it maintains the nominal exchange rate on a stable and predicable path. If the core rate of Bolivian inflation exceeds that in the U.S., a stable exchange rate path will involve a slow crawl against the dollar. A commitment to a stable exchange rate is tantamount to a commitment to passive monetary policy. An important function of the Bolsin may be the timely information it can convey to the BCB regarding exchange rate pressures. Bid prices and demand at the Bolsin can serve as signals to the central bank of the direction monetary policy must take to maintain stable prices and exchange rates.

One might have expected that when the BCB established a de facto crawling peg system that a gap between the parallel and official rate would have reappeared. This did not occur. Presumably the BCB was able to keep the exchange rate unified by providing adequate foreign exchange to the auction and by using monetary policy to offset demand pressures signalled in the Bolsin. Indeed, real interest rate and monetary base data suggest that over this period the BCB was slow to remonetize. And there were only 104 out of 1107 auction days when the demand for dollars at or above the reserve price exceeded the Bolsin supply.

In conclusion, the Bolivian experience suggests that even for highly indexed economies, an exchange rate auction can achieve not only efficiency but also stabilization of the exchange rate. However, credit for stabilization in the Bolivian case should be attributed largely to central bank policy at the auction rather than the auction as an institution. In the first year the Bolsin served to unify the parallel and official markets. Once credibility was re-established in the foreign exchange market, the Bolsin evolved into a de facto crawling peg system. The BCB was able to stabilize the exchange rate by maintaining consistent monetary policy, providing transparent exchange rate targets (using the reserve price) and adequate dollar reserves in the Bolsin.

FIGURE 1.

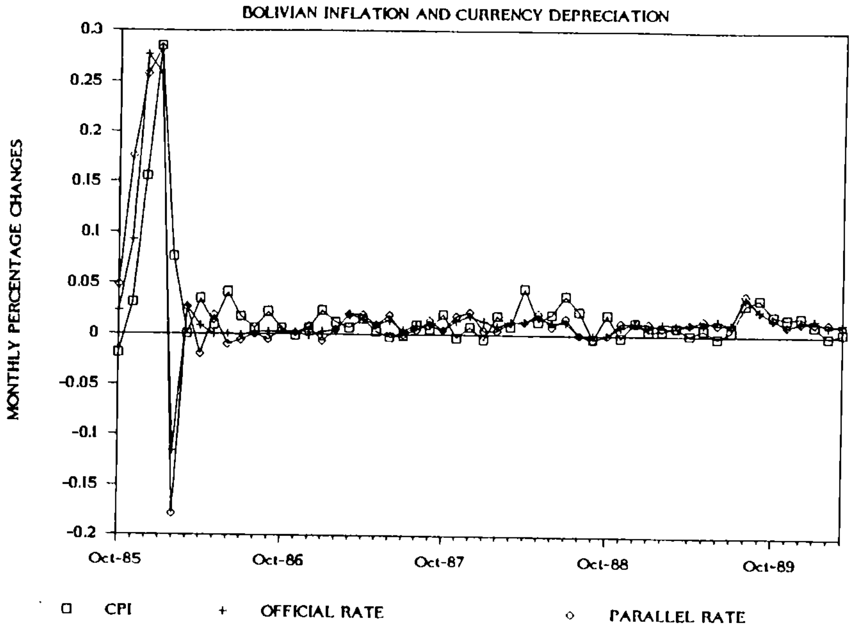

BOLIVIAN INFLATION AND CURRENCY DEPRECIATION
MONTHLY PERCENTAGE CHANGES
0.3
0.25
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
Oct-85
Oct-86
Oct-87
Oct-88
Oct-89
CPI
OFFICIAL RATE
PARALLEL RATE

FIGURE 2.

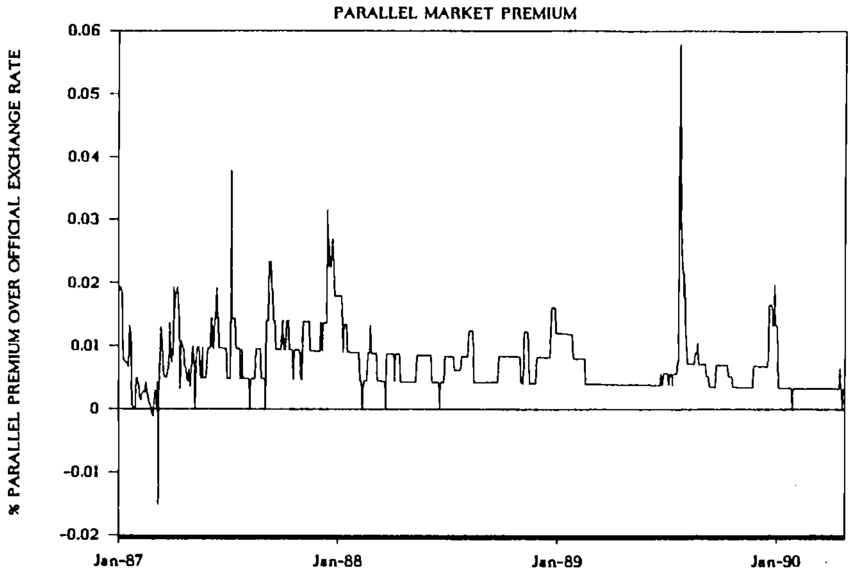

PARALLEL MARKET PREMIUM
% PARALLEL PREMIUM OVER OFFICIAL EXCHANGE RATE
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
Jan-87
Jan-88
Jan-89
Jan-90

FIGURE 3.

