Discussion Papers in Economics

Do Security Deposit Rates Matter: Evidence from a Secondary Market

Susumu Imai

Kala Krishna
and
Abhiroop Mukhopadhyay

December 2004

Discussion Paper 05-02

STATISTICAL INDIAN INSTITUTE

UNITY IN DIVERSITY

Indian Statistical Institute, Delhi
Planning Unit
7 S.J.S. Sansanwal Marg, New Delhi 110 016, India

Do Security Deposit Rates Matter: Evidence from a Secondary Market

Susumu Imai, Kala Krishna and Abhiroop Mukhopadhyay[1]

Preliminary Draft: December 2004.

Abstract

In the recent past, many economies, attempting to become more open, have adopted policies fostering a less restrictive trade regime. In their attempts to become more open, policy makers can, with the best of intentions, adopt policies that have unforeseen and often undesirable side effects. In the 1980s, Australia was in the process of converting quotas to tariffs. In the process they auctioned off import quota licenses in order to use the submitted bids to calculate equivalent tariff rates. A security deposit was charged to prevent frivolous bidding. The collection of security deposits may be seen as a harmless policy with the only discernable cost being the opportunity cost of the funds while they are on deposit. We argue that, at least in the Australian context, this is not so. Using data from a middleman in the secondary market for these licenses, we show that the policy may have led to welfare losses in the secondary market.

[1] Concordia University, Pennsylvania State University and Indian Statistical Institute respectively. We wish to thank Joris Pinkse, Bee-Yan Roberts and others for their useful comments. Usual disclaimers apply.

1.1 Introduction

In the recent past, many economies, attempting to become more open, have adopted policies fostering a less restrictive trade regime. In their attempts to become more open, policy makers can, with the best of intentions, adopt policies that have unforeseen and often undesirable side effects. Australia, New Zealand and Colombia in 1980s and 90s, attempted a gradual phase out of quantitative restrictions by converting quotas to equivalent tariffs followed by a reduction in these tariffs. This was undertaken by auctioning import quota licenses and using the auction prices as a source of information for setting equivalent tariffs. Auctions of import licenses have also been suggested as a means to phase out negotiated quota arrangements such as the Multi-Fiber Arrangement (MFA).

In Australia, bidders (who participated in a series of uniform price auctions) offered to pay, not a price for the license, but an ad-valorem tariff in excess of the base rate, or the premium for short.[2] These licenses were transferable and a few brokers coordinated transactions in the secondary market. When auctioning quota licenses, the authorities wanted to discourage frivolous bidders as well as ensure that allocated licenses were claimed and utilized. To prevent frivolous bidding, only registered bidders could bid in the auction[3]. To ensure utilization and discourage hoarding, security deposits were collected upon acceptance of the allocation. These deposits were refunded when the licenses were used. The collection of security deposits may be seen as a harmless policy with the only discernable cost being the opportunity cost of the funds while they are on deposit. We argue that, at least in the Australian context, this is not so.

In Australia, through the late part of 80s, a security deposit of 10% was charged. The security deposit rate was cut to 5% in 1992. We use this natural experiment and data on the behavior of a single middleman in 1989 and 1992 to analyze the effects of the security deposit policy. Our analysis suggests that cutting the deposit rate reduced

[2] Note that as a result, any change in macroeconomic conditions would be reflected in the premium bid in equilibrium, not in the license price in the secondary market.

[3] Bidders who failed to pick up their allocations were banned from registering in subsequent auctions.

inefficiency in the secondary market as measured by welfare relative to perfect competition. In 1989, there were fewer trades (buys and sells) than in 1992 and these trades occurred at a higher price on average. Our estimates suggest that the higher security deposit changed the distribution of prices offered by the buyers and sellers who came to the middleman, and thereby the behavior of the middleman. This generated the rise in price and fall in trades that occurred.

Our work is related to the literature on middlemen and their role in intermediation. Middlemen trade in a product but neither produce nor consume it themselves. They make their money by buying low and selling high. The need for middlemen arises when markets are thin, so that potential buyers and sellers find it difficult to meet directly and conduct trades. In such circumstances, therefore, middlemen serve an important need: they facilitate trade. However, when markets are thin, middlemen also have the ability to influence the terms on which trades occur. They introduce a wedge between the buying price and the selling price of the product. This wedge limits the extent to which they facilitate trade.

Hall and Rust (2002) study the middleman problem in the context of a steel service center, which purchases large quantities of steel on the wholesale market for subsequent resale in the retail market at a mark-up. They utilize a generalized (S, s) setup, where the middleman buys steel at an exogenous price from the wholesale market whenever his inventory falls below a certain level (s) so as to bring his inventory back to the target level, S. At the same time, he sets his retail price to generate sales for the product. Their model is a stationary one and is estimated using Simulated Maximum Likelihood methods. In their data, similar to ours, they do not observe prices when the middleman does not transact. This biases the sample. They solve for this endogenous sampling problem by censoring their distributions.

In our problem, unlike that of Rust and Hall, there is no wholesale market for quota licenses, so bulk-breaking is not a major function of the quota broker. In addition, unlike the steel market, there is no observable spot price for quota licenses and the inventory holding cost, which is an important variable for the steel intermediary, is negligible in the case of a quota broker. Most important, the fact that quota licenses are valid only for a certain period of time (usually twelve months) makes any model of middlemen trading in them intrinsically non stationary.

As a result, much of the existing theoretical work on middleman behavior cannot be readily applied to this setting. For example, Spulber (1996) and Hall and Rust (2003) model middleman behavior using a search-theoretic framework. In such models, middlemen are treated as agents who set bid and ask prices, depending on their type (which is often identified with their cost); when buyers (sellers) meet a middleman, they may choose either to buy from (sell to) him, or to continue searching for a better match. Such models, however, restrict attention to time independent bid-ask prices. Since quota licenses expire after a certain period, the problem of quota brokers is inherently time dependent.

The rest of the paper is organized as follows. Section 1.2 sets out a basic framework for the quota broker's problem. Section 1.3 describes the data. Sections 1.4 and 1.5 discuss the empirical model and estimation strategy. Section 1.6 talks about the results of the estimation and conducts a welfare analysis using simulations. Section 1.7 concludes. Appendix at the end contains a detailed description of the estimation procedure and tables.

1.2 The Model

We term the middleman's potential customers, importers. There are many importers (a continuum of them) and few middlemen. Importers import the restricted product (say, clothing) and sell them to buyers (retailers or final consumers). In order to import one unit of clothing, the importer requires one quota license. Assume that each importer is matched to a buyer only quite rarely. As a result, when an importer obtains an order, he treats it as if it is the only order he will get for the quota period (say, twelve months). This sidesteps having to model the search behavior of the importer. He needs to move quickly to fill the order and visits one of the few middlemen. As the secondary market quota license prices are not centrally posted, he chooses one middleman at random.

