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POLICY RULES AND BIDDING BEHAVIOUR IN THE ETHIOPIAN FOREIGN EXCHANGE AUCTION[1]

JANINE ARON
University of Oxford, Oxford

Abstract

Ethiopia adopted a repeated Dutch auction for foreign exchange in May, 1993, for dedicated imports by the private and state sectors. Various African countries with rudimentary financial systems and thin foreign exchange markets have successfully employed auctions in transition from centralised, controlled systems to decentralised interbank markets. This paper characterises the rules, regime shifts and auction outcomes in Ethiopia. It is emphasised that institutional micro-design and operation of an auction can have important macroeconomic consequences during liberalisation. Models for the Central Bank's supply rules for pre-announced supply of dollars in fortnightly and later weekly auctions, confirm the objective was to stabilise the exchange rate (the marginal auction price) in a thin market around depreciating trends. Bidders were able to learn the supply rules, clustering their bids around predicted target rates. Using a method novel in auction empirical literature, bidders' learning in repeated auctions is examined via the adjustment to equilibrium in error correction equations for the bid spread. Robust models for a similar learning process were found across both frequency regimes; but learning was faster where the exchange rate target was more transparent and uncertainty lower. Thus, a fairly stable depreciation was achieved over four years, despite considerable regime shifts from trade liberalisation, the progressive lifting of auction entry barriers, increased frequency of auctions, fiscal and other seasonality in demand, and temporary price shocks in coffee export earnings.

I. Introduction

Ethiopia has been one of the last of the African countries with a socialist economic legacy to adopt market principles and liberalise its economy. After decades of an overvalued fixed exchange rate, misallocation of foreign exchange by committee, and stringent trade and exchange controls, Ethiopia initiated liberalisation of the foreign exchange regime under a new government at the termination of a lengthy and debilitating civil war.[2] In May, 1993, a system of consecutive foreign exchange auctions was adopted as part of a larger macroeconomic adjustment programme, with a view to achieving a market-determined exchange rate, improved allocation of foreign exchange and shifting transactions from the illegal to the official market. In four years of fortnightly and later weekly auctions, the Dutch auction system has achieved a fairly stable exchange rate (the marginal price) and progressively expanded supply and deepened the official foreign exchange market, while the illegal parallel premium for dollars has fallen dramatically to under 10 percent (see Figure 1).

Foreign exchange auctions have been employed by a number of countries in transition from centralised, controlled foreign exchange systems to decentralised interbank foreign exchange markets, sometimes over several years, and notably in Eastern Europe and ex-Soviet Union transitional economies in the 1990s, and in various African economies since the mid-1980s. These auctions cover a diverse range of design and management rules. Complementary to the set of macroeconomic policies followed, these rules have considerable implications for the achievement of the auctions' objectives.

In the African setting, auctions have offered several advantages as a transitional device to interbank markets. Principally, a transparently-operated auction system can achieve a market-based allocation of foreign exchange even in thin markets, which is optimal in the sense that the highest bidders for a fixed supply of foreign exchange are successful. This is particularly important in cases where the rudimentary development, high concentration or uncompetitive nature of the financial sector is unlikely to achieve a fair and efficient allocation in an interbank market (Krumm, 1985). Auctions offer flexibility for liberalising trade and participant restrictions over time, thereby deepening the market. Auctions are informationally rich, and reveal to the seller information about private agents' valuations.[3] The seller (the Central Bank) is also in the position to reveal information through pre-announcement or publication, or by following an implicit management rule that can be learned by the bidders. This can reduce uncertainty and stabilise the exchange rate in thin markets, promoting investment and exports. The oft-cited disadvantages of an auction system are the increased facility, relative to an interbank system, for government policy discretion, and also, where there are a small number of bidders, for collusion (e.g. Kovanen, 1994). However, possibilities for manipulation are considerably curtailed when rules are transparent and markets are relatively deep (such as in retail auctions to be for importers). In effect, when properly designed, African auctions have proved a useful tool for an orderly and gradual liberalisation in Africa (see a recent critical review of four African auctions in Aron and Elbadawi, 1994a).

Despite the policy importance, there has been limited empirical research on the influence of different microeconomic rules on the achievement of macroeconomic objectives in the foreign exchange auctions.[4] And with the notable exception of Tenorio (1993), who tested for revenue-equivalence under Dutch and uniform pricing in the Zambian auction, and the use of co-integration models to test a range of auction hypotheses in four African auctions (Aron and Elbadawi, 1994b), there is a complete absence of applied microeconomic research on the African auctions (including Ethiopia).

One interesting and important feature of the Ethiopian auction, is that after an initial period of adjustment, there was relative stability of the exchange rate around depreciating trends for over four years (Figure 1). This is despite large and frequent regime shifts and exogenous shocks during the period, including trade liberalisation, the progressive lifting of auction entry barriers, the increased frequency and depth of auctions, strong seasonal elements in demand, and a temporary price boom in coffee export earnings. Our key objective in this paper is to account for the stability by examining design features of the auction and the Central Bank policy management rules, as well as the markets' reaction to these rules.

Changing Central Bank policy rules and bidders' responses were studied in the Bolivian auction by Dominguez (1991). Over five years from late 1985, daily retail auctions were conducted by the Central Bank, which served both to stabilise the exchange rate and virtually eliminate the parallel premium for dollars. This study demonstrates that while other institutional rules did not alter much in the course of the auction, after the first year, in which the emphasis was on unifying the dual rates of exchange, the Central Bank adopted a reserve pricing rule with the objective of stabilising the exchange rate. The reserve price was not pre-announced, but together with the authority's other policy variable, the supply to the auction, it was announced *after* all the bids were submitted, and *before* they were unsealed. Granger causality tests suggest that both policy instruments, the reserve price and the supply offered at each auction, were exogenously determined after 1986. For periods where the exchange rate targets were transparent, market variables such as bid spreads and demand were influenced by past reserve price movements, such that the exchange rate system came to resemble a crawling peg. By dint of the lack of rationing in the auction (for only 107 out of 1107 auctions did demand exceed supply) and by the reaction of monetary policy to offset demand pressures, the parallel premium did not reappear.

The Ethiopian case offers an interesting contrast with policy management in the Bolivian auction. Several differences are important. The auctions were conducted fortnightly for the first three years, and then weekly, with average supply per auction in the two regimes, respectively, being 17.2 and 17.6 million dollars. By contrast, in daily auctions in Bolivia supply ranged between about 5 and 10 million dollars. The forex market was thus far thinner in Ethiopia and demand exceeded supply for the majority of the auctions. Thus, by contrast with Bolivia, there was an illegal dual market for much of the auction period with a sizeable parallel market premium of 15-20 percent (until the *franco valuta* market was banned in August, 1996). In these circumstances, the operation of a reserve price

in a rationed market would resemble too closely the pre-auction regime of a fixed exchange rate, untied to macroeconomic fundamentals.

The Ethiopian Central Bank nevertheless aimed to stabilise the exchange rate in the thin market against volatile demand driven by seasonal influences and episodes of trade liberalisation and further expansion of the auction market (Collier, 1995). The Central Bank pre-announced supply, one week in advance, and adopted supply rules which predicted future demand, responding to market variables such as past excesses in demand and the parallel market behaviour, as well as seasonal influences (especially fiscal year seasonality) and changes in trade and exchange regimes. The supply rule was not revealed, and the rule appears to have changed over time.[5] As with the Bolivian auction. market reaction tried to predict the target exchange rate. Bid spreads appear to decrease in periods where supply rules were unchanged and hence targets were more predictable; and to increase in periods when operational rules or design features altered (Figure 2).

In this paper, the aim is to estimate supply rules across different frequency regimes (fortnightly and weekly) as a function of past bidder behaviour, anticipated seasonality, various trade liberalisations and changing entry requirements and costs to the auction. Then the determinants of a market variable represented by the maximum bid-marginal bid spread will be investigated and reactions linked to changed design and rules.

One difficulty faced in empirical research is the absence of equilibrium theoretical models for these types of auctions. It is frequently observed in the literature (e.g. McAfee and Macmillan, 1987; Milgrom and Weber, 1982) that auction theory is poorly developed for multi-unit auctions –particularly with endogenous quantity choice– and for repeated auctions, where strategic behaviour may occur (see Bikhchandani, 1988). The foreign exchange auctions further involve the simultaneous relaxation of typical theoretical assumptions such as symmetry of bidders and risk neutrality.

Thus, while Hendricks and Paarsch (1995) in a recent survey of empirical work on auctions discuss the estimation of structural models for very restricted auctions, our research approach will be to follow the earlier empirical tradition and estimate unrestricted reduced-form models, which test some implications of simpler theoretical auction models. The dynamics of the repeated auctions and the non-stationarity of many individual auction variables are captured in a co-integrated (error correction) framework (see Banerjee et al., 1993). This empirical approach, while commonly used for macroeconomic time series data, is novel in auction research (though see also Aron and Elbadawi, 1994b). The advantages are that where a theoretical equilibrium relationship is expected in the long-run for repeated auctions, this is captured in the equilibrium term of the equation, and the error correction coefficient measures adjustment to equilibrium in the face of shocks. Short-term dynamics around equilibrium are simultaneously modelled by including current and lagged differences in the regressors.

The study proceeds as follows. The next section characterises the rules and institutional features of the Ethiopian auction, together with major regime changes occurring during its operation. Theoretical issues for sequentially repeated multi-unit auctions with endogenous quantity choice are discussed in Section III, together with the implications for deriving dynamic reduced form empirical models for the auction variables. Statistics on auction outcomes, the Central Bank's policy variables and bidder behaviour are given in Section IV. Models for the policy rule for pre-announced supply are estimated in Section V, and the response of bidders is evaluated in error correction models for the bid spreads. Section VI concludes.

II. Rules and Institutional Details for Ethiopia's Auction

Since the auctions were adopted as a liberalising mechanism for trade and the foreign exchange market, there have been a large number of rules changes over the four years. The rules are detailed in Table 1, while regime changes are given in Table 2.