DAILY SUPPLY OF DOLLARS OFFERED AT BOLSIN

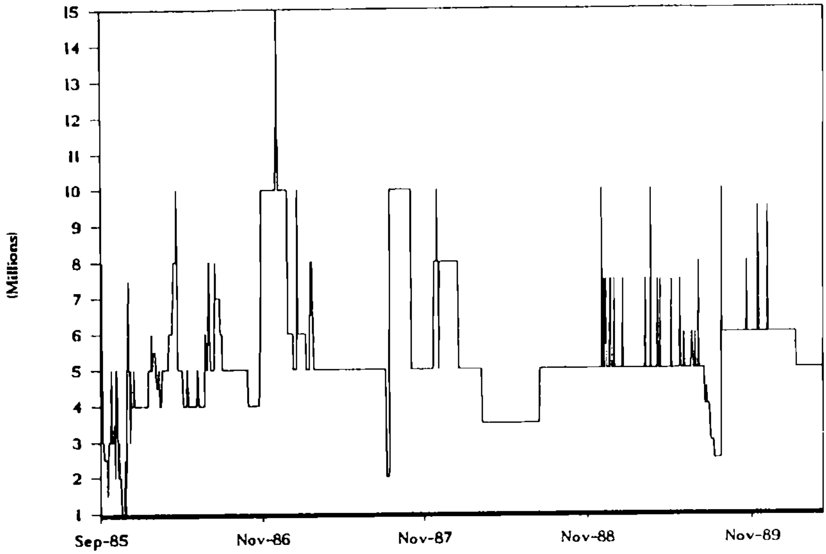


FIGURE 4.

DAILY DEMAND FOR DOLLARS AT THE BOLSIN

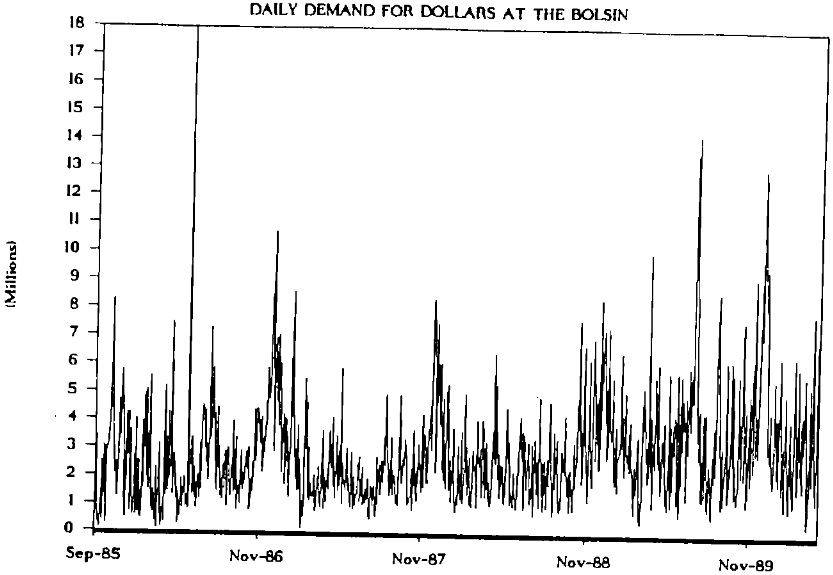


FIGURE 5.

BOLSIN AUCTION RESERVE. MAXIMUM AND MINIMUM BID PRICES

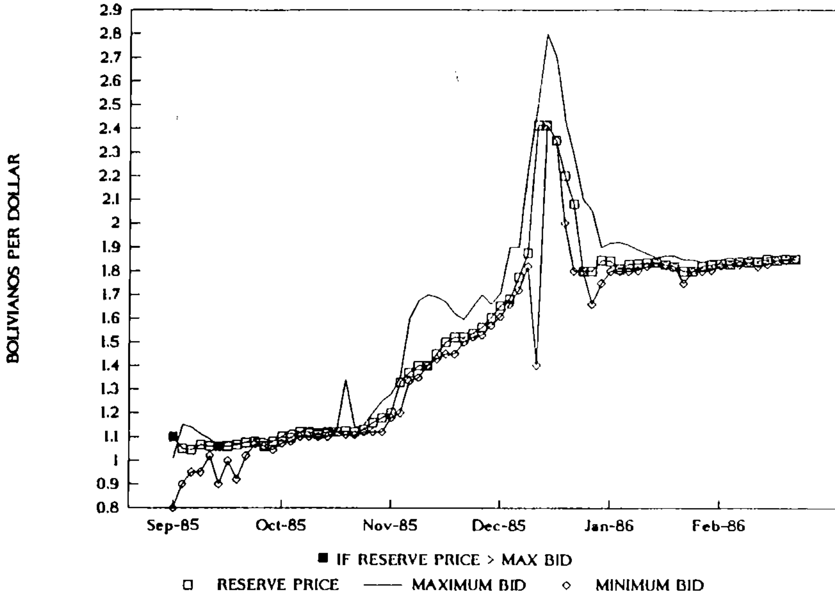


FIGURE 6.