Each day, with probability λ, a middleman meets one such importer who arrives with a buying or selling offer. An offer is a price quantity pair. Conditional on meeting, with probability λ^B, the middleman gets an opportunity to buy q^B at a price p^B where the price quantity pair is drawn from a log normal distribution, i.e. $(\ln p^B, \ln q^B) \sim \phi_{\mu^B, \Sigma^B}$; With probability $1-\lambda^B$, he gets to sell q^S at price p^S where $(\ln p^S, \ln q^S) \sim \phi_{\mu^S, \Sigma^S}$. Let the indicator $I^B = 1$ indicate that middleman has an option to buy and $I^B = 0$ represent an option to sell; I^B is drawn from a Bernoulli distribution each period with parameter λ^B. Let $I = 1$ indicate he meets an importer while $I = 0$ indicates he doesn't; I is drawn from a Bernoulli distribution each period with parameter λ. Thus in any period, the probability of having an option to buy is given by $\lambda\lambda^B$, the probability of having an option to sell is given by $\lambda(1-\lambda^B)$ and the probability of meeting no one is given by $1-\lambda$. Given an offer, the middleman can either say Yes (Y) or No (N).

Define (p,q) such that $p = p^S$ and $q = q^S$ when the middleman has an offer to sell and $p = p^B$, $q = -q^B$ when the middleman buys. To any choice of Yes or No, there may be a non pecuniary aspect which we represent by ω_1 for Yes and ω_2 for No. Let $\omega \equiv (\omega_1, \omega_2)$ be drawn independently from a distribution every time period. To simplify notation later, define $\delta = \omega_1 - \omega_2$. Let S be the middleman's beginning of period stock. The stock constrains what the middleman can sell.

Figure 1.1 gives a schematic display of the model. Note that in our formulation the random variables in period t do not affect random variables in $t+1$ because of our independence assumptions. Given the realizations of p and q, the middleman's decision to say Yes or No depends on the payoffs of doing so. Let $V^Y(.)$ be the value from saying Y. First note that the middleman cannot sell more than his stock. So define $q' = Min(q, S)$. Recall that when the middleman chooses to buy, q has been defined to be negative. Since stock S is always positive, q' may be different from q only in the case of a sale. If the middleman sells, he receives revenue pq'. Note that since in the case of buying, q' is negative, pq' is negative, that is, there is a current period monetary cost. The trade affects his stock and next period he starts with $S - q'$. Let Q (S,t:Ω) denote the expected value of the stock S to the middleman at the beginning of the period t (before the realization of any random variables) given the parameters of the distribution represented by $\Omega \equiv (\mu_p^B \quad \mu_p^S \quad \mu_q^B \quad \mu_q^S \quad \lambda^B \quad \lambda \quad E(\delta))'$ We assume there is no discounting.

Therefore

$$V^Y(p, q, \omega, t, S) = pq' + \omega_1 + Q(S - q', t + 1 : \Omega) \tag{1}$$

The value from saying No is

$$V^N(p, q, \omega, t, S) = \omega_2 + Q(S, t + 1 : \Omega) \tag{2}$$

In this case, the stock stays the same and the only current period payoff is what comes from the non pecuniary aspect. Given these payoffs of saying "Y" or "No", the middleman chooses the option which gives him the higher payoff. Thus

$$V(p, q, \omega, t, S) = MAX[V^Y, V^N] \tag{3}$$

where V(.) is the value function conditional of meeting an importer.

Finally the expected value at the beginning of the period Q(.,.) depends on the probability of meeting, possible realizations of offers and ωs. Hence

$$Q(S, t : \Omega) = \lambda * EV(p_j, q_j, \omega_j, t, S) + (1 - \lambda) * Q(S, t + 1 : \Omega) \tag{4}$$

where the expectations are taken over prices, quantity and the ωs. With probability λ he may meet an importer and be called upon to make a choice of Yes or No; otherwise he moves to the next period with same stock.

This is a finite horizon dynamic optimization problem. While the algorithm to solve it is rather simple (solving backwards from the last period), there is no analytical solution. Solving it would require us to calculate V for every possible realization of p, q,

ω and S at every point in time. Given that for our empirical exercise, we do not know what the parameters of the distributions are, the problem has to be solved repeatedly for a large range of values of the unknown parameters. This is likely to be an extremely time consuming exercise. For these reasons, we look for an alternate way of estimating the model without explicitly solving the dynamic programming problem. We follow the approach of Geweke and Keane (2000).

Define

$$Z(p,q,\omega,t,S) \equiv V^{Y} - V^{N} \tag{5}$$

Substituting the value of V^Y and V^N from (1) and (2) we get

$$Z(p,q,\omega,t,S) = pq' + \delta + Q(S-q',t+1:\Omega) - Q(S,t+1:\Omega) \tag{6}$$

where $\delta = \omega_1 - \omega_2$.

In any time period t, given an offer (p,q), δ and his S, the function $Z(.)$ indicates whether the middleman will agree to the trade or not. If the realized value Z is greater than zero, then the middleman will say Yes, otherwise he will say No. We use this observation about Z in our estimation procedure, but before we do so, let us discuss the available data.

1.3 Data

Australia auctioned a portion of its import quotas on some 22 categories of textiles, clothing, and footwear during 1982--93. The auctions were held once a year, approximately six months in advance of the quota year[4]. Prospective bidders had to register prior to the auctions; individuals, partnerships, domestic corporations, and foreign businesses represented by an Australian citizen were all eligible to bid. Bidders specified the category of the items, the quantity they were bidding for, and the ad valorem duty rate they would pay, above the duty rate otherwise applicable to the item.

[4] The quota year ran from March through February. For example, the auction for 1990 quota year licenses was held in the last quarter of 1989; those licenses became valid on March 1, 1990.

Successful bidders had to pay a security deposit equal to 10 percent of the estimated value of imports, where the valuation was based on the average unit value of imports for the category over the most recent twelve-month period for which data were available. When the goods were imported, each quota holder paid, in addition to the base duty rates, the extra ad valorem charge determined in the auction. Once the quota licenses had been used to import, the quota holder would receive a refund of the corresponding security deposit. Importers who failed to fully utilize their quota forfeited their security deposit. This security deposit was lowered to 5 percent in 1992.[5]

Quota licenses obtained by auction were transferable to a certain extent[6]. However, the secondary market was quite thin, and a number of quota brokerage firms sprang up that specialized in buying and selling these licenses. When quota was transferred, the new quota holder was required to submit the security deposit and the seller received a refund of the security deposit that had been paid.