Ethiopia's official exchange rate remained fixed at Birr 2.07 per US dollar from 1973 to 1992, and given adverse macroeconomic and political developments in the period, the premium between official and illegal parallel markets had widened to over 100 percent by the early 1990s. In late 1992, the Birr was devalued to 5 Birr per US dollar, and in May, 1993 a foreign exchange auction was instituted as part of an overall adjustment package. with the principal aims of unifying the official and parallel markets, providing efficient allocation of foreign exchange, and, for a given supply to the auction, a market determination of the exchange rate.

The auction was held every fortnight for the first three years, and thereafter auctions were conducted weekly. The auction format is a standard sealed bid Dutch (or discriminatory) auction where bidders submitted price-quantity pairs, and could make multiple bids. The participants were importers, including parastatals, government departments and the private sector. Bidders were required to provide various documents[6] with their bids by the afternoon preceding the auction, and the absence of correct documents disqualified a bid.[7] A minimum bid was applied throughout the auction system, which was doubled in auction 47 (see rules in Table 1). Trade restrictions at first limited the types of imports that could be bought with auction-acquired foreign exchange. Over time, the auction was gradually widened to allow most goods through the auction (see trade regime shifts in Table 2).

There were asymmetries amongst the types of bidders, specifically between government ministries versus private and parastatal importers. While there may be enhanced transparency when government departments bid for their foreign exchange needs, in practice, slow disbursement in the fiscal system resulted in delayed local currency disbursements. Ministries therefore frequently "overbid" at the very end of the fiscal year (i.e. securing foreign exchange at too high cost), against the event that departments would have to surrender unspent funds or have their allocation reduced for the following fiscal year (see Figures 5). These bidders therefore operated with a different objective function from the profit-maximising private sector and, to the extent that they were autonomous, the

parastatal bidders. It is clear that the Central Bank attempted to accommodate this "budgetary" demand by discretionary seasonal increases of supply.

The amount of dollars supplied to the auction was pre-announced a week in advance. Supply to the auction stemmed from private and public sector exports and from foreign aid.[8] All export receipts had to be surrendered (this rule was slightly relaxed in July, 1996 - see Table 2), and certain essential imports as well as debt servicing were settled outside the auction.[9] Decisions about supply obviously required a longer-term view for sustainable (hence credible) supply across auctions. However, it was confirmed by the Central Bank's first governor during the auction that pre-announced supply was not exogenous to bidder behaviour in the short-term, but essentially predicted future demand, responding to market variables such as past excesses in demand and the parallel market behaviour, as well as seasonal influences[10] and changes in trade and exchange regimes. The clear aim was to smooth the exchange rate against seasonal and other volatile demand in a thin market.

Bids were opened publicly on the Friday morning, and in the presence of an Auction Committee, comprising members of the private sector, the government and Central Bank.[11] The bids were ordered by decreasing price, until the pre-announced supply target was reached. Below this marginal price, bids were deemed unsuccessful. As in all other African auctions this marginal bid determined the exchange rate for exports until the next auction. By contrast, in Bolivia's Dutch auction, the exchange rate was the demand-weighted average of the reserve price and successful bids.

However, bidders with bids at the marginal price did not receive a pro-rated fraction of their demand, as applied in the Bolivian auction. Instead, the committee had to decide whether it was feasible to expand supply to provide fully for all bidders' demands at this marginal price, or to decrease supply from the pre-announced level and make the next higher price the marginal price. The reason for this inflexibility was to simplify the monitoring of foreign exchange usage which was required by donor countries and organisations, since sufficient foreign exchange was required to purchase particular or dedicated imports for which pro-forma invoices were provided (Loha, 1996). Providing partial amounts of foreign exchange for these "lumpy" imports would have meant bidders returning at another auction, considerably increasing monitoring bureaucracy.

Thus, there was limited discretion, namely whether the marginal bid would be accepted, if the actual supply implied at that price exceeded announced supply, or whether to raise the marginal price to the preceding higher bid. In general, supply was expanded. Only in 12 auctions out of 143 was supply contracted when demand was higher than pre-announced supply.[12] This "rule" accounts for all positive deviations of actual from pre-announced supply with the exception of 26 auctions out of 143, 16 of which fall in the fortnightly period. For these special cases, all but four cases fall clearly in specific periods where demand is seasonally high or where trade liberalisation or some other rule change expanding demand takes place. Here discretion does appear to have been used to expand supply when pre-announced supply had been underestimated by the Central Bank given the rule changes. While there was wide variation, the additional amounts in these auctions averaged 13 percent of preannounced supply.[13]

It would clearly have been an improvement if these instances of supply discretion due to lumpy imports and to fiscal pressures had been formalised explicitly and transparently in the auction rules, as it has caused confusion and concern about manipulation by some commentators,[14] and no doubt also diminished stability in the auction.

The opportunity cost for bidders was the parallel market exchange rate. The parallel market has a long history in Ethiopia, and is a legacy of the severe shortages of foreign exchange faced by the private sector when the exchange rate was fixed and over-valued, and foreign currency was allocated by non-price (administrative) methods. An important component of demand on the parallel market is goods imported on a *franco valuta* basis, that is, brought into the country *without* having received foreign currency from a commercial bank or the Central Bank, on the importer's "own resources". Such goods could cover items not allowed through the auction. However, much of the *franco valuta* demand was accounted for by imports for aid organizations and government entities, including famine relief.

III. Theoretical and Empirical Issues

As pointed out above, theory has largely focussed on single-unit auctions, or multiple-unit auctions where bidders receive at most one unit of a divisible good. While recent papers examine more general multiple-unit, one-shot auctions (e.g. Back and Zender, 1993), it remains the case that there is no theoretical model for equilibrium bidding behaviour in a repeated, multiple-bid, multiple-unit auction. Instead some of the implications of equilibrium models for simpler auctions will be explored.

3.1 Theoretical complexities of the foreign exchange auctions

It is worth emphasising some of the theoretical complexities of these auctions. It has been shown that in multiple-unit auctions, where bidders select both the price and the quantity of units they wish to buy at that price, that integrated price-quantity bids can involve strategic behavior (Tenorio, 1992). Repeated auctions introduce the possibility of strategic dynamics and learning behavior (Bikhchandani, 1988). Deception effects may develop in sequential sales (Hausch, 1986); cooperative collusive behavior amongst bidders may be facilitated (Feinstein et al., 1985); and the commitment of the seller becomes especially important in repeated auction games (McAfee and McMillan, 1987). Thus the credibility of the exchange rate liberalization will matter, which is also influenced by a combination of macro-economic policies, exogenous shocks and political-economic features.

Further, the set of bidders is not exogenous when rules are altered over time (e.g. on information revelation), and different rules and formats can attract differ-

ent sets of bidders (Samuelson, 1990). Bidders are asymmetric, falling into identifiable sub-classes based on systematic ownership and production differences between firms (multinational, domestic and publicly-owned firms, government ministries), and variations in credit-worthiness (bids required domestic currency deposits). Bidders may be highly risk-averse, since foreign exchange is a crucial input in often highly import-intensive production.

Finally, the relevant value assumptions are a mix of independent private values (IPV) and the common values (CV) models. As suggested in Tenorio (1993), private values are probably dominant in these auctions, given that the acquired foreign exchange was applied to dedicated imports for firms with import licences and pro-forma invoices. However, a CV component is introduced in such retail auctions, for instance when information is published or where consistent rules in repeated auctions can be learned by bidders. However, these auctions do not allow resale in a secondary market for foreign exchange. While a more general model (MW) has been developed which encompasses the CV and IPV models (Milgrom and Weber, 1982), most auction predictions stem from pure IPV or CV models, and little is known about MW models.

3.2 Equilibrium bids in a one-shot multiple unit auction

To motivate an empirical model for possible determinants of bid spreads between extreme bids (maximum and minimum bids) and the marginal price, we turn to simpler auctions. We initially set out the Harris and Raviv (1981) theory of Nash bidding behaviour, where multiple units are sold in a single auction, and (risk neutral or risk averse) bidders can purchase at most one of these units under a Dutch pricing arrangement.

There are Q units of a homogeneous good to be sold. The market consists of $N > Q$ bidding agents, who each compete for one unit of the good. Assume that bidding agent i, $i = 1,\ldots, N$ places a monetary value v_i on a unit of the good, and that each is drawn with replacement from a distribution with density function h and probability function H, where the support of h is $[0,\bar{v}]$. If bidder i submits a sealed bid b_i which is accepted, then the monetary gain is $v_i - b_i$, with utility $u(v_i - b_i)$. It is assumed that $u(0) = 0$, that $u(.)$ is increasing, concave and differentiable, and that the utility of an unsuccessful bid is zero. Bids $b_i = b_i(v_i)$ are assumed to be symmetric Nash equilibrium strategies.[15]

These bids are arranged by the auctioneer in decreasing order of price. In the discriminatory auction, the Q highest bidders pay the rate that they bid. Assume that bidder i believes his competitors will bid according to the differentiable bidding function $b_j = b(v_j)$, $j \neq i$, where b_j is increasing on $[0,\bar{v}]$. Let π denote the inverse of b_j, i.e. $\pi(b(v_j)) = v_j$. The probability that a bid b_i will be accepted, is the same as the probability that at least N–Q of the values drawn by bidding agent i's competitors are below $\pi(b_i) = v_i$. This probability, $F(\pi(b_i))$, is given by the distribution function of the N–Qth order statistic for a sample of size N–1 from the distribution H:

$$F(\pi(b)) = \frac{(N-1)!}{(N-Q-1)!(Q-1)!} \int_0^{\pi(b)} (H(v))^{N-Q-1}(1-H(v))^{Q-1} h(v)dv \qquad (1)$$

The ith bidding agent then has to choose b_i to maximise $u(v_i - b_i)\ F(\pi(b_i))$, i.e. to maximise the bidder's utility should the bid be accepted, multiplied by the probability that it will be accepted. Under risk neutrality, Harris and Raviv (1981) show that the Nash strategy emerging from the solution of the first order condition for this maximisation problem is:

$$b_{D_n}(v_i) = \frac{1}{F_{v_i}} \int_0^{v_i} x dF(x) \qquad (2)$$

where D_n indicates risk neutrality under discriminatory pricing. Note that Harris and Raviv also prove that where all bidders are risk averse and have the same strictly concave utility function, they will bid higher than risk neutral bidders.