BOLSIN AUCTION MAXIMUM AND MINIMUM BID PRICES

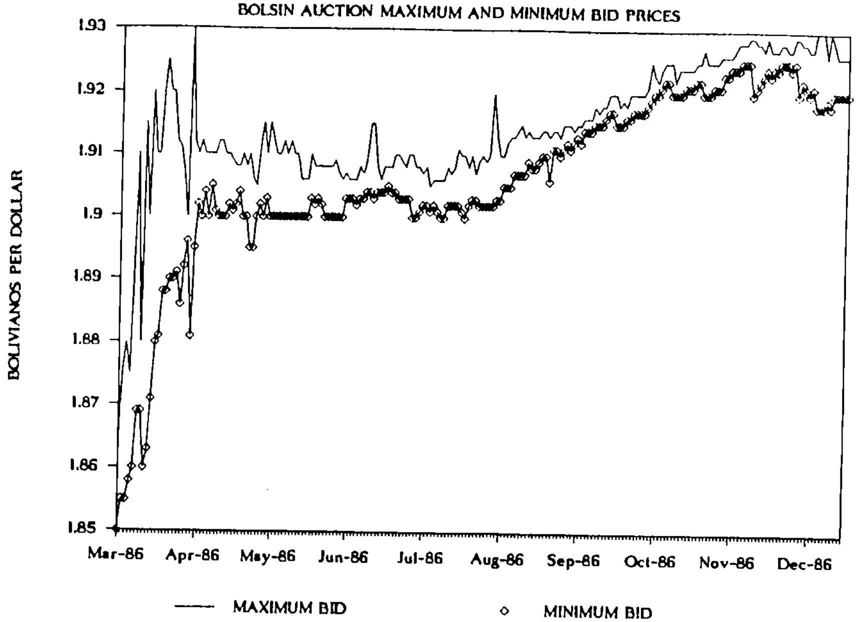


FIGURE 7.

BOLSIN AUCTION RESERVE*, MAXIMUM AND MINIMUM BID PRICES

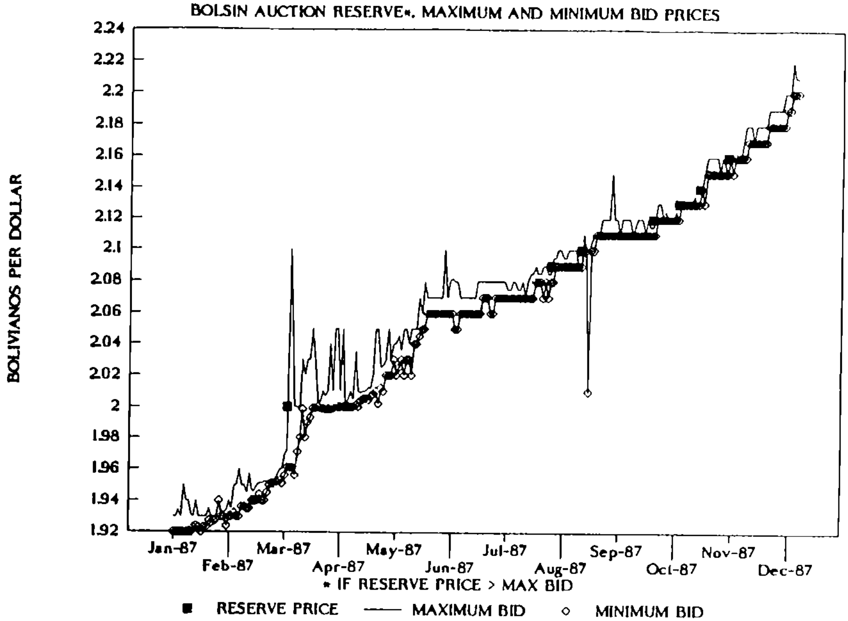


FIGURE 8.

BOLSIN AUCTION RESERVE*, MAXIMUM AND MINIMUM BID PRICES

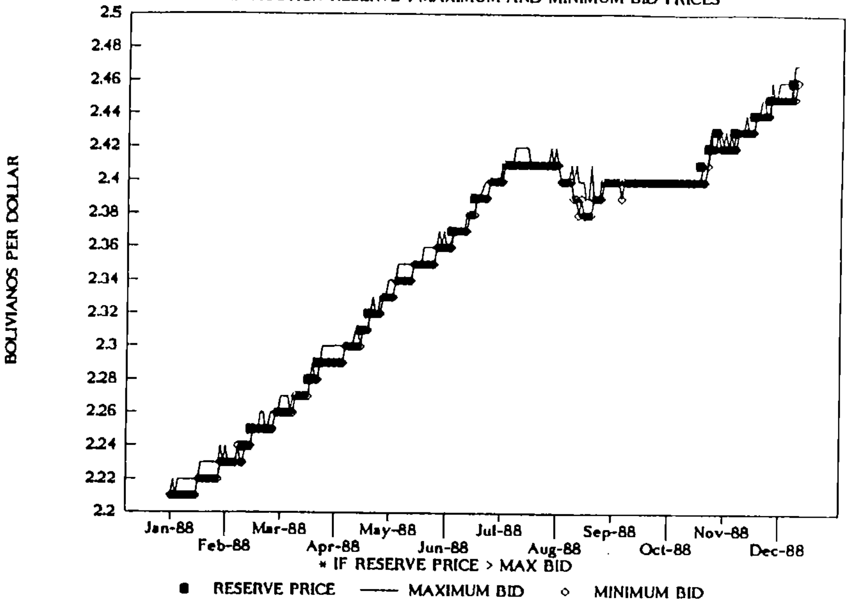


FIGURE 9.