Our dataset consists of the transactions (purchases and sales, quantities and prices) of an Australian quota brokerage firm during 1989-1992, involving some 20 categories of quota licenses[7]. (Transactions involving licenses for a particular quota year could take place before the start of that quota year since, as noted above, the official auctions were held well in advance of the quota year.). However for this empirical exercise we restrict our attention to 7 categories for which there are a large number of transactions in a quota year and to quota years 1989 and 1992. Both 1989 and 1992 have the best quality of data. Moreover there was a shift in the security deposit rate[8] from 10 percent in 1989 to 5 percent of unit value of imports in 1992. Table 1.1 shows that the unit values for both years. While the unit values vary over the years, most of the variation

---

[5] During the same time, New Zealand auctioned off quota licenses to convert quotas to tariffs. MacAfee, Takacs, Vincent and Takacs (1999) discuss the case of New Zealand.

[6] Further details on Australia's textile, clothing, and footwear quota system may be found in Takacs (1994).

[7] This data was collected by Wendy Takacs and we are grateful to her for making it available to us.

[8] Some other years pose problems of changes in policy within the year. For example in 1990, the security deposit was waived midway during the year. In 1991, the deposit was waived but we still observe negative prices which one would expect to result from importers trying to sell their stock to get back their security deposits. The years 1989 and 1992 do not suffer from these problems.

between the two years in the security deposit paid by importers comes from the halving of the security deposit rate. The number of transactions in 1992 are much larger than in 1989 for most commodities. Moreover while in 1989, one observes transactions at negative prices, we observe none for 1992 (Negative prices can occur because of security deposits that need to be paid: people may pay to get rid of their stock to get their deposit back). In macro economic terms, both 1989 and 1992 were somewhat similar in that Australia was going through a recessionary phase. Unemployment rates were high 6% in 1989 and 10% in 1992. The exchange rate (US $/ Aus $) in 1989 was 0.78 and it was 0.73 in 1992. While the quota level allocated through auctions varied over these years, two things needed to be pointed out: First, there was a gradual move from base quota (that were allocated based on history of the importer) to quota allocated through tender. So there was some reallocation. However, according to the 1989–92 TCF assistance plan, both base and tender quota were transferable." (IAC Annual Report 1986–87, p. 118.)]. Thus greater trade was not because of this reallocation. Secondly, the prices that the quota licenses trade at are percentage over base rates. Thus a change in quota level should not affect the license price through the scarcity value at all.

Absent information on the broker's stock of licenses at any point in time, we constructed initial stock on the assumption that he could not sell licenses he did not hold[9]. Hence, we assume the broker starts each year with at least one license in each category, and that his stock never falls below one[10]. We denote stock at beginning of time t as S_t.

The transaction book reports prices at which trade took place. We take into account the deposit rate as this should be factored in to calculate net prices. We add the

---

[9] Specifically, the broker's initial stock of licenses (i.e., his stock of licenses before the start of trading for a particular quota year) is calculated in the following way. For a given category and quota year, let $D_t = \sum_{\tau=0}^{t}\left(q_\tau^B - q_\tau^S\right)$, i.e., the cumulative difference, up to period t, of quantities bought and sold by the broker (q_t^B and q_t^S, respectively), and let $\min[D_t]$ denote the smallest value of D_t over all t. If $\min[D_t]$ is positive, then initial stock for that category and quota year is set at 1. If $\min[D_t]$ is negative, then initial stock for that category and quota year is set at 1- $\min[D_t]$. His stock of licenses at the beginning of period t (i.e., his stock of licenses at the end of period $t-1$) is thus his initial stock plus cumulative purchases less sales up to $t-1$: . $Stock_t = Stock_0 + D_{t-1}$.

[10]This assumption is arbitrary. We could just as well have assumed any non negative starting stock.

deposit rate to both the selling and buying price. This is clearly what is required as when an importer (or the middleman) buys, he has to pay the price as well as the security deposit and Sellers get back their security deposit when they sell.

1.4 Approximation of Q(.)

As pointed above, we do not explicitly solve the dynamic problem. Our model of the middleman tells us that when Z>0 the middleman says “Yes” and when Z<0 he says “No”. Recall from (6) that

$$Z(p,q,\omega,t,S) = pq' + \delta + Q(S-q',t+1:\Omega) - Q(S,t+1;\Omega)$$

However we do not have an analytical form for Q( ). So following Geweke and Keane, we take a second degree polynomial approximation for Q. Let us represent the approximation of Q(S,t:Ω) by the function F(S,t, Ω). Recall that Q(.,.) is a function of only the deterministic variable S and t conditional on the distribution parameters. This is because of our independence assumptions where realizations of random variables in period t do not give any information about their values in the next period. However for our empirical exercise, we do not know what the distribution parameters are. So we need to include the distribution parameters in a second degree taylor approximation given by the function *F(S,t,* Ω). Let $X \equiv (S \quad t \quad \Omega')$. Therefore

$$F(S,t,\Omega) = Q(S^0,t^0,\Omega^0) + \left(X - X^0\right)\left(Q_S \quad Q_t \quad Q_\Omega\right)' + \frac{1}{2}(X - X^0)'P(X - X^0)$$

where P is a symmetric matrix with second derivates as diagonal elements and cross partials as off diagonal elements; Q_Ω is a row vector of first derivatives of Q with respect to elements of Ω.

Substituting *Q(S-q’, t+1:*Ω*)* and *Q(S,t+1:* Ω*)* by their approximations and noting that the only thing difference between the two functions is the stock (see Appendix B for full derivation), we get

$$Z(p.q,\omega,t,S) = pq^{'} + \delta + \{Q_S + Q_{S\Omega}\Omega\}(-q') + \frac{1}{2}Q_{ss}\left\{(S-q')^2 - S^2\right\} + Q_{st}(-q')(t+1)$$

where Q_{ij} (i,j=S, t) are second derivatives and cross partials and $Q_{S\Omega}$ is a vector of cross partials with respect to the elements of Ω. In our data, *p, q, S* and *t* vary over time. However given our time invariant distributions, we have no variation in the distribution parameters. Hence it is not possible to separately identify elements of $Q_{S\Omega}$ and Q_S. All we can hope to do is to estimate the linear combination of the terms in front of *q'*. Thus we rewrite $Z(p,q,\omega,t,S)$ as

$$\begin{aligned} Z(p,q,\omega,t,S) &= pq' + \delta + \theta^{*}{}_1(t+1)(-q') + \theta^{*}{}_2(-q') + \theta^{*}{}_3\{(S-q')^2 - S^2\} \\ &\equiv pq' + \delta + f(S,q',t+1,\theta') \qquad (7) \end{aligned}$$

where $\theta' = (\theta_1^*, \theta_2^*, \theta_3^*)$, $\theta_1^* = Q_{St}$, $\theta_2^* = Q_{S\Omega}\Omega + Q_S$ and $\theta_3^* = \frac{Q_{SS}^0}{2}$

This form is in the same spirit as Geweke and Keane who take their approximations as a function of only deterministic variables which vary over time.