We now turn to implications of these theoretical results for the specification of a reduced-form empirical model for an equilibrium bid for the ith bidder. The above solution for the equilibrium bid under discriminatory pricing depends on the private value of the bidder, v_i, the number of bidders, N, the size of supply, Q, and the distribution of private values, $H(v)$. Following Laffont and Vuong (1992), we observe that since equilibrium bids are functions of private values, which are random by assumption, then observed bids for a single auction will also be random, and be uniquely determined by the above theoretical determinants. Thus, a log-linearised, reduced-form empirical model for a bid, such as the maximum bid or the average bid, for a series of mutually independent (no strategic behaviour), multi-unit auctions, where bidders bid for at most one unit of a homogeneous good is:

$$bid_t = \sum_{i=1}^{m} \beta_{1i} X_{it} + \sum_{i=1}^{n} \kappa_{1i} dum_i + \varepsilon_t \qquad (3)$$

where bid_t is the logarithm of a bid in an auction at time t; $X_{it} = [constant, N, R_p, Q_s, Z]$ is a vector of variables in logs including the number of bidders N, a reservation price R_p, if one is used, the size of pre-announced supply Q, and various Z variables, which are variables reflecting the observable characteristics of the auctioned object,[16] and of the buyer side of the market, which may affect the distribution of private values; the dummy terms *dum* reflect other qualitative auction fundamentals or regime shifts, such as changing the auction rules (lowering entry requirements), or policy intervention, both of which can introduce uncertainty; and finally, ε_t is a stationary disturbance term.

An important Z variable in the context of foreign exchange auctions is the secondary market (black or bureaux) exchange rate, *ber*. In the event of the bid being unsuccessful, the bidder could resort to the more expensive secondary market,

so that the *ber* reflects the opportunity cost to bidders. As a free market exchange rate, it is also a relevant indicator of macro-economic policy and credibility of the reform which influence the expected exchange rate (Aron and Elbadawi, 1997).

Where quantity choice is allowed to be endogenous, maximising expected utility will yield two marginal conditions, for both the price and the quantity demanded. Quantity demanded can then be solved for and substituted into the marginal price condition. The functional form of the solution will be different to the single unit case, however the determinants remain identical, and given the choice of a log-linear empirical specification, equation (3) will still be applicable.

The reduced-form model also assumes a series of mutually independent auctions. The equilibrium solutions for a repeated multi-unit auction are very difficult to characterise, given the possibilities for learning by agents or strategic behaviour (e.g. Weber, 1983). We aim at least to model the dynamic behaviour empirically, by employing unrestricted dynamics in a time series error correction equation or ECM (which is the reduced form of some forward-looking model). This is discussed further in Section V.

3.3 Motivating an empirical model for bidspreads

We are interested in the possible determinants of the spread between extreme bids and the marginal bid[17] in a repeated Dutch auction, where pre-announced supply follows a supply rule to target the marginal price (exchange rate), but there is no pre-announced reserve price. Essentially we are modelling errors, or, in the case of the maximum bidder, the loss of profit by the bid being higher than required. Where the Central Bank operates a stable policy intervention over time, such as altering pre-announced supply to target the exchange rate on a depreciating trend, learning this rule reduces uncertainty for bidders and is expected to produce a clustering of bids around the predicted marginal price. If the supply rule changed unexpectedly, the bid spreads would be expected to increase until the bidders learned the new rule.

There are other types of learning involved too. In general, uncertainty is initially increased by changing the rules affecting the bidding environment (e.g. lower entry requirements altering demand), and by exogenous shocks. While shock variables inducing uncertainty will be the most important determinants of the spreads, one might expect a stable long-term relationship in a sustainable system of consecutive auctions, between the bid spread, pre-announced supply and a measure of auction demand. In the language of co-integration, one would expect these variables to have a co-integrated equilibrium relationship.[18] Thus,

$$(max - oer)_t = \sum_{i=1}^{m} \beta_{2i} X_{it} + \sum_{i=1}^{n} \kappa_{2i} dum_i + \varepsilon_t = \lambda G_t + \varepsilon_t \qquad (4)$$

where $(max - oer)_t$ is the log difference between the maximum bid and the marginal rate of the auction; X_{it} = [*constant, N, Q_s, Z*] is a vector of variables defined as above, but where Z includes measures of uncertainty; and ε is a white noise term. The short-hand is used in equation (4) where for G a vector, λG is a linear function of the dummies and variable components of X_t. The familiar form of the one-step ECM regression equation for the spread is then as follows:

$$\Delta (max - oer)_t = \gamma(\lambda G - (max - oer))_{t-1} + \sum_{i=1}^{M_1} \delta_i \Delta G_{t-1} + \sum_{i=1}^{M_2} \alpha_i \Delta (max - oer)_{t-1} + \eta_t \qquad (5)$$

where, η is a stationary disturbance term. The first term on the right hand side, dated *(t-1)*, is the equilibrium term, where λG is the log-linearised specification of equation (4) above, giving the long-term relationship between the spread and supply and demand in the market. The second set of terms on the right hand side captures short-run dynamic adjustments (for M_1 lags) about the equilibrium, where Δ is the difference operator. The third set of terms are M_2 lags of the dependent variable.

To illustrate the equilibrium correction mechanism, suppose the supply rule changes and that bidders' predictions overshoot the new target. That is, the actual bid spread is larger than required in equilibrium given the new supply rule. Then the equilibrium term in the bracket will be negative. This indicates a correction is required in this forward-looking model in the *next* period, so that the bid spread will fall (since the dependent variable is negatively related to the equilibrium term dated (t-1)). The coefficient of the equilibrium term, or γ, captures the extent of the required adjustment that occurs per period. In practice, γ will also reflect many other factors which could also induce disequilibrium (e.g. shocks, or changes in entry rules). Moreover, there may be learning associated with the new bidders if they are new to auction procedures, which further increases uncertainty and hence bidspreads. We implement a version of this model in Section V.

IV. Statistics on Auction Outcomes

In Table 3, basic statistics are presented for Ethiopia's foreign exchange auctions during 1993-97 (amounting to 143 auctions). For analytical purposes, the statistics are differentiated according to three distinct periods of exchange rate behaviour, and also by auction frequency (fortnightly and then weekly).[19] The three periods cover auctions 1-29, auctions 30-104 and auctions 105-143, respectively. In the first, a period of learning for both the Central Bank and bidders, the exchange rate was fairly volatile and the emphasis was on reducing the parallel premium. Fiscal demand was particularly high in this period (see below). The second period includes both weekly and fortnightly auctions, and a fairly stable "crawl" for the exchange rate is evident. The third period of weekly auctions, occurs shortly after the banning of the *franco valuta* market and extension of the auction to include second-hand goods (see Section II).[20] Demand was considerably increased as new bidders came in from the *franco valuta* market, yet supply was

constrained. This engineered a different depreciation pattern for the exchange rate, where the Central Bank stabilised the change rather than the level of the rate.

The evolution of the clearing rate and the parallel market premium for the duration of the auctions is shown in Figure 1, by exchange rate periods and frequency regimes. A summary of the main stylised facts for the Ethiopian case and their possible explanations follow.

First, auction prices (the clearing rate and the maximum and minimum bids) have been fairly stable in Ethiopia's retail Dutch auction. After an early period of volatility (see Figure 2), stability of prices improved around a depreciating trend across the first two periods, though stability decreased somewhat in period three. Price stability however improved on moving from the fortnightly auction regime to weekly auctions. The mean exchange rate of 5.64 birr per dollar in the first period, had fallen to a mean of 6.64 birr per dollar by the third period, effecting a depreciation of almost 25 percent between 1993 and 1997.

Similarly, the mean bid-spreads fell across the first two periods, though rose in period three; and spreads also fell across the frequency regimes. The bid spreads are shown in Figure 2, differentiated by exchange rate periods and frequency regimes. Bid-spreads were thus at their highest and most volatile during auctions 1-29 and 105-143. As we have argued, the former period probably captures learning of auction procedures both by the new bidders and the Central Bank. In addition, probably due to supply constraints the Central Bank appears largely not to have accommodated demand. By contrast, in the subsequent period 2, it operated a fairly transparent supply rule. The third period due to a number of rule changes has seen increased uncertainty, with new bidders from the banned *franco valuta* market learning auction procedures.[21] Moreover, supply constraints in the face of the higher demand altered the Central Bank's target (see Section V).

Second, foreign exchange rationing reflected in the measure of effective demand (that is, the demand satisfied over total eligible demand) decreased across the first two periods, though increased somewhat in period three. Effective demand, or satisfied demand, was also lower under the weekly than the fortnightly auctions. Similarly, the winning or successful bids measured as a ratio to the eligible bids, another measure of the importance of rationing, displays the same pattern as effective demand (see alternate rationing measures in Figure 3). As shown in Table 2, the auction system was gradually widened by admitting more types of participant and more eligible imports, both of which increased competition and fostered confidence in the system. The banning of the *franco valuta* market (deliberately) coincided with the onset of weekly auctions and a liberalisation of auction rules to allow second-hand goods through the auction. While supply per month under the weekly regime auctions almost doubled from the fortnightly regime (see below), this was not quite sufficient to absorb the on average $40 million per month demand from the *franco valuta* market. This may explain increased rationing from auction 86.

Third, the parallel market premium both decreased in volatility and experienced a sharp decline, over the period as a whole, moving from an average 28 percent in the first period to under 8 percent in the third. However during late

1994 and 1995. the premium rose. After some early volatility (see Figure 1), the premium steadily averaged 15 percent after auction 34, and then after auction 47, the premium rose over a few auctions to an average 21 percent, where it remained until after auction 80. Likely reasons for the increased demand in the parallel market at this time are both the increased incomes from sharply higher coffee prices in late 1994/1995, and also increased entry requirements in the auction from auction 47, when the minimum bid was doubled to $10,000. Volatility of the premium rose in 1996, but halved on moving to weekly auctions within 1996 alone.