BOLSIN AUCTION RESERVE*, MAXIMUM AND MINIMUM BID PRICES

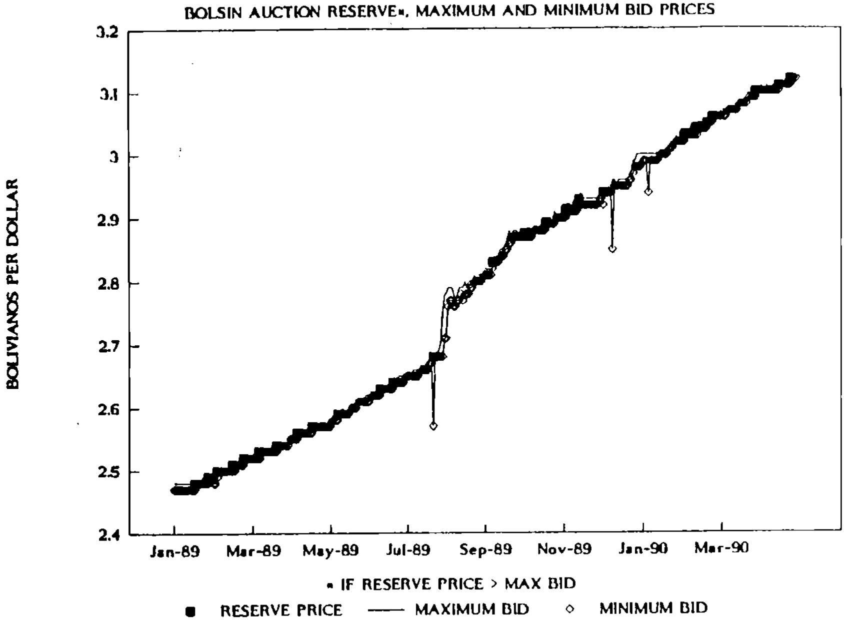
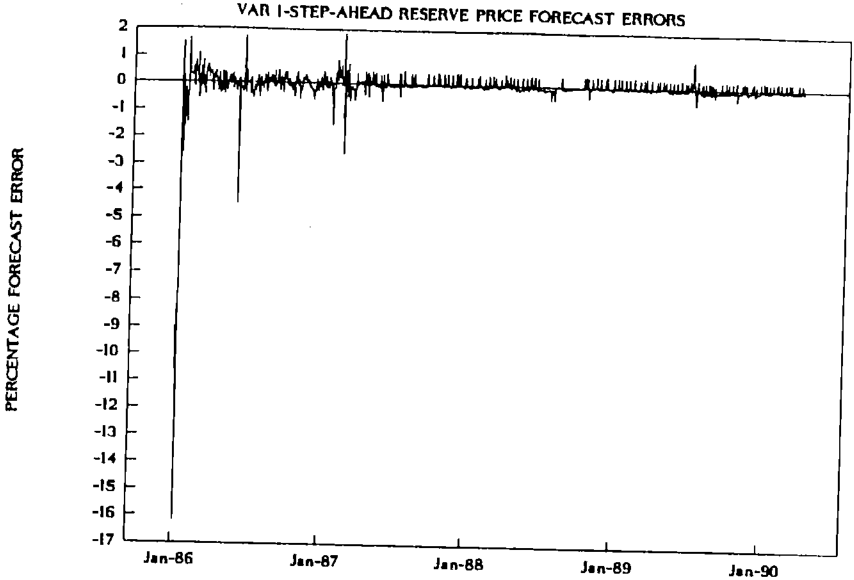


FIGURE 10.



VAR 1-STEP-AHEAD RESERVE PRICE FORECAST ERRORS
PERCENTAGE FORECAST ERROR
2
1
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
-14
-15
-16
-17
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90

FIGURE II.

REAL INTEREST RATES (BASE-1980)

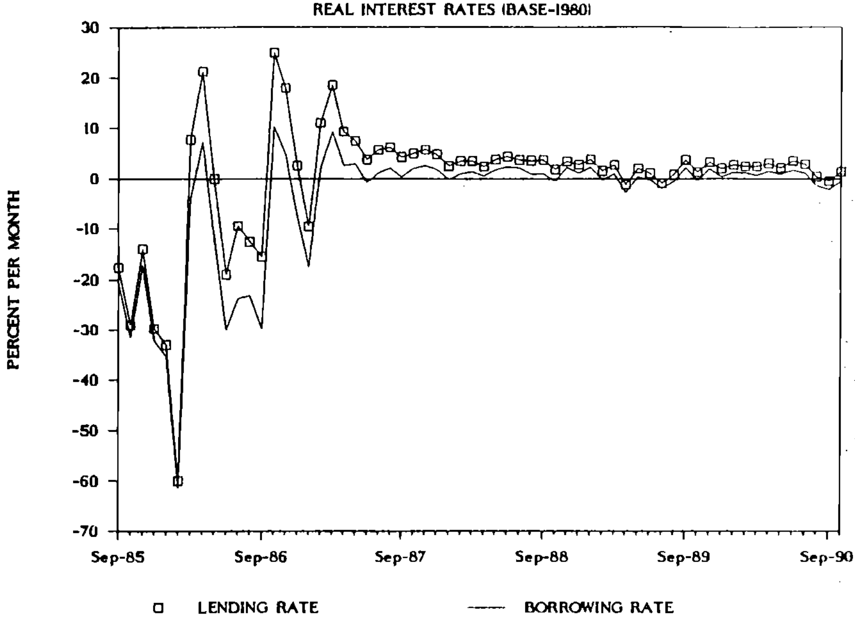


FIGURE 12.