The identification of the distribution parameters comes from the observed prices and quantities, the distributional assumptions and the choices of the middleman. We discuss this in the next section.

1.5 The Empirical Model and Identification

The model above gives us a formulation that we can take to data. Note however that δ, while known to the middleman, is not known to us. So we assume that $\delta \sim N(\mu_\delta, \sigma_\delta^2)$. At any point in time t, we observe whether trade takes place or not. If trade takes place we know Z>0 though we do not observe the value of Z. If trade did not take place, that could be because the middleman did not meet an importer or because the offer by the importer was not attractive enough to the middleman. When the middleman meets a trader and no trade occurs, we know it must be that Z<0 though as above, we do not observe the value of Z.

Given these we can identify parameters of our approximation and the distributions using the strategy explained below. It is very important to note here that none of the steps described below are independent of each other and that they have to be mutually consistent helps us identify the system as a whole. So each step implicitly assumes "given everything else".

To start with, note that anytime we talk about Z, we assume that $\delta \sim N(\mu_\delta, \sigma_\delta^2)$. Let us assume, initially, that we know all the prices and quantities. How likely is it that the middleman said No depends on how likely it is that $Z < 0$. The distribution of δ tells us how likely. For example

$$prob(Z < 0) = prob(p_t q_t' + \delta_t + \theta^*{}_1 (t+1) * (-q_t') + \theta^*{}_2 (-q_t') + \theta^*{}_3 \{(S_t - q_t')^2 - S_t{}^2\} < 0)$$

$$= prob(\delta_t < -(p_t q_t' + \theta^*{}_1 (t+1) * (-q_t') + \theta^*{}_2 (-q_t') + \theta^*{}_3 \{(S_t - q_t')^2 - S_t{}^2\})$$

$$= \Phi_{\mu_\delta, \sigma_\delta^2}(-(p_t q_t' + \theta^*{}_1 (t+1) * (-q_t') + \theta^*{}_2 (-q_t') + \theta^*{}_3 \{(S_t - q_t')^2 - S_t{}^2\}).$$

where $\Phi_{\mu_\delta, \sigma_\delta^2}(.)$ is a normal cdf.

When trade does take place at *(p,q)*, stock S and time *t*, we know that *Z<0*. Thus given our data, *(p,q,t,S$_t$)* when there is a transaction we know that

$$p_t q_t' + \delta_t + \theta^*{}_1 (t+1) * (-q_t') + \theta^*{}_2 (-q_t') + \theta^*{}_3 \{(S_t - q_t')^2 - S_t{}^2 \geq 0$$

This step gives us some information on what the θ_i^* s could be.

To identify the price and quantity distributions, notice that these are the price and quantity offers that prevail in the economy. The observed price and quantities, when there is trade, helps us identify part of the distribution. The unobserved price and quantities are pinned down by the dynamic problem (recall they must be such that $Z<0$). With these two parts, the price and quantity distributions in the economy are identified. Given everything else, there is a unique value of probability of meeting, λ , that maximizes the likelihood function[11].

Following Geweke and Keane, we use Bayesian inference via Gibbs Sampling data augmentation techniques to estimate the parameters of the model (For a discussion of application of bayesian inference to dynamic choice models see Geweke and Keane 2000). While a detailed description of the method is given below, in short Gibbs sampling makes it easy to calculate expectations of functions. The method of data augmentation refers to adding data to cases when they are not observed by drawing them from distributions. Bayesian inference via Gibbs Sampling data augmentation techniques has found to used to estimate a large number of discrete choice problems (Wong and Tanner).

The first step in the process requires us to form the “complete data” likelihood function. This is the likelihood function that could be formed if we observed the value function differences Z_t , the complete set of buying and selling prices including the ones when there is no buy or sell[12] and days when the middleman met an importer I_t. Given our model assumptions about the distribution of buying and selling offers, the distribution of δ , the distribution of buyers and sellers, the distribution of meetings, and our data, we can form the "complete data" likelihood function. Define

$$\varphi(p,q) = I_t^B (p*q)^{-1} \phi_{\mu^B,\Sigma^B}(\ln p_t, \ln q_t) + (1 - I_t^B)(p*q)^{-1} \phi_{\mu^S,\Sigma^S}(\ln p_t, \ln q_t)$$

All this says is that when $I_t^B = 1$ we draw prices and quantity from a log normal buying distribution and when $I_t^B = 0$ we draw them from the log normal selling distribution.

[11] We are not as confident of λ as other parameters as we do not have variables to properly identify it. We also estimated a model where λ was assumed to be 1. The results obtained were similar to the ones obtained here where we allow it to be anything positive less than 1.

[12] This includes knowledge of whether the middleman met a buy or seller, i.e. I_t^B .

Thus the "complete data" likelihood function is given by

$$
\begin{aligned}
L = & \prod_{t\in TR} \lambda^{I_t} \lambda^{B I_t^B}\left(1-\lambda^{B I_t^B}\right) * \varphi(p,q) \\
& * \phi_{0,\sigma_\delta^2}(Z_t - p_t q_t^{'} - f(S_t, q_t^{'}, t+1, \theta') - \mu_\delta) * Ind(Z_t \geq 0) \\
& * \prod_{t\varepsilon NTR} \lambda^{I_t}(1-\lambda)^{1-I_t} * \left(\lambda^B\right)^{I_t^B}\left(1-\lambda^B\right)^{1-I_t^B} \varphi(p,q) \\
& * [I_t * \phi_{\mathbf{0},\sigma_\delta^2}(Z_t - p_t q_t^{'} - f(S_t, q_t^{'}, t+1, \theta') - \mu_\delta) * Ind(Z_t < 0) + (1-I_t)]
\end{aligned} \qquad (8)
$$

TR refers to all dates when we observe trades. NTR refers to periods where there is no trade. $Ind(Z \geq 0)$ is an indicator function reflecting that $Z > 0$ when there is a trade. The first part refers to when the middleman trades while the latter part refers to when we see no trade. The latter part includes both the possibilities: that the middleman did not meet anyone as well as the possibility of unfavorable offers.