Fourth, pre-announced foreign exchange supply (in U.S. dollars) was found to be more volatile in period two than the others, and volatility also fell from fortnightly to weekly auctions. This is consistent with supply constraints in the first and third periods, and a flexible use of supply to target the level of the exchange rate in period two. Supply was successively adjusted upwards to allow convergence of the auction rate to a unified target rate, as the auctions were liberalised. The mean level of announced supply shows a consistent and dramatic rise from $7.07 million per fortnight in 1993, to $29.27 million per fortnight in 1996. The apparent fall in announced supply per auction between 1996 and 1997 is merely due to the frequency change. In fact from the fortnightly to weekly auction regimes, there was a rise in average supply, on a *monthly* basis, from $34.32 to $70.4 million. In 1996 alone, the rise across frequency regimes was from $58.27 to $71.12 million (i.e. mean pre-announced supply in auctions 71-85 versus auctions 86-108).

Actual supply was on average slightly larger than announced supply in all fortnightly auctions, for reasons which have been explained (Section II), though it was lower than announced supply in the overall weekly auctions, and hence in 1997. This has to do with a change in the exchange rate target (see above). Supply per bid rose too across the first two exchange rate periods, but fell thereafter, due largely to the effect of increased bid numbers in the weekly auctions.

Fifth, mean total demand (excluding the disqualified bids) rose strongly from around $13 to $34 million in 1993-96 (fortnightly auctions only). Demand, pre-announced supply and actual supply are contrasted in Figure 4. Demand also rose across the frequency change: monthly, the rise was from $43 to $104 million; or, examining 1996 alone, from $68 to $96 million. Demand also showed increasing volatility in later years relative to the first two years, likely related to the larger number of bidders.

Eligible bids (that is, bids not disqualified due to inadequate documentation) increased in number by 60 percent across the frequency regimes. In fact eligible bids also increased sharply in the fortnightly 1996 auctions to around 320 mean bids, as compared with around 230 mean bids throughout 1993-95. This had to do with a tariff reduction in early 1996 (Table 2). The number of bids doubles in 1996 relative to earlier years, and is 30 percent higher again in 1997, largely reflecting increased numbers of bidders entering the market virtually concurrently with the change to weekly auctions, due to the abolition of the *franco valuta* market. However, it is important to note that the number of bids is *not* the same as the number

of bidders. Multiple bids were allowed, and bids typically corresponded to the foreign exchange required for a particular import (complete with invoices).

An interesting feature of the auction is the involvement of government ministries, in addition to parastatals and the private sector as bidders. The table shows the percentage shares of ministries (budgetary) and the private sector out of actual supply (the residual is due to parastatals). It is notable that the share of the private sector increases from around 50 percent in the first three years to about 70 percent in the last two years. The share is greater in the weekly auctions. Budgetary supply was high at 22 percent of all supply in the first period, but fell to about 9 percent by the third period. Bid levels by sector for the first 78 auctions show the high prices bid by ministries relative to the other players in clear fiscal episodes (see Table 2 on fiscal seasonality, and Figures 5).

V. The Central Bank's Policy Rules and Bidders' Reactions

In what follows, we use error correction models (defined in section 3) to explore the Central Bank's supply rule strategy across fortnightly and weekly auction regimes; and also, via bid spread models, bidders' reactions to changes in the supply rule and other design changes in the auctions.

Given the use of error correction models, unit root test are undertaken in Table 5 for a range of auction variables used in the models. The tests were executed both for high frequency auction data, and data aggregated up to a monthly frequency. This is because the fortnightly, then weekly, auctions are subject to frequent regime shifts which contaminate the test statistics. These changes are likely to be smoothed to a degree in monthly data, and therefore we place greater reliance on monthly statistics.

As expected, the auction prices and parallel premium appear to be non-stationary and integrated of order one (a unit root cannot be rejected). The bid spread and effective demand also appear non-stationary; while most other variables are stationary. Attention should be drawn to the apparent non-stationarity of pre-announced supply across all auctions, but its stationarity in the weekly period (see Figure 4).

5.1 Estimating the supply rule of the Central Bank

Supply was pre-announced from auction 5 (Table 1). The presence of supply rules was tested for separately across weekly and fortnightly auctions. This is because the regime shift around the frequency change is very large, given the banning of the *franco valuta* market and various other rule changes (Table 2), and consequently there are large shifts in supply and demand, as well as increased uncertainty and a new set of bidders. We also amalgamate all the fortnightly auctions, including the volatile period of auctions 5-29, because error correction models require as long an estimation period as possible to capture "equilibrium" relationships.

The equilibrium term for the error correction model for pre-announced supply in fortnightly auctions is as follows:

$$\log(preQs)_t = \sum_{i=1}^{m} \beta_{3i} X_{it} + \sum_{i=1}^{n} \kappa_{3i} dum_i + \varepsilon_t = \tau K_t + \varepsilon_t \qquad (6)$$

where X_{it} = [*constant, oer, effQd, premium*] is a vector of variables (in logs) as defined as in Table 4, and τK, K a vector, is the short-hand for a linear combination of the variables and dummies, while ε_t is a white noise error term. Pre-announced supply is expected to be in equilibrium with an exchange rate target, oer, given the degree of rationing, and the size of the parallel premium. That is, pre-announced supply would have to increase to achieve a lower target rate when demand pressures rise, as evidenced by increased rationing[22] or a rise in the parallel premium. Further, to maintain a target, pre-announced supply would have to expand to meet seasonal demand or demand due to the lifting of trade restrictions, or changes in the eligibility rules (proxied by dummy terms-see Table 4).

The dynamic one-step ECM model which incorporates the equilibrium term is then:

$$\Delta \log(preQs)_t = \gamma(\tau K - \log(preQs))_{t-1} + \sum_{i=1}^{M_1} \delta_i \Delta K_{t-i} + \sum_{i=1}^{M_2} \alpha_i \Delta \log(preQs)_{t-i} + \varepsilon_t \quad (7)$$

where, ε_t is a stationary disturbance term. Analogous with equation (5), the first term on the right hand side, dated *(t-1)*, is the equilibrium term and γ is the adjustment coefficient. Thus, γ measures the extent of adjustment per period when, for example, the Central Bank underestimates seasonal demand and overshoots the desired *oer* target. The second set of terms on the right hand side are lagged short-run dynamic deviations of the regressors, while the third set of terms are lags of the dependent variable itself.

Parsimonious equations for the supply rules in both frequency regimes from a general-to-specific procedure (taking into account theoretical priors on signs) are given in Table 6. The equations 1a and 1b cover all fortnightly auctions, and differ only with respect to the measure employed for rationing, effQd or bidratio (the latter is expected to have a positive sign). Considering first the equilibrium relationship, the expected signs are achieved for the regressors, and the adjustment coefficient, γ, suggests almost 40 percent of the error is corrected each period. In addition to fiscal dummies, a range of trade and bidder entry liberalisation dummies were tested, which all gave the expected signs, but with statistical significance below ten percent. Moreover, by an augmented Dickey and Fuller test, co-integration appears to be satisfied for the equilibrium residual term. Finally, the signs and sizes of coefficients for the dynamic terms suggests a reparametrisation in which the premium operates at a lag of three auctions[23] and in which the exchange rate of three auctions ago as well as the most recent auction is relevant. The persistent effects for *oer* is consistent with the targeting procedure. The equations achieve quite a reasonable explanatory power, given the

number of regime changes in the period (Table 2), and the choice of a fairly simple equation.[24]

It appears, therefore, that after an initial period of volatility, the *level* of the exchange rate, *oer*, was targeted during the fortnightly auctions. By contrast, in equation 2 for the weekly period, the level of *oer* drops out of the equilibrium relationship (and indeed, pre-announced supply is stationary for this period-Table 5). It is the change in *oer* that now appears positive and very important in explaining the change in pre-announced supply. The Central Bank is here clearly stabilising the *change* in the exchange rate. The premium is not a regressor here, given the abolition of the *franco valuta* market. Moreover, for much of the weekly period, supply does not respond flexibly to past rationing. However, the relevant fiscal dummy for the period is significant.

5.2 Market forecasts and reactions to NBE policy

We now examine bidders' reactions to the different environments in the fortnightly and weekly auction regimes, due to changes in auction rules and also the Central Bank's supply rule for preannounced supply. Specifically, we are interested in learning behaviour over repeated auctions when rules alter. As explained earlier, the error correction formulation can capture adjustment to equilibrium (equation (5)), and as such represents a particular form of a learning model (it need not be a Bayesian model). When a rule is transparent and consistently applied one would expect rapid learning and equilibrium adjustment coefficients, γ, to be close to one.

Parsimonious error correction equations for bid spreads over the two regimes are presented in Table 7, and are derived from a general-to-specific procedure. These equations are the empirical counterpart to equations (4) and (5) in the text (Section III). The bid spread is defined as the logarithmic difference between the maximum and marginal bids. This definition is not the only possible measure, but is a measure of the range of the bid distribution for winning bids.

Equations 1a and 1b cover the fortnightly period from the first auction with pre-announced supply (auction 5); and equations 2a and 2b, the weekly period from auction 86. The equation labelled 'a' uses "effective" demand, or the ratio of supply to demand, in the equilibrium term; while equations 'b' use a proxy for demand (the number of bids) and preannounced supply as separate regressors.[25] We expect to find a similar equilibrium relationship for these two equations, and both were included to demonstrate robustness.

Dealing first with the equilibrium relationship, all the long-term variables have the expected signs, while the adjustment coefficient, γ, suggests around 60 to 70 percent of the equilibrium error is corrected each period. Dummies are defined in Table 4 and have the expected signs, operating largely through increasing demand. The equations have a reasonable explanatory power and co-integration appears to be achieved for the equilibrium residual term.[26]

Moving to the dynamic terms, the signs of the lagged dependent variables reinforce the equilibrating mechanism: a higher bid spread in the previous period, implies there will be a contraction in the next period. The signs of the other delta terms suggests a reparametrisation which places the lag further back (e.g. in equation 1a, effective demand appears to enter with a three period lag, while in equation 1b, the number of eligible bids enters with a two auction lag). Such lags are consistent with targeting behaviour in the first regime.