REAL MONETARY BASE, MI, M2 AND M3

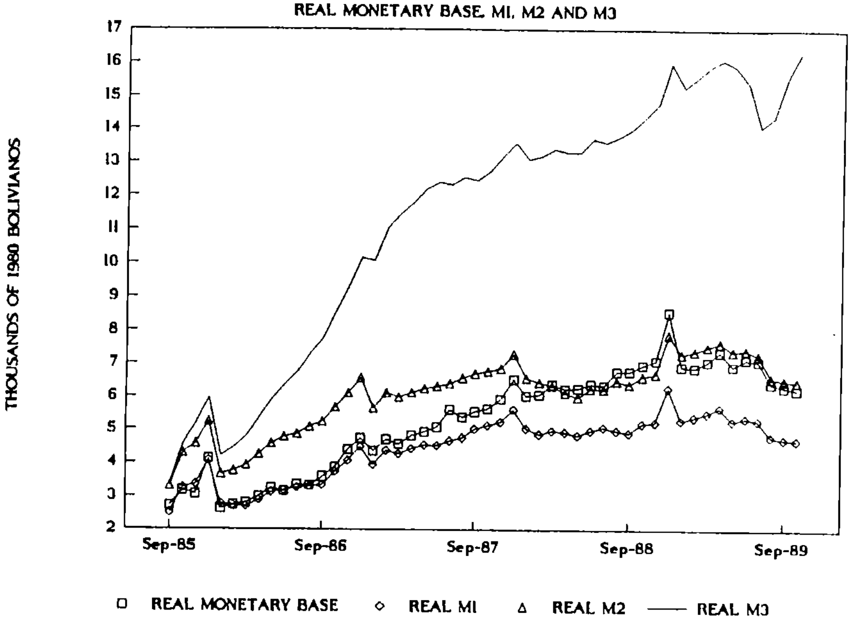


Table 1

BOLSIN RESERVE PRICE CHANGES

	1985-86	1987	1988	1989	1990
PERCENT RESERVE PRICE CHANGE DAYS	0.54	0.30	0.12	0.20	0.16
PERCENT RESERVE PRICE INCREASE DAYS	0.36	0.27	0.11	0.19	0.16
PERCENT RESERVE PRICE DECREASE DAYS	0.17	0.04	0.01	0.01	0.00
AVERAGE # OF DAYS BETWEEN RESERVE CHANGES	1.8	3.2	7.7	4.7	6.1
STANDARD DEVIATION	1.3	4.1	6.9	2.8	2.3
AVERAGE SIZE OF RESERVE CHANGES	0.005	0.004	0.008	0.01	0.01
STANDARD DEVIATION	0.06	0.009	0.005	0.005	0.00
AVERAGE SIZE OF RESERVE INCREASES	0.02	0.006	0.01	0.01	0.01
STANDARD DEVIATION	0.06	0.006	0.00	0.003	0.00
AVERAGE SIZE OF RESERVE DECREASES	0.02	0.01	0.01	0.01	0.00
STANDARD DEVIATION	0.04	0.009	0.00	0.00	0.00

Table 2

RESERVE PRICES, BIDS AND AUCTION OUTCOMES

	MIN<RESERVE	MIN=RESERVE	MIN>RESERVE
% OBSERVATIONS			
1985-86	.53	.37	.08
1987	.39	.53	.08
1988	.16	.83	.02
1989	.22	.76	.01
1990	.20	.79	.00
% SUPPLY DEMANDED [a]			
1985-86	.66	.47	.44
1987	.47	.39	.37
1988	.51	.57	.68
1989	.84	.64	.82
1990	.63	.67	NA
% DEMAND AWARDED [b]			
1985-86	.57	.80	.96
1987	.61	.95	.97
1988	.30	.96	.89
1989	.27	.93	.93
1990	.31	.91	NA

(a) Ratio of total demand to total supply of dollars at auction.

(b) Ratio of effective demand to total demand for dollars at auction.

Table 2 (cont.)

RESERVE PRICES, BIDS AND AUCTION OUTCOMES

	MAX<RESERVE	MAX=RESERVE	MAX>RESERVE
% OBSERVATIONS			
1985-86	.01	.02	.97
1987	.03	.08	.89
1988	.06	.45	.48
1989	.08	.59	.33
1990	.09	.65	.25
% SUPPLY DEMANDED [a]			
1985-86	.08	.37	.58
1987	.34	.59	.41
1988	.50	.48	.64
1989	.62	.62	.80
1990	.57	.58	.91
% DEMAND AWARDED [b]			
1985-86	.00	.41	.70
1987	.00	.34	.88
1988	.00	.87	.94
1989	.00	.84	.87
1990	.00	.85	.85

(a) Ratio of total demand to total supply of dollars at auction.

(b) Ratio of effective demand to total demand for dollars at auction.

Table 3

BIDDER STRATEGIES AND RESERVE PRICE CHANGES

I. PROBABILITY THAT BIDS<RESERVE ON DAYS THAT THE RESERVE PRICE IS INCREASED

If $R_t > R_{t-1}$, probability that $B_t < R_t$

	1985-86	1987	1988	1989	1990
MAX BID	.00	.10	.51	.35	.29
MIN BID	.96	.94	.97	.96	.93

II. PROBABILITY THAT BIDS INCREASE IN RESPONSE TO RESERVE PRICE INCREASES

If $R_t > R_{t-1}$, probability that $B_{t+1} > B_t$

	1985-86	1987	1988	1989	1990
MAX BID	.56	.59	.79	.60	.43
MIN BID	.64	.52	.82	.79	.78

III. PROBABILITY THAT BIDS DECREASE IN RESPONSE TO RESERVE PRICE INCREASES

If $R_t > R_{t-1}$, probability that $B_{t+1} < B_t$

	1985-86	1987	1988	1989	1990
MAX BID	.23	.19	.00	.01	.00
MIN BID	.09	.13	.00	.01	.00

IV. PROBABILITY THAT BIDS<RESERVE ON DAYS THAT THE RESERVE PRICE IS DECREASED

If $R_t < R_{t-1}$, probability that $B_t < R_t$

	1985-86	1987	1988	1989	1990
MAX BID	.00	.00	.00	.00	.00
MIN BID	.28	.11	.00	.00	.00

V. PROBABILITY THAT BIDS DECREASE IN RESPONSE TO RESERVE PRICE DECREASES

If $R_t < R_{t-1}$, probability that $B_{t+1} < B_t$

	1985-86	1987	1988	1989	1990
MAX BID	.64	.44	1.00	1.00	.00
MIN BID	.34	.44	1.00	1.00	.00

VI. PROBABILITY THAT BIDS INCREASE IN RESPONSE TO RESERVE PRICE DECREASES

If $R_t < R_{t-1}$, probability that $B_{t+1} > B_t$

	1985-86	1987	1988	1989	1990
MAX BID	.20	.11	.00	.00	.00
MIN BID	.26	.11	.00	.00	.00

Table 4

GRANGER-CAUSALITY TESTS

$$Y_t = \alpha_0 + \alpha_1 T + \sum_{j=1}^{n} \alpha_{2j} Y_{t-j} + \sum_{j=1}^{n} \alpha_{3j} X_{t-j} + v_t$$