If we start with flat priors, the joint density of parameters $\left(\theta', \sigma_\delta^2\right)$, the unknown days of meeting (I_t when $t \in NTR$) , the unknown identity of the importer $(I_t^B$ when $t \in NTR)$, the price and quantity when there is no trade $\left(p_t, q_t \text{ when } t \in NTR\right)$ and the value function differences (Z_t when $t \in NTR$) are proportional to the likelihood function in (8). It is not feasible to construct the posterior analytically due to large number of integrations required over the unobservables. But we can simulate draws from the posterior using a Gibbs sampling data augmentation method. The method entails factoring the joint posterior into a series of conditional densities that are easier to draw from. We draw cyclically from these distributions, one at a time. For a large number of such cycles, the draws obtained converge in distribution to that of the complete joint posterior (Gelfand and Smith 1990).

We make these draws in the following steps. We start with initial guesses for parameters and unknowns. When we draw a variable or variables, we keep all others variables to their values in the last cycle. Then

Step 1:We draw Z_t s for when there is trade and I_t and Z_t jointly when there is no trade.

Step 2: We draw missing prices and quantities (p_t, q_t) as well as the identity of the traders (I_t^B) .

Step 3: We draw parameters that determine the f function as well as μ_δ .

For this we rewrite (7) as

$$Z_t - p_t q_t' = \theta_1^*(t+1)(-q_t') + \theta_2^*(-q_t') + \theta_3^*\left[(S_t - q_t')^2 - S_t^2\right] + \mu_\delta + \delta_t'$$

where $E(\delta') = E(\delta - \mu_\delta) = 0.$

We draw $(\mu_\delta, \theta_1^*, \theta_2^*, \theta_3^*)$.

Step 4 We draw Σ^B and Σ^S

Step 5 We draw μ^B and μ^S

Step 6: We draw σ_η^2

Step 7: We draw λ^B

Step 8: We draw λ

We return to Step 1.

Each step is explained in detail in the appendix.

1.6 Results

1.6.1 The Middleman's problem:

The profit maximization decision to agree or not agree to trade, according to our model, depends on Stock, time to end of the quota year and the offers made. Our results bear out the importance of all three.

At any given point, we would expect that higher the stock, the higher the expected value at the beginning of any time period, represented by the function Q(.) as the middleman can always ignore the extra stock. So he cannot be worse off. We have taken an approximation to Q(.) given by F(.). Differentiating F(.) with respect to S we get

$$\frac{\partial F}{\partial S} = \theta_1^* t + \theta_2^* + 2\theta_3^* S$$

Results in Table 1.2 show that while θ_1^* and θ_3^* are usually negative, θ_2^* is positive. The sign of $\frac{\partial F}{\partial S}$ depends on the relative magnitude of the three terms. Table 7 reports the minimum value of $\frac{\partial F}{\partial S}$. These have been calculated using the highest value of t and the highest value of S in our data (which would tend to make the expression negative). We find that with the exception of one case, it is positive for all other cases.

We are however unable to check any other properties of the value function. We have estimated the difference of value functions V^Y and V^N and thus some common terms of the approximation *F(.)* cancel out and we cannot recover them. Hence instead of concentrating on properties of the value function, we focus on the middleman's decision to agree or not agree to a trade. Conditional on getting an offer to buy or sell licenses, the probability that the middleman agrees to the offer is given by $prob(Z > 0)$. Note that given our notation, when the middleman buys, $q<0$. Our results shed light on how this decision, conditional on receiving an offer, depends on Stock and time to end of the year. If we differentiate the $prob(Z > 0)$ with respect to t, we get

$$\frac{\partial prob(Z > 0)}{\partial t} = -\theta_1^* * q' * \phi(.)$$

This marginal effect of time on the probability of selling is positive since $q'>0$ and θ_1^* is negative, while the effect is negative for a buy $(q'<0)$ (Since $\phi(.)$ is a density it is always positive). This makes sense as the middleman is more willing to buy in the earlier time periods while at the end, the middleman is more inclined to sell. This makes sense as in finite horizon problem, this is expected to be true.

Moreover whether the middleman agrees to buy or sell also depends crucially on the offer he gets as well as his existing stock *(S)*. Let us look at the marginal effect of higher buying quantity offer on probability of agreeing to the trade. Recall q'=Min(S,-$I^B q^B + (1-I^B) q^S$). Therefore when the middleman buys, i.e. when $I^B=1, q'=-q^B$. Hence

$$\frac{\partial pr(Z>0)}{\partial q^B} = -p + \theta_1^*(t+1) + \theta_2^* + 2\theta_3^*(S+q^B)$$

Thus the probability of a buy depends negatively on the price (the middleman is more likely to say yes if price is lower), negatively on time (as θ_1^* is negative) and negatively on stock and the size of q^B (as θ_3^* is negative). In other words, the higher the stock and the larger the size of q^B, the less inclined the middleman is to agree to buy.

When the middleman sells, $q'=Min(q^S,S)$. The marginal effect of a higher selling quantity on the probability of saying yes is given by

$$\frac{\partial pr(Z>0)}{\partial q^S} = p - \theta_1^*(t+1) - \theta_2^* - 2\theta_3^*(S-q^S)$$

The probability of saying Yes to a sale is higher the greater the price offered, the higher is t and the higher is S and lower is q^S.

These results show the workings of an active inventory accumulation model. The middleman behaves optimally and chooses his reservation prices to maximize his profit. Table 1.6 shows the derived means of the buying and selling price distributions and the means of prices in actual trades. The middleman sells when the selling price offers are high and buying prices are low. Note that these are always higher than the mean of their respective distributions. This is more pronounced for most categories in 1989. One reason why this might be so, is the larger variance in prices in 1989 as compared to 1992. The higher security deposits of 10% were causing people to trade (sometimes at negative prices) to avoid paying the penalty, which increased the variance. The higher variance would tend to make the middleman hold out for lower buying and higher selling prices.

1.6.2 Behavior of Importers:

The price, quantity distributions that have been estimated reflect the market that the middleman faces. It would be interesting to ask if these prices reflect true valuation of the licenses. To start with, let us remind ourselves that usually we expect sellers, on an average, to have low valuation and buyers, on an average, to be customers who value the license higher[13]. If the price distributions reflected true valuation, the mean of the buying price distribution (note that the middleman's buying price distribution is the mean of prices offered by the sellers in the economy), should not be lower than his selling price distribution (the mean of prices offered by the buyers). However Table 1.6 shows us that this is not always the case. In many cases the mean of buying price distribution is higher than the selling price distribution, for example, categories 601, 602 in 1989, categories 610, 616 in 1992. For this to happen, it must be that importers are quoting prices different from their valuation. In particular, when a buyer wants to buy from a middleman, he offers a price lower than his true valuation to elicit a profit from the transaction. Similarly a seller would try to sell at a price higher than his valuation.