We further use a surprise formulation in equation (4), to capture uncertainty. This is the absolute value of last period's shock, or the extent to which bidders incorrectly forecast next period's exchange rate. The worse the forecast, the greater the uncertainty next period, and hence the larger the bid spread.[27] The coefficient indeed suggests that forecast errors increase uncertainty and the bids spread in the next period.

Adjusting to rule changes are not the only form of learning in these auctions. Fairly cumbersome bureaucratic requirements resulted in larger percentages of disqualified bids in periods where new sets of bidders entered the auction (bids could be rejected for 16 reasons related to incorrect documentation). Specifically these periods are at the beginning of the auction; and after the *franco valuta* market was banned when demand on this market was transferred to the official market. An attempt was made to proxy for this learning by including in the equation a moving average term for the percentage of bids disqualified out of total eligible bids, and alternatively, a non-linear trend term, defined as the inverse of t-squared. While these terms had the correct positive sign, they were not significant (with t ratios of around 1.3).

It is notable that the two different formulations of the equation give similar outcomes across the two periods suggesting a robust learning process has been captured by these regressors. The different regressors do of course differ in their size and importance across regimes. For instance, rationing, the number of bids and shocks are more important in the second than in the first period.

The equations tell us, unsurprisingly, that there is learning in both periods. However, there are three pieces of evidence to suggest that learning is faster in the first period. First, the error correction coefficients are higher (adjustment is faster) in equations 1a and 2a than in equations 1b and 2b. Secondly, the lagged dependent variables, which reinforce the adjustment, are more important for the first than the second period. Thirdly, surprises capturing uncertainty and misforecasts are more important in the second period. This finding corresponds with a less transparent target for the exchange rate in the weekly auctions and greater uncertainty from a range of rule changes, as compared with the fortnightly auctions.

VI. Conclusions

This paper has characterised the rules, regimes shifts and outcomes of over four years of foreign exchange auctions in Ethiopia. A novel empirical method in auction literature, the estimation of dynamic error correction models, has been used to examine policy targets and learning in repeated auctions. Such models

can capture a long-term equilibrium relationship between auction variables, adjustment to equilibrium after shocks or rules changes, and short term dynamics around equilibrium.

First, models were estimated to explore the equilibrium exchange rate or marginal price target of the Central Bank when setting its pre-announced supply. After some initial volatility in the fortnightly auctions, it is apparent that a *level* of the rate was targeted, achieving something akin to a crawling peg. The onset of weekly auctions (which are ongoing) coincided with the banning of the parallel market and much increased demand on the auction. Supply constraints relative to long-term sustainable supply from aid and coffee exports forced a more rapid depreciation of the exchange rate, where it appears the role of the Central Bank was to stabilise the *change* in the rate.

Secondly, learning in repeated auctions was examined via the adjustment to equilibrium in error correction models for the bid spread. We find robust models for a similar learning process across both frequency regimes, as expected. However, learning appeared to be faster in the fortnightly period, where the exchange rate target was more transparent and uncertainty lower (after some initial volatility).

The results of this paper emphasise that the micro-design and operation of an institution like the foreign exchange auction can have important macroeconomic consequences during liberalisation. A fairly transparent design (see Section II) and Central Bank operational rules that can be learned by bidders in repeated auctions, have been crucial in achieving a fairly stable depreciation from what was initially a very thin market. This has been achieved despite large regime shifts from fiscal and other seasonality in demand, considerable trade liberalisation, absorbing parallel market transactions after banning the *franco valuta* market, progressively lifting auction entry barriers, and increasing the frequency of the auctions. Fledgling private banks and foreign exchange bureaux have been set up during the auction period, though the financial system remains dominated by state-owned financial intermediaries. In due course, Ethiopia is expected to follow Uganda and Ghana in moving from a retail to a wholesale auction (where auction participants are banks and bureaux, which then allocate directly to importers), as a prelude to a competitive interbank market.

TABLE 1

RULES AND INSTITUTIONAL FEATURES OF THE ETHIOPIAN AUCTION

Duration	1 May 93, ongoing.
Number	May 93 - Aug. 97 (143 auctions).
Frequency	Fortnightly, and weekly from auction 86 (Jul. 96).
Pricing	Dutch (discriminatory pricing) throughout.
Sale	Retail.
Bidders	Licenced importers: individuals, firms, public enterprises and government departments.
Submission	Individual bids submitted by importers (direct submission, not using banks as conduits).
Type of bids	Sealed price/quantity bids; unrestricted multiple bids at different exchange rates.
Entry restrictions	An import licence was required for dedicated import purchase. A minimum auction bid required (the level was increased during the auction). A birr-equivalent-deposit was required in advance (later lowered).
Trade restrictions	No service payments allowed. A negative list of imports was progressively narrowed.
Auctioned supply	Primarily foreign aid and coffee export receipts. Supply was expanded in tandem with trade and entry liberalisation, the banning of the *franco valuta* market and seasonal influences.
Allocative caps	No. Amounts required above US $1 million by investors possessing a licence were allocated outside the auction.
Use of reserve price	No.
Pre-announced supply	Supply was announced one week in advance, and followed a policy rule to smooth the exchange rate.[1] Actual supply could be revised upwards or downwards at the auction to accommodate (indivisible) bids at the marginal rate. Apart from this limited discretion, some discretion over supply was exercised if forecasts had underestimated seasonal demand (particularly by government ministries directly before the Budget).
Published bids	Results were available to bidders immediately after the auction. Minimal information was published in the media (the lowest winning bid i.e. marginal rate).
Monitoring	Fairly stringent, given required documentation.[2]

Transparency	High. Auctions were open to the public and the media, and presided over by an Auction Committee (comprised of Chairpersons of the two Chambers of Commerce, as well as personnel from the NBE and Ministries of Trade and Finance, and Planning). Reasons were furnished for rejection of bids, and such deposits were returned promptly.
Secondary markets	A parallel market existed, part of which was the legal market for *franco valuta* imports,[3] established in 1983 and operated until Aug. 96, when it was abolished. Operation of licenced foreign exchange bureaux in commercial banks was announced in Jul. 96 (effective from Mar. 97).
Official rate	A separate fixed rate, employed for petroleum, fertilizer, pharmaceuticals and food imports, progressively devalued, and unified with the auction rate in auction 60.

Source: Interviews in Ethiopia and NBE Documentation.

1. The supply rule is discussed in sections II and V (Table 6).
2. Bids accompanied by serial number of application form, import licence number, proforma invoice for imported item, specification of amount and type of forex applied for, price bid, and proof of equivalent birr-deposit at CBE.
3. *Franco valuta* imports were paid for by importers' own funds, source undeclared, and attracted an additional tariff (for details and regime changes, see Table 2).

TABLE 2

REGIME SHIFTS AND SEASONAL INFLUENCES IN THE ETHIOPIAN AUCTION

Regime Change	Auction	Date	Policy Change
Frequency change	86	27 Jul. 96	Frequency changes from fortnightly to weekly.
Supply announcement	5	12 Jun. 93	Supply begins to be pre-announced.
Trade liberalisation	60/61	Aug. 93	Customs duties considerably simplified.
	10	4 Sept. 93	Negative list narrowed from 101 to 73 items.
	23	5 Mar. 94	Negative list narrowed from 73 to 43 items.
	47	3 Feb. 95	Negative list eliminated (43 to 0 items)[1].
	72	mid-Jan. 96	Further tariff reduction: from average 30 to 25%.
	85/86	4 Jul. 96	Used goods (excl. clothing) eligible in auction.
Entry costs	34	Nov .95	Bid deposit is lowered from 100 to 25%.
	47	3 Feb. 95	Forex use within 30 days extended to 90 days. Minimum bid raised from $5,000 to $10,000.[2]
	71	6 Jan. 96	Proforma invoice requirements tightened for this auction only (resulted in 166 disqualifications)
	116	17 Feb. 97	Commission (0.5%) on all forex transactions abolished.
	103	23 Nov. 96	Bids require 3 decimal places
	105	7 Dec. 97	Bids require 3 decimal places without zeroes
	127	3 May 97	Commercial banks are allowed to bid
Unification of official and auction rates	25	2 Apr. 94	Official rate devalued to 5.13 birr/$.
	29	28 May 94	Official rate devalued to ~5.6 birr/$.
	41	12 Nov. 94	Official rate devalued to 5.95 birr/$.
	55	7 May 95	Official rate devalued to 6.26 birr/$.
	58	8 July 95	Official rate devalued to 6.30 birr/$.
	60	5 Aug. 95	Official and auction rates unified at 6.30 birr/$.
Parallel markets	87	3 Aug. 96	End of *franco valuta* for new goods.
	96	30 Sep. 96	End of *franco valuta* for used goods.
	117	1 Mar. 97	Operation of licenced forex bureaux effective.
Orthodox Easter seasonality	27	1 May 94	Last auction before Easter
	52	23 Apr. 95	
	78	14 Apr. 96	
	125	27 Apr. 97	
Fiscal Year[3] *seasonality*	6	10 Jul. 93	First auction after the close of the fiscal year
	32	9 Jul. 94	
	58	8 Jul. 95	
	85	20 Jul. 96	
	136	12 Jul. 97	

Source: Interviews in Ethiopia and NBE Documentation

Notes:

1. Except for service payments, still disallowed through the auction.
2. Importer requirements below $10,000 directly allocated via the Ministry of Industry.
3. Fiscal year ends on 7th July.