$$H_0 : \sum_{j=1}^{n} \alpha_{3j} = 0$$

SAMPLE PERIOD I : SEPTEMBER 2, 1985 TO MARCH 21, 1986 (80 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	SUPPLY	DEMAND
RESERVE		13.09*	32.26**	16.89**	48.23**
MAX	5.59		15.62**	5.42	27.30**
MIN	24.16**	7.81		14.06*	65.65**
SUPPLY	17.01**	6.08	6.28		7.93
DEMAND	5.22	8.42	3.28	5.56	
EFFD/D[1]	7.98	4.44	3.38	6.74	2.48
(S-D)/D[2]	55.87**	37.55**	35.28**	5.26	24.16*

SAMPLE PERIOD II: MARCH 24, 1986 TO JANUARY 30, 1987 (214 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	SUPPLY	DEMAND
RESERVE		11.35*	38.20**	8.36	2.83
MAX	1.21		4.44	8.90	13.78*
MIN	7.28	5.54		6.64	5.29
SUPPLY	5.26	4.09	6.67		4.67
DEMAND	9.97	5.62	5.03	3.06	
EFFD/D[1]	17.91**	2.07	5.72	3.51	26.96**
(S-D)/D[2]	14.13*	10.47	3.37	3.31	6.59

1) Ratio of effective demand to total demand.
2) Percentage of supply demanded.

All price variables are in natural logarithms. Regressions were estimated using White's (1980) heteroskedasticity correction. The number of lags (n) for each regression is determined using the Akaike Information Criterion. The Chi-square test statistic displayed is distributed as $\chi^2(n)$ and pertains to the hypothesis that all n lags of the independent variable (X) are equal to zero; * denotes rejection at the .05 level, and ** at the .01 level of H_0.

Table 4 (cont.)

GRANGER-CAUSALITY TESTS

$$Y_t = \alpha_0 + \alpha_1 T + \sum_{j=1}^{n} \alpha_{2j} Y_{t-j} + \sum_{j=1}^{n} \alpha_{3j} X_{t-j} + v_t$$

$$H_0 : \sum_{j=1}^{n} \alpha_{3j} = 0$$

SAMPLE PERIOD III: FEBRUARY 2, 1987 TO JULY 14, 1988 (358 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	PARALLEL	SUPPLY	DEMAND
RESERVE		16.54**	30.99**	18.88**	5.54	15.32**
MAX	2.95		14.34**	10.41*	6.04	2.62
MIN	6.86	5.52		2.61	6.35	5.00
PARALLEL	6.17	26.24**	8.25		4.89	20.78**
SUPPLY	3.27	9.33	3.64	3.27		7.27
DEMAND	1.37	18.38**	3.73	9.21	5.84	
EFFD/D[1]	10.41	17.23**	24.87**	6.56	8.26	73.10**
(S-D)/D[2]	1.45	17.40**	5.26	6.31	5.16	10.72

SAMPLE PERIOD IV: JULY 15, 1988 TO DECEMBER 1, 1988 (99 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	PARALLEL	SUPPLY	DEMAND
RESERVE		37.67**	40.25**	8.69	0.51	58.59**
MAX	2.98		5.04	9.08	1.12	2.18
MIN	3.09	15.24**		8.72	0.28	7.70
PARALLEL	2.71	6.63	12.84*		0.01	1.79
SUPPLY	4.25	95.21**	20.39**	6.89		88.81**
DEMAND	4.77	11.36*	4.91	7.33	1.08	
EFFD/D[1]	10.20	12.50*	20.94**	3.04	0.97	23.77**
(S-D)/D[2]	4.31	9.10	4.97	7.76	1.14	11.14*

1) Ratio of effective demand to total demand.
2) Percentage of supply demanded.

All price variables are in natural logarithms. Regressions were estimated using White's (1980) heteroskedasticity correction. The number of lags (n) for each regression is determined using the Akaike Information Criterion. The Chi-square test statistic displayed is distributed as $\chi^2(n)$ and pertains to the hypothesis that all n lags of the independent variable (X) are equal to zero; * denotes rejection at the .05 level, and ** at the .01 level of H_0.

Table 4 (cont.)

GRANGER-CAUSALITY TESTS

$$Y_t = \alpha_0 + \alpha_1 T + \sum_{j=1}^{n} \alpha_{2j} Y_{t-j} + \sum_{j=1}^{n} \alpha_{3j} X_{t-j} + v_t$$

$$H_0 : \sum_{j=1}^{n} \alpha_{3j} = 0$$

SAMPLE PERIOD V: DECEMBER 2, 1988 TO AUGUST 1, 1989 (162 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	PARALLEL	SUPPLY	DEMAND
RESERVE		81.79**	30.15**	12.61*	19.25**	65.98**
MAX	5.18		23.68**	5.10	6.39	10.29
MIN	5.50	6.94		4.12	10.33	15.95**
PARALLEL	7.18	75.04**	81.82**		13.75*	76.22**
SUPPLY	5.48	6.44	9.58	7.07		2.39
DEMAND	7.59	2.17	12.83*	3.23	6.59	
EFFD/D[1]	4.26	29.43**	36.05**	7.50	26.59**	70.74**
(S-D)/D[2]	9.37	1.73	8.14	7.93	6.21	1.88