Notice that the extent to which importers can sell at a price above their valuation and buy at below their valuation depends partly on the prices that are acceptable to the middleman. In particular, the middleman's reservation prices, i.e. prices which make the middleman indifferent between trading and not trading, are crucial to an importers decision. But these prices depend on how much stock the middleman has; something that importers do not know. Hence the importers quote prices based on a probability distribution of the middleman's reservation buying and selling price. Let u represent the valuation of the license to importers. Let R^B and R^S represent the middleman's reservation buying and selling price. Then a seller sells quantity q_I^S at price p_I^S that maximizes $\left(p_I^S - u\right) * q_I^S * prob(p_I^S < R^B)$ while buyers set a price p_I^B to maximize $\left(u - p_I^B\right) * q_I^B * prob(p_I^B > R^S)$. Let $F^B(.)$ and $F^S(.)$ denote the distribution function of the

[13] In a standard demand analysis think of buyers being on the demand curve and sellers as the supply curve. Then buyers are usual higher valuation customers and sellers are lower valuations customers.

middleman's reservation buying and selling price respectively. Let $f^B(.)$ and $f^S(.)$ denote the respective density functions. Thus necessary conditions for optimal selling and buying price are:

$$p_I^S = u + \frac{1 - F^S(p_I^S)}{f^S(p_I^S)}$$

$$p_I^B = u - \frac{F^B(p_I^B)}{f^B(p_I^B)}$$

Thus sellers will price higher than their valuation while buyers will offer lower that their valuations. The extent to which they do so depends on reservation price distribution and density functions. It is possible then, for some distributions, that the mean of prices offered by the sellers will be greater than those offered by the buyers.

. Given our data, we have no idea what the probability distribution of reservation prices are. We thus simulate the valuation distribution implied by one possible distribution: The empirical distribution of reservation prices. We assume all importers perceive the same distribution for the middleman's reservation buying and selling prices as they have no idea what the middleman's stock is.

We use the distribution of reservation prices implied by the actual stock levels over time. Recall that the reservation prices are prices for which $Z = 0$. This implies

$$R^i(.) = \frac{-\left[\theta_1^*(t+1)(-q^{i'}) + \theta_2^*(-q^{i'}) + \theta_3^*\left[(S_t - q^{i'})^2 - S_t^2\right] + \mu_\delta + \delta_t^{'}\right]}{q^i}$$

where $i \in \{B, S.\}$. We derive $R^i(.)$ for $t = 1, T$ and actual stocks in our data $\{S_t\}_{t=1}^T$ We use the estimated values of parameters, draws of q^i and δ' from the estimated distributions. We derive two sets of reservation prices, one for buys and one for sales. For each set of reservation prices, R^i, we find the empirical distribution, that is the proportion of times $R^i < a$ where a is a positive number. We use the two distributions as the reservation price distributions. Using these two distributions, we take T draws of prices and find the valuation distribution[14].

The results from the simulation results are shown in Table 1.10. Clearly the mean valuation of buyers is much higher than those of sellers in all cases, suggesting that our results are consistent with a model where buyers, on an average, have higher valuation than sellers. Figures 1.2 and 1.3 show output of one such simulation exercise for Category 602. Simulations suggest that the buying reservation prices in 1989 (Figure 1.2). tended to be, on an average, lower than the valuation of the sellers. In such a situation, sellers are looking at the tail of the reservation price distributions and find it optimal to quote prices relatively higher than their valuations as there is not too much loss (in terms of lower probability of the middleman agreeing to the trade) in doing so[15]. This is in contrast to 1992 (Figure 1.3), where the means of the valuation and reservation price distributions are close Thus the costs to charging a price much higher than valuation, in terms of much lower probability that the middleman will agree, are greater . Thus there is a much smaller spread between the price and valuation for sellers. Table 1.11 shows that this spread is, for most categories, greater in 1989 than in 1992.

Similarly Figure 1.2 suggests that in 1989, the buyers offered prices much lower than valuations, as the reservation price to sell, as compared to valuations, was much lower. While, in Figure 1.3, prices are on average lower in 1992 (because of the lower security deposit), they are not too much lower than the valuations. Table 1.11 shows that this difference between 1989 and 1992 bears out for buyers in many other categories too.

1.6.3 Welfare Analysis:

If there are very few middlemen in a market where importers don't meet each other very often (thin markets), the middlemen have market power. They exercise their

[14] The derived reservation distributions are not nice. So second order conditions may not be met. Therefore we use grid search to find valuations that justify the observed prices. We also check if any of the prices are consistent with a zero valuation for sellers. Simulations show that are usually not! For one or two cases that justified by negative valuations, we assume valuations are zero.

[15] Note that the sellers will charge a price at least equal to their valuation.

market power by restricting the number of trades that can take place. In our model where importers arrive with offers, the middleman exercises his power by agreeing to buy and sell only at prices favorable to him[16]. His decisions, as we have seen above, depends on how much stock he has and how much time is left to the end of the quota year. To conduct a welfare analysis, we also need to infer how much the importers value the good. However as we have seen above, prices should not be used as proxies for valuations. In this section we try to look at the welfare consequences of having such a market where middleman and customers both have some market power.

To examine the effect of the security deposit we calculate the loss in welfare relative to perfect competition. Merely comparing surplus under the two security regimes is erroneous as when the security changes, market conditions, as given by distribution of buyers and sellers, changes. Thus the demand and supply curves change and the perfect competitive outcome itself changes. Hence there is a need to normalize the surpluses to what could be attained relative to perfect competition. Figure 1.4 explains what we seek to do. The valuations of buyers and sellers yield the demand and supply curves under perfect competition and the surplus is given by AFI. However as importers do not price according to their true valuations, the price offered by the buyers and sellers yield the pseudo demand and supply curves. For buyers, prices are lower than valuation and for sellers, prices are higher than valuation. Thus at any price, there are fewer sellers than in a competitive market. Similarly at any given price, there are fewer buyers. In addition, the middleman buys at a lower price than he sells at creating a wedge in the buying and selling price. Hence only an amount Q^{MM} rather than Q^{PC} is traded in the market. Thus the total loss in the secondary market, as compared to perfect competition is given by ADE.

Using our estimates, we seek to calculate the area ADE as a percentage of AFI. However perfect competition in our set up is not so obvious as the problem is non stationary.

---

[16] In a scenario where middlemen post prices, they maintain a wedge between the buying and selling price to earn profits. This leads to welfare losses for society. See Krishna et. al (2004).