TABLE 3

STATISTICS BY EXCHANGE RATE REGIME AND BY FREQUENCY REGIME

	auction rate	max. bid	min. bid	max-auct spread	min-auct spread	announced supply[1]	actual supply	supply per bid	budgetary supply (%)	private supply (%)	total demand	effective demand	eligible bids	disqualified bids (%)	successful/ elig. bids	parallel premium
Exchange Regime 1: 1993/4Auctions 1-29 Fortnightly																
Mean	5.64	6.37	5.21	0.74	0.42	9.6	9.27	67.44	21.95	44.79	15.92	0.64	243.41	14.66	0.63	28.12
Std Dev	0.45	0.33	0.28	0.57	0.32	4.15	4.54	24.11	19.45	18.84	6.84	0.25	77.14	8.38	0.26	14.39
Minimum	5	5.75	5	0.11	0	6	3.55	37.97	0	15.27	3.55	0.32	62	4.97	0.27	11.29
Maximum	6.29	7.05	5.9	2.05	1.02	19	19.39	130.85	53.36	100	29.69	1	366	41.04	1	52
Exchange Regime 2: 1994/5/6 Auctions 30-104 Fortnightly/Weekly																
Mean	6.31	6.43	6.23	0.12	0.074	19.87	20.54	86.52	9.21	62.43	23.98	0.88	282.97	9.46	0.87	16.97
Std Dev	0.059	0.06	0.17	0.074	0.14	6.54	8.48	29.1	11.76	15.48	10.54	0.14	94.08	5.04	0.15	3.94
Minimum	6.15	6.32	5.27	0.03	0	9	8.11	37.06	0	24.67	8.69	0.4	145	3.54	0.41	9.32
Maximum	6.42	6.61	6.39	0.41	1.01	35	46.4	182.38	59.07	92.95	54.36	1	629	45.48	1.01	24.01
Exchange Regime 3: 1996/7 Auctions 105-143 Weekly																
Mean	6.64	6.91	6.51	0.28	0.13	17.46	16.66	58.55	9.25	70.45	27.44	0.67	436.72	15.08	0.72	7.88
Std Dev	0.13	0.18	0.16	0.12	0.15	4.38	5.2	16.08	12.8	18.2	9.96	0.23	158.37	4.42	0.2	1.55
Minimum	6.38	6.45	5.99	0.051	0	12	10.2	32.99	0	23.08	10.3	0.3	178	8	0.41	5.11
Maximum	6.85	7.16	6.76	0.56	0.81	32	32.6	122.13	54.37	96.8	44.3	1	823	29.06	1	11.44
Auctions 1-85 All Fortnightly																
Mean	6.06	6.4	5.86	0.34	0.2	17.16	17.25	85.73	14.31	53.35	21.5	0.81	251.25	11.21	0.79	21.72
Std Dev	0.41	0.2	0.52	0.44	0.28	8.14	9.74	29.67	15.52	16.5	10.79	0.21	71.87	7.16	0.22	9.92
Minimum	5	5.75	5	0.05	0	6	3.55	37.97	0	15.27	3.55	0.32	62	3.54	0.27	9.32
Maximum	6.35	7.05	6.35	2.05	1.02	35	46.4	182.38	59.07	100	54.36	1	416	45.48	1	52
Auctions 86-143 All Weekly																
Mean	6.55	6.77	6.46	0.21	0.095	17.6	17.11	59.32	8.14	72.31	25.93	0.72	413.07	13.28	0.76	9.48
Std Dev	0.16	0.26	0.15	0.13	0.13	4.14	5.34	15.06	12.74	16.89	9.49	0.23	147.54	4.58	0.21	2.72
Minimum	6.33	6.4	5.99	0.03	0	12	8.11	32.99	0	23.08	10.3	0.3	178	6.85	0.41	5.11
Maximum	6.85	7.16	6.76	0.56	0.81	32	32.6	122.13	54.37	96.8	44.3	1	823	29.06	1.01	15.3

1. Figures for pre-announced supply only from auction 5 (see Table 2).
2. Data from the National Bank of Ethiopia.

TABLE 4

VARIABLE DEFINITIONS FOR REGRESSION EQUATIONS

ECM coefficient	Error correction coefficient, or γ in equations (5) and (7)
constant	Constant term
oer	Auction clearing rate (domestic currency/$)
preQs	Pre-announced U.S. $ (millions) auctioned (i.e. supply)
Qs	U.S. $ (millions) auctioned (i.e. supply)
Qd	U.S. $ (millions) demanded (for all eligible bids)
effQd	Effective demand, or Qs/Qd, is a measure of rationing
max	Highest (eligible[1]) bid price (domestic currency/$)
min	Lowest (eligible) bid price (domestic currency/$)
ber	Parallel market exchange rate (domestic currency/$)
premium	Parallel market exchange rate divided by the auction clearing rate
bids	Number of winning bids
bidel	Total eligible bids offered
bidratio	Ratio of successful to eligible bids (alternative rationing measure)
reserves	End of month international reserves (minus gold) in US$
|Δlog (oer) - Forecast|	*Surprise* term, the absolute value of the change in the exchange rate less a forecast change in the exchange rate.
D1113	Dummy = 1 for the 3 auctions following the first trade liberalisation in auction 10; dummy = 0 otherwise
D34	Dummy = 1 for auction 34 when the domestic currency bid deposit was lowered from 100 to 25%; dummy = 0 otherwise
DF93 to DF97	Dummies = 1 for the 3 auctions prior to the close of the fiscal year; dummies = 0 otherwise
D105	Dummy = 1 for auction 105, when three decimal places were first required on bids (excluding zeroes); dummy = 0 otherwise
D127	Dummy = 1 for auction 127, when commercial banks were first allowed to bid; dummy = 0 otherwise

Notes:
1. Bids which did not satisfy specific documentation requirements were deemed ineligible for the auction and rejected by the auctioneer.
2. Reserves are from the IMF database, and are interpolated for bi-weekly and weekly auctions by dividing by 2 and by 4, respectively, and using 2-auction and 4-auction moving averages, respectively.

TABLE 5

UNIT ROOT TESTS FOR AUCTION VARIABLES

Null Order	By auction (1-143) I(1)	I(2)	By month (May 93-Aug 97)[2] I(1)	I(2)
log (oer)	-4.04**		-4.03*	6.20**
log (max)	-4.20**		-1.03	5.87**
log (min)	-3.17**		-3.52*	6.81**
log (max) - log (oer)	-4.12**		-2.70	7.40**
log (premium)	-1.67	-8.26**	-0.58	5.33**
log (preQs) *all auctions:*	-2.57	-10.51**	-2.42	-7.15**
log (preQs) *weekly auctions (86-143):*	-4.78**		-4.38**	
log (Qs)	-3.94**		-2.15	-7.38**
log (Qd)	-4.46**		-2.38	-7.67**
log (effQd)	-4.33**		-2.22	-11.67**
log (bidel)	-4.27**		-4.26**	-8.79**
log (bids)	-4.72**		-5.71**	-8.48**
log (bidratio)	-5.35**		-2.80	-8.42**
|Δlog (oer) - Forecast| *fortnightly*	-4.30**			
|Δlog (oer) - Forecast| *weekly*	-3.40*	-12.76**		

Notes:

1. For a variable X, the augmented Dickey and Fuller (1981) statistics is the t ratio on π from the regression: $\Delta X_t = \pi X_{t-1} + \sum_{i=1}^{K} \theta_i \Delta X_{t-i} + \psi_0 + \psi_1 t + \varepsilon_t$, where k is the number of lags on the dependent variable, ψ_0 is a constant term and t is a trend. The kth-order augmented Dickey-Fuller statistic is reported, where k is the last significant lag of the 6 lags employed for auction data and 2 lags for aggregated monthly data. The trend was included only if significant. For null order I(2), Δx replaces x in the equation above. Asterisks * and ** denote rejection at the 5% and 1% critical values. Critical values with constant, and with and without trend, are obtained from MacKinnon (1991).
2. Monthly data aggregate the fortnightly and weekly auctions.

TABLE 6

PARSIMONIOUS EQUATIONS FOR THE SUPPLY RULE OF THE NBE

Dep. Variable: $\Delta log\ (preQs)_t$		Equation 1a *Auctions 5-85 (Fortnightly)*	Equation 1b *Auctions 5-85 (Fortnightly)*	Equation 2 *Auctions 86-143 (Weekly)*
ECM coefficient:				
γ	log (preQs) $_{t-1}$	-0.372	-0.362	-0.367
		(-6.21)	(-5.74)	(-4.12)
Long-run Terms:				
$\gamma\beta_0$	constant	-8.88	-7.88	1.00
		(6.53)	(-5.71)	(3.91)
$\gamma\beta_1$	log (oer) $_{t-1}$	4.74	4.23	–
		(6.71)	(5.90)	
$\gamma\beta_2$	log (effQd) $_{t-1}$	-0.20	–	–
		(-3.25)		
$\gamma\beta_2'$	log (bidratio) $_{t-1}$	-	-0.088	–
			(-1.69)	
$\gamma\beta_3$	log (premium) $_{t-1}$	0.428	0.402	–
		(5.32)	(4.78)	
Dynamic Terms:				
δ_{11}	Δlog (oer)$_{t-1}$	-2.27	-1.23	15.9
		(-2.01)	(-1.09)	(3.87)
δ_{12}	Δlog (oer)$_{t-2}$	-3.01	-2.61	8.09
		(-3.07)	(-2.55)	(2.09)
δ_{31}	Δlog (premium)$_{t-1}$	-0.332	-0.290	–
		(-2.29)	(-1.91)	
δ_{32}	Δlog (premium)$_{t-2}$	-0.393	-0.443	–
		(-2.81)	(-3.03)	
κ_1	DF94	0.158	0.151	–
		(2.78)	(2.46)	
κ_2	DF95	0.103	0.124	–
		(1.75)	(1.97)	
κ_3	DF96	0.194	0.183	–
		(3.63)	(3.24)	
κ_4	DF97	–	–	0.228
				(2.73)
Diagnostics: (t statistics in parenthesis)				
Std. error of regression		0.092	0.097	0.124
R-squared		0.609	0.567	0.574
Adjusted R-squared		0.546	0.498	0.542
Durbin-Watson statistic		2.20	2.24	1.71
Chow statistic		0.839 [.611]	0.967 [.491]	0.492 [.780]
Jarque-Bera test		1.62 [.446]	0.238 [.888]	12.4** [.002]
Breusch/Godfrey LM:AR/MA4		2.20	1.82	1.44
ADF test of regression resid.		-4.483**	-4.055**	-4.033**
ADF test of equilibrium resid.		-3.424	-3.658**	-3.646**