SAMPLE PERIOD VI: AUGUST 16, 1989 TO MAY 9, 1990 (181 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	PARALLEL	SUPPLY	DEMAND
RESERVE		78.44**	56.64**	12.60*	4.95	48.84**
MAX	10.64		13.07*	2.22	2.38	1.88
MIN	1.55	7.81		2.21	4.51	2.37
PARALLEL	6.95	61.72**	33.44**		4.96	66.78**
SUPPLY	12.06*	2.22	12.67*	12.43*		11.08*
DEMAND	5.12	45.81**	8.94	6.77	4.79	
EFFD/D[1]	6.72	52.26**	26.76**	2.45	6.97	86.72**
(S-D)/D[2]	7.93	50.40**	6.04	10.39	3.57	25.53**

1) Ratio of effective demand to total demand.
2) Percentage of supply demanded.

All price variables are in natural logarithms. Regressions were estimated using White's (1980) heteroskedasticity correction. The number of lags (n) for each regression is determined using the Akaike Information Criterion. The Chi-square test statistic displayed is distributed as $\chi^2(n)$ and pertains to the hypothesis that all n lags of the independent variable (X) are equal to zero; * denotes rejection at the .05 level, and ** at the .01 level of H_0.

Table 4 (cont.)

GRANGER-CAUSALITY TESTS

$$Y_t = \alpha_0 + \alpha_1 T + \sum_{j=1}^{n} \alpha_{2j} Y_{t-j} + \sum_{j=1}^{n} \alpha_{3j} X_{t-j} + v_t$$

$$H_0 : \sum_{j=1}^{n} \alpha_{3j} = 0$$

FULL SAMPLE PERIOD: FEBRUARY 2, 1987 TO MAY 9, 1990 (807 OBS)

Dependent variables (Y)

(X)	RESERVE	MAX	MIN	PARALLEL	SUPPLY	DEMAND
RESERVE		25.19**	91.07**	11.35*	9.38	39.36**
MAX	7.09		15.36**	12.61*	3.99	4.26
MIN	2.71	8.31		5.01	4.20	10.64
PARALLEL	10.54	29.12**	13.15*		3.89	26.39**
SUPPLY	5.89	5.79	3.24	6.21		15.51**
DEMAND	5.06	28.86**	6.99	10.28	6.29	
EFFD/D[1]	6.53	57.86**	69.16**	9.31	29.03**	99.86**
(S-D)/D[2]	4.09	25.46**	9.79	10.55	7.62	23.08**

1) Ratio of effective demand to total demand.
2) Percentage of supply demanded.

All price variables are in natural logarithms. Regressions were estimated using White's (1980) heteroskedasticity correction. The number of lags (n) for each regression is determined using the Akaike Information Criterion. The Chi-square test statistic displayed is distributed as $\chi^2(n)$ and pertains to the hypothesis that all n lags of the independent variable (X) are equal to zero; * denotes rejection at the .05 level, and ** at the .01 level of H_0.

Table 5a

MAXIMUM BID PREMIUMS AT THE BOLSIN

$$B_t^j - R_{t-1} = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k}(R_{t-k}-R_{t-k-1}) + \sum_{k=1}^{n} \alpha_{2k}(P_{t-k}-P_{t-k-1}) + \alpha_3(P_{t-1}-O_{t-1})$$

$$+ \sum_{k=1}^{n} \alpha_{4k}D^{e}_{t-k} + \sum_{k=1}^{n} \alpha_{5k}(B^j_{t-k}-R_{t-k-1}) + e_t$$

SUBPERIODS[a]

	I	II	III	IV	V	VI
α_0	0.04 (1.29)	0.001 (0.70)	0.01 (2.39)**	0.001 (0.36)	0.003 (0.98)	0.001 (0.99)
$\Sigma\alpha_{1k}$	0.81 (1.37)	1.21 (2.12)*	2.79 (2.10)*	3.15 (3.16)**	3.19 (2.66)*	1.68 (1.97)*
$\Sigma\alpha_{2k}$			1.54 (2.35)*	0.64 (0.83)	2.06 (4.34)**	0.14 (1.16)
α_3			0.11 (1.38)	0.18 (2.52)*	0.02 (0.61)	0.29 (2.78)**
$\Sigma\alpha_{4k}$	0.82 (1.22)	0.001 (0.12)	0.01 (1.98)*	0.002 (0.75)	0.003 (0.85)	0.002 (0.56)
$\Sigma\alpha_{5k}$	0.79 (8.16)**	0.79 (9.63)**	0.69 (6.82)**	0.63 (2.99)**	0.55 (4.94)**	0.41 (3.53)**
R^2	0.45	0.55	0.40	0.37	0.52	0.54
D.W.	2.04	2.01	1.99	1.94	1.93	2.02
χ^2	22.65	106.21**	66.06**	142.84**	112.12**	133.09**

a) Subperiods: I. September 2, 1985 to March 31, 1986; II. March 24, 1986 to January 30, 1987; III. February 2, 1987 to July 14, 1988; IV. July 15, 1988 to December 1, 1988; V. December 2, 1988 to August 1, 1989; VI. August 16, 1989 to May 9, 1990.

Parallel market data are unavailable for the first two subperiods. j=1, n=10. All price variables are in natural logarithms. Demand is divided by 1,000,000. Regressions were estimated using White's (1980) heteroskedasticity correction. Numbers in parentheses are the estimated t-statistics of the coefficients; * denotes rejection at the .05 level and ** at the .01 level of the hypothesis that the coefficient is significantly different from zero. The χ^2 statistic pertains to the hypothesis that $\alpha_1=\alpha_2=\alpha_3=\alpha_4=0$.