To find ADE, we need Q^{MM}. Since the quantity bought and sold are not equal, the choice of Q^{MM} is difficult. So instead, we use the T prices, quantities and valuations used to derive AFI. We then simulate the T period model with the middleman to derive the producer and consumer surplus and the profit. We subtract the total surplus obtained from AFI to get a measure of ADE. This not a perfect measure but captures our intentions.

Table 1.7 shows that, as expected, there is always a deadweight loss with a middleman as compared to a frictionless markets. These losses range from 27% to about 87% . There are two sources of losses in these markets: one emanates from the seller quoting prices higher than their valuation and buyers shading their buying price. In figure 1.4, this loss is denoted by the area ABC. The other source of loss is because of the middleman's optimal behavior. In the absence of the middleman, if the importers behaved as described above, there would still be one market clearing price. But the middleman extracts profit by creating a wedge between the price he pays for his purchases and sales. By doing so, he restricts the number of trades in the market causing further losses.

Table 1.7 suggests a relation between number of trades the middleman undertakes and the extent of the deadweight loss. If one looks at the same categories for different years, there is a clear relationship between the number of trades and the extent of deadweight loss. In particular the higher the number of trades, the lower the deadweight loss. As Figure 1.4 shows, the primary loss of the secondary market as compared to perfect competition comes through curtailment of the number of trades. The further Q^{MM} is from the perfect competition level of output, the higher the losses. The number of trades is a proxy for the amount of quantity that is transacted in a market.

The year 1989 has lower number of trades. But 1989 was the year the 10% security deposit rule was in place! Throughout the period of our study, the market conditions were nearly the same. As we have pointed earlier, the market conditions affect the base rate and therefore the secondary market prices are not affected by them. The reason for the losses seems to emanate from the change in distribution of buyers and sellers and the middleman's optimal reaction to these changes in distribution. Our estimates in Table 1.5 show that for most categories, the middleman's probability of meeting a seller (probability of buying) given by λ^B was much higher in 1989, consistent with the idea that in 1989, there were a large number of sellers. While in 1989, sellers were trying to sell off their license, sometimes at negative prices (net of security deposit) to regain their security deposit, the proportion of buyers were fewer. Given the smaller proportion of buyers, the middleman was not willing to buy licenses. As we see in Figure 3, this meant that the sellers were looking at the tail of the reservation price distribution while deciding their selling prices. The optimal behavior in such a case resulted in importers trying to sell at prices much higher than their valuation, hoping to extract some surplus. Similarly, the buyers were trying to quote prices much lower than their valuation to secure the license because they knew that the middleman would want to get rid of the license to get the deposits back. Table 1.11 shows that within each category group, the difference between valuation and price for both buyers and sellers tended to be larger in 1989. This behavior by the importers, coupled with the middleman waiting for favorable trades to maximize profit, led to fewer trades in 1989 and greater losses. Thus we can argue that security deposit, through changing the distribution of importers adversely affected the secondary market for licenses.

1.7 Conclusion

This paper looks at the effect of a change in security deposit policy on a secondary market where there are no centralized clearing markets: thus there are a few middlemen who coordinate transactions among buyers and sellers. Using data from 1989 and 1992 in Australia on one such middleman, we content that the change in deposit rate from 10% in 1989 to 5% in 1992 affected the secondary market for licenses.

To understand how middlemen behave in such markets, we model one such middleman's dynamic profit maximization exercise. When customers, also called importers, come to the middleman they announce a price-quantity offer to buy or sell.

Given the offer the middleman either agrees or refuses to trade. There are two factors that effect the middleman's decision. First the middleman must find it consistent with his optimal inventory decision. Second the middleman must find the prices attractive enough to trade at. These two factors imply that there will be a large number of trades that do not take place and cause inefficiency as compared to a frictionless market.

The transactions data that are recorded suffer from endogenous sampling problem. As has been noted above, the transactions data only reflects the trades that the middleman found attractive. We correct for the endogenous sampling problem in the estimation procedure. Our results show that this is indeed a serious problem as the mean of the distribution of prices that sellers offer is above the mean of actual buying prices of the middleman. On the other hand, the mean of distribution of the prices that the buyers offers is below the actual selling price of the middleman.

Estimation results yield that the value function is increasing in stock and decreasing over time. The results are consistent with an inventory accumulation model, wherein the middleman is more inclined to buy when the stock is low and to sell when the stock is high. Moreover, consistent with a finite horizon dynamic problem, we find that the middleman is more inclined to buy when there is a lot of time left to the end of the quota year, while is more inclined to sell in the end.

A further inefficiency in such markets comes from diversion of valuation from prices. The buying and selling price offers of the customers do not necessarily reveal true valuation for the license. In particular, buyers tend to quote prices lower than their valuation while sellers tend to ask for prices above their valuation to elicit some gain from the trade. The extent to which they can do so depend on the reservation prices that the middleman sets. The reservation prices depend to a large extent on the stock that the middleman possesses but importers do not know the inventory holdings of the middleman. They therefore decide the optimal prices to quote using a distribution of the middleman's reservation prices. We conduct simulations using the empirical distribution of reservation prices as implied by the middleman's actual stock over the trading period.

Given these distributions, we derive the valuation distribution from the price distributions in the economy. Our results show that buyers do tend to quote prices lower than valuation and sellers prices higher than their valuation. An interesting result from the estimation of the price distribution is that for some categories and years, the mean of the seller's price distributions is higher than that of the buyers. However when we recover the valuation distributions, we obtain that, as expected, the buyers have on an average higher valuation than the sellers. This is reassuring and flies in the face of studies that tend to use the resale prices in the secondary markets as a proxy for the real valuation of the good!

Using the valuation distributions derived, we do simulations to conduct a welfare analysis to compare a secondary market with such a middleman to a perfectly competitive market. We find that the welfare losses range from 20% to 87% of the surplus under perfect competition. Within the same category, we find that in 1989 the losses are greater than in 1992. We argue that the higher security deposit might be responsible for these losses in the secondary market. Our analysis shows that that the number of the trades undertaken by the middleman is lesser in 1989 than 1992. The lower number of trades leads to the welfare losses.

The reason for lower trades is due to two interrelated factors. Our estimates show that the higher security deposit in 1989 led to a larger proportion of sellers than buyers. Given the lower probability of meeting a buyer, the middleman was hesitant to buy and willing to sell. Given this, sellers expected the middleman's reservation buying prices to be skewed towards low prices. Thus most sellers were choosing prices in the right tail of the reservation price distribution and found it optimal to charge prices much higher than their valuation. Buyers, knowing that the middleman was eager to sell quoted prices much lower than their valuation. Moreover, the middleman too behaved optimally and given his stock, traded when he got favorable prices. These two factors implied that a large number of trades did not take place.