1. Coefficients correspond to equations (6) and (7) in the text, and all variables are defined in Table 4.
2. Note that equations with effective demand (effQd) are an alternative form of equations with the ratio of bids satisfied to total eligible bids (bidratio) - see text. Both are included to show robustness.
3. Pre-announced supply only begins in auction 5.
4. Almon lags of interpolated end-of-period dollar-denominated international reserves (minus gold) were included as regressors to test for a coffee boom effect (1994/5), but were not found significant (t ratio of 1.2 for an 8 auction lag).
5. Tests of the equilibrium residual use estimated coefficients and incorporate the dummy terms

TABLE 7

PARSIMONIOUS EQUATIONS FOR THE BID SPREAD

Dep. Variable: $\Delta log\ (max\text{-}oer)_t$		Equation 1a *Auctions 5-85 (Fortnightly)*	Equation 1b *Auctions 5-85 (Fortnightly)*	Equation 2a *Auctions 86-143 (Weekly)*	Equation 2b *Auctions 86-143 (Weekly)*
ECM coefficient:					
γ	log $(max\text{-}oer)_{t-1}$	-0.631 (11.70)	-0.711 (-12.30)	-0.532 (-4.42)	-0.619 (-4.87)
Long-run Terms:					
$\gamma\beta_0$	constant	0.48E-02 (1.84)	-0.83 (-1.84)	0.471E-02 (1.11)	-0.042 (-1.04)
$\gamma\beta_1$-$\gamma\beta_2$	log $(effQd)_{t-1}$	-0.020 (-2.50)	–	-0.017 (-3.27)	–
$\gamma\beta_1$	log $(bidel)_{t-1}$	-	0.025 (2.70)	-	0.021 (3.13)
$\gamma\beta_2$	log $(preQs)_{t-1}$	–	-0.015 (-2.29)	–	-0.24 (-2.21)
$\gamma\beta_3$	$\lvert\Delta log\ (oer)\text{-}Forecastl\rvert_{t-1}$	1.05 (3.50)	1.10 (3.28)	1.47 (2.17)	1.76 (2.36)
Dynamic Terms:					
α_1	$\Delta log\ (max\text{-}oer)_{t-1}$	-0.427 (-6.23)	-0.324 (-4.91)	-0.248 (-2.37)	-0.195 (-1.84)
α_2	$\Delta log\ (max\text{-}oer)_{t-2}$	-0.370 (-6.15)	-0.333 (-5.26)	–	–
δ_{11}-δ_{21}	$\Delta log\ (effQd)_{t-1}$	0.031 (3.60)	–	0.018 (2.12)	–
δ_{11}-δ_{22}	$\Delta log\ (effQd)_{t-1}$	0.026 (2.85)	–	–	–
δ_{11}	$\Delta log\ (bidel)_{t-1}$	–	-0.018 (-1.71)	–	-0.026 (-2.57)
κ_1	D1113	0.131 (10.40)	0.143 (11.70)	–	–
κ_2	D34	0.027 (1.77)	0.022 (1.35)	–	–
κ_3	D105	–	–	0.070 (5.16)	0.062 (4.56)
κ_4	D127	–	–	0.020 (1.47)	0.033 (2.24)
Diagnostics (t statistics in parenthesis)					
Std. error of regression		0.015	0.016	0.013	0.013
R-squared		0.819	0.794	0.654	0.653
Adjusted R-squared		0.795	0.767	0.605	0.597
Durbin's h alt. statistic		1.60 [.110]	1.52 [.129]	0.027 [.979]	1.20 [.231]
Chow statistic		0.336 [.968]	1.29 [.257]	2.34* [.035]	2.81* [.012]
Jarque-Bera test		8.13 *[.17]	16.2** [.000]	28.5** [.000]	42.3 ** [.00]
Breusch/Godfrey LM:AR/MA4		11.7	12.8	2.69	1.99
ADF test of regression resid.		-6.558**	-6.665**	-7.228**	-6.620**
ADF test of equilibrium resid.		-3.131*	-3.054*	-5.958**	-5.412**

1. Coefficients correspond to equations (4) and (5) in the text, and all variables are defined in Table 4.
2. Note that equations with effective demand (effQd) are an alternative form of equations with the number of bidders (bidel) and the pre-announced supply (preQs) - see text. Both are included to show robustness.
3. Pre-announced supply only begins in auction 5.
4. Learning about auction bureaucracy in the first part of the auction was tested for by including a moving average of the percentage of bids disqualified, and also a non-linear trend term defined as the inverse of t-squared. Both entered with the expected positive sign and a t ratio of about 1.3.
5. The term denoted $\lvert\Delta log\ (oer) - Forecastl_{t-1}$ is a *surprise* term, the absolute value of the change in the exchange rate less a forecasted change in the exchange rate. The exchange rate forecast equations for each period are discussed in the text.
6. Tests of the equilibrium residual use estimated coefficients and incorporate the dummy terms.