Table 5b

MINIMUM BID PREMIUMS AT THE BOLSIN

$$B_t^j - R_{t-1} = \alpha_0 + \sum_{k=1}^{n} \alpha_{1k}(R_{t-k}-R_{t-k-1}) + \sum_{k=1}^{n} \alpha_{2k}(P_{t-k}-P_{t-k-1}) + \alpha_3(P_{t-1}-O_{t-1})$$

$$+ \sum_{k=1}^{n} \alpha_{4k}D_{t-k}^{e} + \sum_{k=1}^{n} \alpha_{5k}(B_{t-k}^{j}-R_{t-k-1}) + e_t$$

SUBPERIODS[a]

	I	II	III	IV	V	VI
α_0	-0.001 (-0.05)	-0.001 (1.16)	-0.001 (0.60)	-0.004 (2.19)*	0.01 (1.49)	-0.002 (1.74)
$\Sigma\alpha_{1k}$	1.03 (1.42)	1.86 (5.54)**	1.66 (1.96)*	1.40 (1.73)	6.59 (1.77)	5.84 (1.99)*
$\Sigma\alpha_{2k}$			0.06 (0.27)	0.41 (1.93)	1.47 (1.98)*	5.21 (1.72)
α_3			0.04 (1.12)	0.01 (0.11)	0.09 (2.08)*	0.05 (1.57)
$\Sigma\alpha_{4k}$	-0.004 (0.14)	0.001 (1.12)	0.05 (0.31)	0.004 (2.17)*	-0.009 (1.38)	0.001 (1.69)
$\Sigma\alpha_{5k}$	0.44 (2.63)**	0.36 (2.48)*	0.33 (1.81)	0.31 (2.16)*	0.52 (1.96)*	0.27 (1.99)*
R^2	0.25	0.34	0.45	0.39	0.22	0.23
D.W.	2.14	1.99	2.00	1.89	1.97	1.98
χ^2	23.68	125.56**	56.28*	264.98**	116.27**	111.33**

a) Subperiods: I. September 2, 1985 to March 31, 1986; II. March 24, 1986 to January 30, 1987; III. February 2, 1987 to July 14, 1988; IV. July 15, 1988 to December 1, 1988; V. December 2, 1988 to August 1, 1989; VI. August 16, 1989 to May 9, 1990.

Parallel market data are unavailable for the first two subperiods. j=2, n=10. All price variables are in natural logarithms. Demand is divided by 1,000,000. Regressions were estimated using White's (1980) heteroskedasticity correction. Numbers in parentheses are the estimated t-statistics of the coefficients; * denotes rejection at the .05 level and ** at the .01 level of the hypothesis that the coefficient is significantly different from zero. The χ^2 statistic pertains to the hypothesis that $\alpha_1=\alpha_2=\alpha_3=\alpha_4=0$.

Table 6

DEMAND FOR DOLLARS AT THE BOLSIN

$$D_t = \sum_{i=1}^{12} \beta_{0i} M_{it} + \sum_{k=1}^{n} \beta_{1k}(R_{t-k}-R_{t-k-1}) + \sum_{k=1}^{n} \beta_{2k}(P_{t-k}-P_{t-k-1}) + \beta_3(P_{t-1}-O_{t-1})$$

$$+ \sum_{k=1}^{n} \beta_{4k} D^{*}_{t-k} + \sum_{k=1}^{n} \beta_{5k} D_{t-k} + e_t$$

SUBPERIODS[a]

	I	II	III	IV	V	VI
$\Sigma\beta_{0i}$	-5.23 (-0.55)	6.65 (0.51)	10.85 (1.04)	88.53 (5.28)**	85.53 (1.89)	3.42 (0.36)
$\Sigma\beta_{1k}$	0.95 (0.65)	-78.86 (-0.12)	279.81 (2.21)*	268.21 (3.38)**	531.91 (2.12)*	250.17 (1.19)
$\Sigma\beta_{2k}$			234.93 (2.27)*	484.79 (2.15)*	374.74 (0.58)	394.63 (1.96)*
β_3			6.35 (0.32)	32.01 (0.36)	-10.39 (-0.8)	107.59 (0.47)
$\Sigma\beta_{4k}$	7.99 (2.61)*	1.62 (2.55)*	0.09 (0.10)	-12.11 (-1.79)	-8.38 (-1.55)	1.19 (1.10)
$\Sigma\beta_{5k}$	0.03 (0.09)	0.36 (2.17)*	0.44 (3.57)**	0.43 (2.33)*	0.46 (1.85)	0.41 (3.18)**
R^2	0.35	0.27	0.44	0.55	0.43	0.56
D.W.	1.92	2.02	1.99	1.97	1.93	1.98
χ^2	404.54**	64.81*	122.88**	305.63**	156.85**	208.35**

a) Subperiods: I. September 2, 1985 to March 31, 1986; II. March 24, 1986 to January 30, 1987; III. February 2, 1987 to July 14, 1988; IV. July 15, 1988 to December 1, 1988; V. December 2, 1988 to August 1, 1989; VI. August 16, 1989 to May 9, 1990.

Parallel market data are unavailable for the first two subperiods. n=10. All price variables are in natural logarithms. Demand is divided by 1,000,000. Regressions were estimated using White's (1980) heteroskedasticity correction. Numbers in parentheses are the estimated t-statistics of the coefficients; * denotes rejection at the .05 level and ** at the .01 level of the hypothesis that the coefficient is significantly different from zero. The χ^2 statistic pertains to the hypothesis that $\beta_1=\beta_2=\beta_3=\beta_4=0$.

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