FIGURE 1

THE AUCTION RATE AND PARALLEL PREMIUM 1993-97

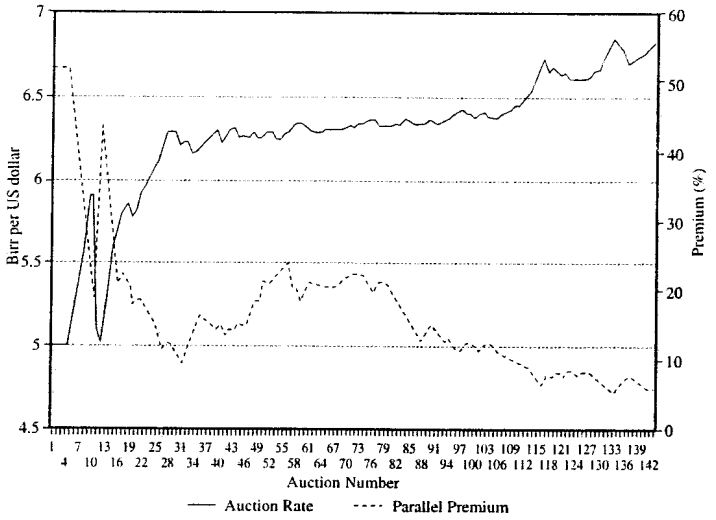


FIGURE 2

BEHAVIOUR OF AUCTION SPREADS

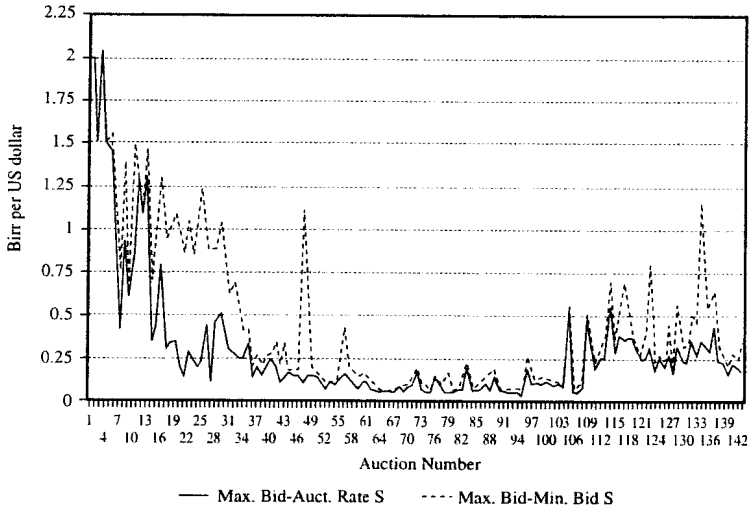


FIGURE 3a

FORTNIGHTLY SUPPLY AND DEMAND

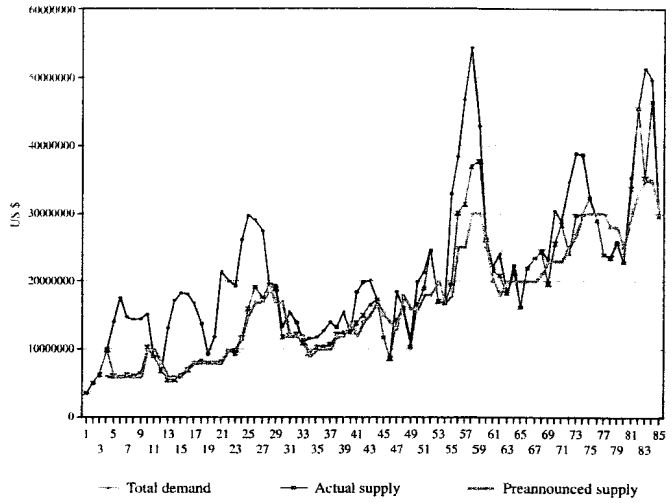


FIGURE 3b

WEEKLY SUPPLY AND DEMAND

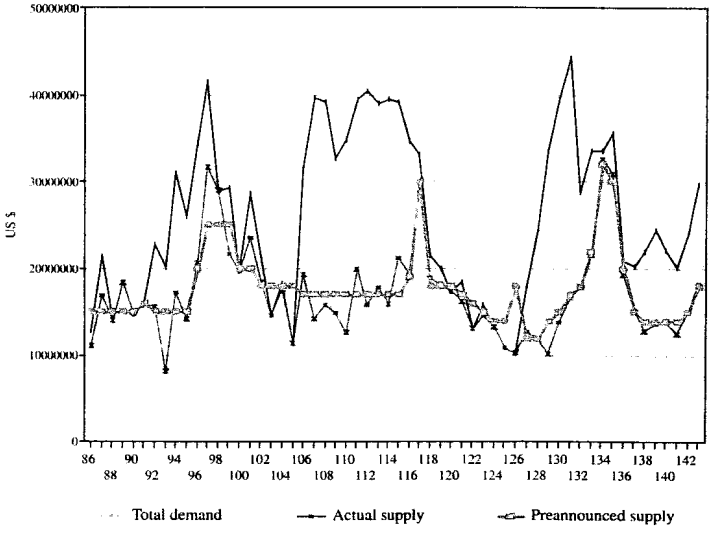


FIGURE 4a

MEASURES OF EXCESS DEMAND IN FORTNIGHTLY AUCTIONS

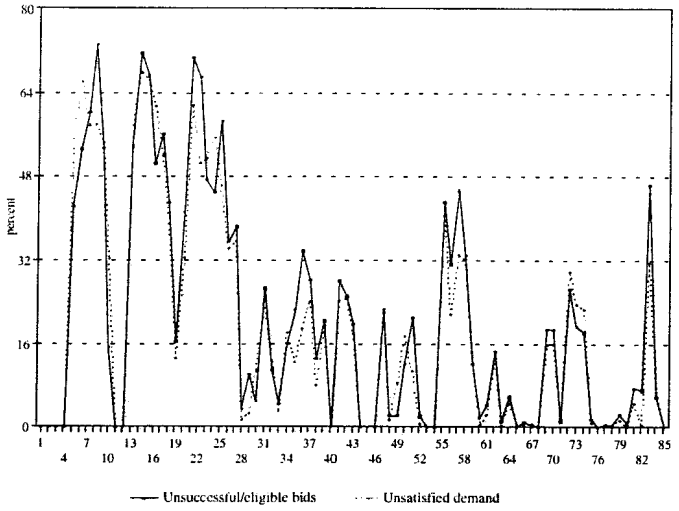


FIGURE 4b

MEASURES OF EXCESS DEMAND IN WEEKLY AUCTIONS

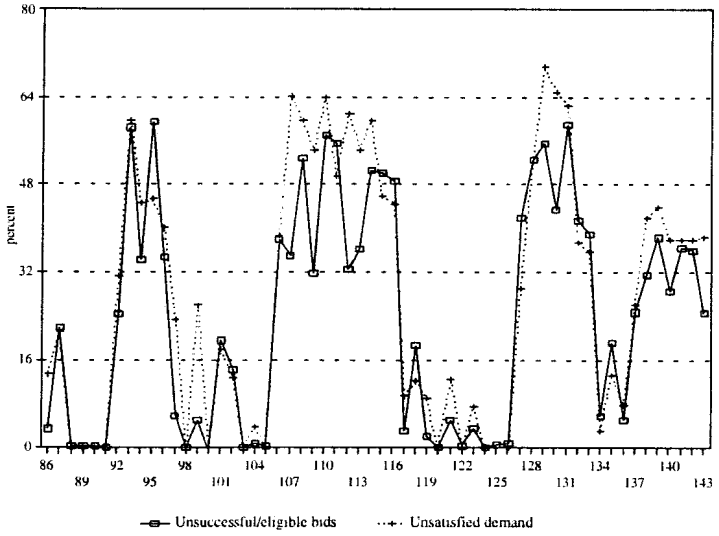
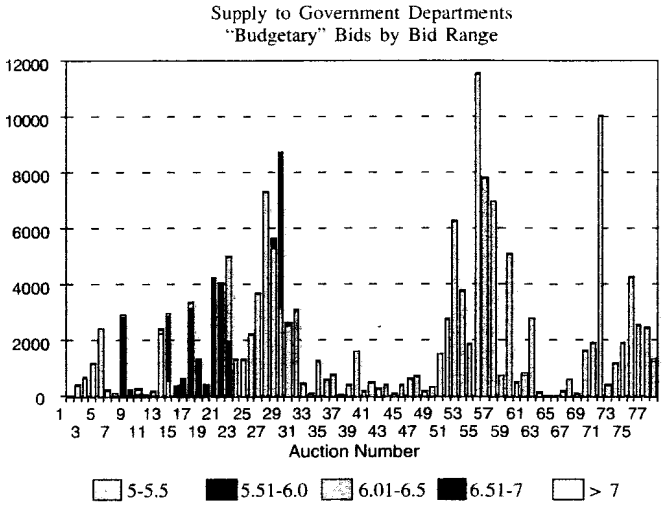


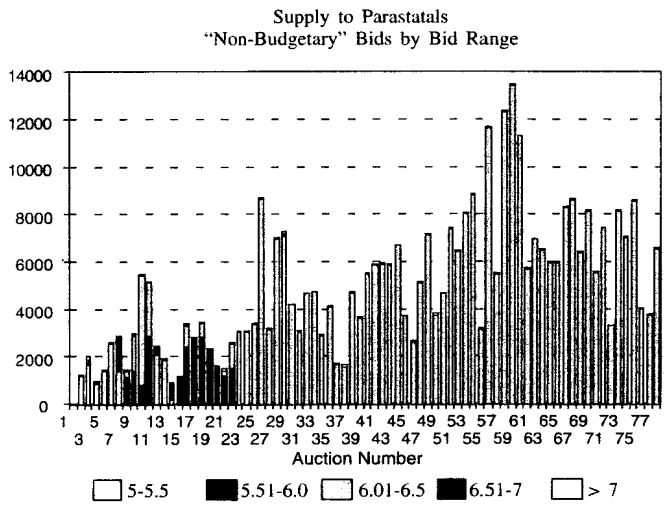
FIGURE 5

ALLOCATION OF SUPPLY BY TYPES OF BIDDER

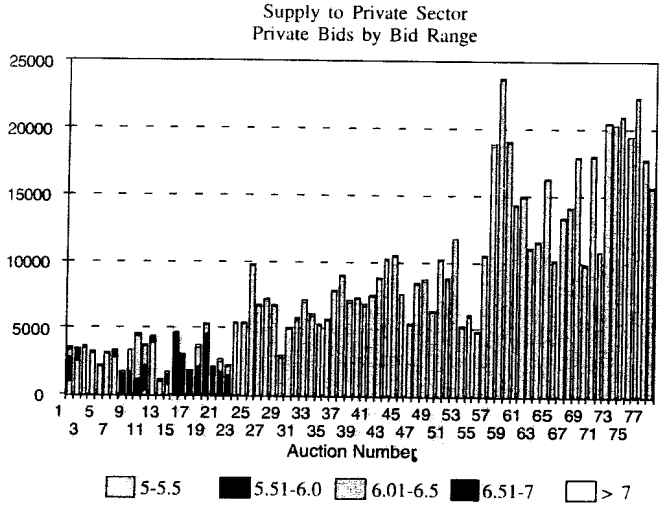
(a) Fiscal seasonality in supply to government departments



(b) Supply to state enterprises



(c) Supply to the private sector



Notes

[1] This paper has been prepared for the Revista de Analisis Economico Special Issue on "Auctions and Procurements". Conference at University del Pacifico, Lima, Perú, 1-2 December, 1997. I am grateful for assistance from Bill Easterly, Ejaz Ghani, Fayez Omar and Eyerusalem Fasik of the World Bank; Elias Loha and many others at the National Bank of Ethiopia; and for comments from Peter Moll, John Muellbauer, Helaway Tadesse and members of the CSAE. Errors or omissions are my responsibility. I acknowledge a Research Fellowship, Economic and Social Sciences Research Council, U.K., for research into African auction markets.

[2] For an account of the macroeconomic history and evolution during the auction, see Aron and Tadesse (1997).

[3] In the view of Dominguez (1991), this was a principal advantage of the Bolivian auction where demand pressures signalled in the auction enhanced monetary management.

[4] Research includes Bennett (1986) on Jamaica's foreign exchange auction; Kafka (1956) on Brazil's auction; Dominguez (1991) on Bolivia's "Bolsin"; and Goldberg and Tenorio (1995a,b) on Russia's double auction. There are numerous policy reviews, including Kovanen (1994), Krumm (1985), Quirck et al. (1987), and Bates and Collier (1993).

[5] The existence of a supply rule was confirmed in an interview with a Governor of the National Bank of Ethiopia.

[6] These documents were required in part to monitor allocations for the donor community (which provided through aid and grants a considerable proportion of the foreign exchange auctioned). The documents comprised an import licence for dedicated import purchase (and two proforma invoices for the intended import), and evidence of a local currency bid deposit, initially for the full value of the bid, but lowered in late 1995 (see Table 1).

[7] There were 16 possible reasons for rejecting a bid, related to absent or incorrectly filed documents, and bidders were furnished with the reasons for rejection.

[8] Data on the relative proportion of aid to exports in supply is not available, but judging by earlier African auctions (e.g. Uganda and Ghana), aid provision is likely to have been substantial.

[9] For the first 59 auctions, a separate, more appreciated official exchange rate was used for these transactions, which was unified with the auction rate from auction 60.

[10] An interesting seasonal influence was due to the unusual (at least in African auctions) participation of government departments in the auction, which due to laggardly budgetary procurement procedures, exerted a strong influence on the price and demand in auctions just preceding the end of the fiscal year.

[11] Specifically, the committee consisted of Chairs of the two Chambers of Commerce (representatives of the private sector) as well as personnel from the NBE, and Ministries of Trade, Finance and Planning.

[12] Of course, there are the expected instances where allocated supply fell *below* pre-announced supply due to insufficient demand.

[13] Obviously, adding an extra decimal place to the bid price required from bidders would have given the Central Bank more flexibility in this respect. However, it is only from auction 103, that the rules appeared to require three decimal places in the bid price. By auction 105 it appeared to be necessary to ban zeroes in the third decimal place, whereupon the number of bid levels increased dramatically.

[14] Warner (1995).

[15] The function $b(v_i)$ will be a Nash equilibrium bid function if, for every i, $b(v_i)$ maximises bidder i's expected utility, given that every other bidder j uses the same strategy $b(v_i)$.

[16] The Z variables may be directly observable, or be variables over which bidders can form expectations.

[17] The differential between the maximum bid and the marginal rate is not the only possible measure, though it does measure the range of the bid distribution for winning bids. An alternative is the average of successful bids minus the marginal rate.

[18] Note that by assuming the main intertemporal link between repeated auctions is learning, the analysis abstracts from other dynamic effects such as collusion, which could result in different equilibria.

[19] Some of the auction variables are non-stationary (see Table 5), and hence conventional measures