The change in the security deposit rate in 1992 changed the distribution of importers. There were now a greater proportion of buyers, prices were on an average lower and there was lower variance in the prices. Hence the middleman was more inclined to trade, since buying offers were more frequent and given their lower variance, there was less advantage in waiting. The difference in the importers price and valuation was lower, hence larger number of trades took place leading to lower losses.

Thus our analysis indicates that collecting security deposits, which was envisioned as a useful policy for preventing frivolous bidding, had harmful effects in the secondary market. The cutting of the rate alleviated some of these harmful effects in 1992.

It is important to note here that higher prices and lower quantity in 1989 can also come from a competitive model. Suppose importers (the customers of the middleman) are differentiated in two dimensions: the certainty with which they expect an order and the profit they expect to make from that order. The two characteristics are likely to be negatively correlated: high profit orders are risky while low profits are more certain. With a large security deposit, the licenses in the auction tend to go to those who are relatively sure of their order since there is a large penalty associated with non utilization. Hence there is less supply of licenses with a large deposit rate. Demand for licenses comes from those with unexpected profitable orders. But as these do not get the allocation in the auction with a high deposit, we expect demand for licenses to shift out. If this is less than the shift in of supply the price rises and quantity falls. However a preliminary look at the data for the middleman suggests that there was a large wedge between the actual buying and selling price, which seems to indicate that this was not a competitive market. Hence we chose to model the secondary market with frictions caused by middleman and importers.

It would be interesting to integrate the effect of the security deposit on the primary market; the bidding behavior itself to the changing distribution of importers in the secondary market. However this necessities the study of bidding behavior in a multi unit uniform price auction, the format for auctions in Australia. Studying such an auction and evaluating the effect on both markets in an integrated framework is an issue we hope to study in the future.

References

- Geweke, John and Michael Keane, 2000, Bayesian Inference for Dynamic Discrete Choice Models without the need for Dynamic Programming, in Roberto Mariano et. al. edited. Simulation-Based Inference in Econometrics, Cambridge University Press.
- Hall, George and John Rust, 2002, Econometric Methods for Endogenously Sampled Time Series: The Case of Commodity Price Speculation in the Steel Market, NBER Technical Working Paper 278 (Cambridge: National Bureau of Economic Research).
- ------, 2003, Middlemen versus Market Makers: A Theory of Competitive Exchange, *Journal of Political Economy*, Vol. 111, No. 2 (April), pp. 353--403.
- Krishna, Kala and Ling-Hui Tan, 1996, The Dynamic Behavior of Quota License Prices, *Journal of Development Economics*, Vol. 48, No. 2 (March), pp. 301--21.
- McAfee, R. Preston, Daniel Vincent and Wendy Takacs, 1999, Tarrifying Auctions, *Rand Journal of Economics,* Vol. 30, No. 1. pp. 158-179.
- Spulber, D., 1996, Market Making by Price Setting Firms, *Review of Economic Studies*, Vol. 63, No. 4 (October), pp. 559--80.
- Takacs, Wendy, 1994, Import License Auctions and Trade Liberalization: Theory and Experience (unpublished; Washington: The World Bank).

Appendix

Step1

- When there is trade, with everything known

draw Z_t from $N^+(p_t q_t' + \theta_1^*(t+1)(-q_t') + \theta_2^*(-q_t') + \theta_3^*\left[(S_t - q_t')^2 - S_t^2\right] + \mu_\delta, \sigma_\eta^2)$

where N^+ denotes that the normal density is truncated from below at 0. This can be drawn using an inverse CDF method.

- When there is no trade,

Draw Z_t from $N^-(p_t q_t' + \theta_1^*(t+1)(-q_t') + \theta_2^*(-q_t') + \theta_3^*\left[(S_t - q_t')^2 - S_t^2\right] + \mu_\delta, \sigma_\eta^2)$ where N^- denotes that the normal density is truncated from above at 0. We use a simple inverse CDF method.

Given Z, draw I from

$$g(I) = \lambda^{I_t}(1-\lambda)^{1-I_t}[I_t * \phi_{\mathbf{0},\sigma_\delta^2}(Z_t - p_t q_t' - f(S_t, q_t', t+1, \theta') - \mu_\delta) * Ind(Z_t < 0) + (1 - I_t)]$$

To draw I we use an acceptance rejection (A/R) algorithm. The above density function is the target density function. We take the sampling density function as $\lambda^{I_t}(1-\lambda)^{1-I_t}$ and denote it by $g^*(I)$ The acceptance probability in the A/R algorithm is given by $\{\max \frac{g(I)}{g^*(I)}\}^{-1} \frac{g(I)}{g^*(I)}$.

Step 2

- When there is no trade, given everything else, if $I_t = 1$, the missing p s and I^B are jointly drawn from

$$(\lambda^B)^{I_t^B}(1-\lambda^B)^{1-I_t^B} * \varphi(p,q) * \phi_{\mathbf{0},\sigma_\delta^2}(Z_t - p_t q_t' - f(S_t, q_t', t+1, \theta') - \mu_\delta)$$

Recall $q' = I^B * -q^B + (1 - I^B) * Min(S, q^S)$. Thus we use

$$(\lambda^B)^{I_t^B}(1-\lambda^B)^{1-I_t^B} * \varphi(p,q)$$

as the sampling distribution in an A/R algorithm. The acceptance probability is given by

$\phi_{\mathbf{0},\sigma_\delta^2}(Z_t - p_t q_t' - f(S_t, q_t', t+1, \theta') - \mu_\delta)$. Note that if $I_t = 0$, that is there is no meeting, then we draw p, q and I^B from $(\lambda^B)^{I_t^B}(1-\lambda^B)^{1-I_t^B} * \varphi(p,q)$ and derive q' .[17]

Step 3

We take all the periods where there was a meeting, i.e. when $I_t = 1$. Let T^* denote the number of periods when the middleman meets a trader. Let Z^* denote a T^* X 1 matrix where the t th element is $Z_t - p_t q_t$. Let D be a T^* X 4 where the t th row is $[1 \quad (t+1)(-q_t') \quad (-q_t') \quad (S_t - q_t')^2 - S_t^2]$. Then the parameters $(\mu_\delta, \theta_1^*, \theta_2^*, \theta_3^*)$ follow $N((D'D)^{-1}D'Z^*, \quad \sigma_\delta^2(D'D)^{-1})$. Note that the mean is just a simple OLS estimator.

Step 4

Let B be number of buys and S be the number of sells. To draw Σ^B let e_p be a B X 1 matrix with t th term as $(\ln p_t^B - \mu_p^B)$. Similarly let e_q be a B X 1 matrix with t th term as $(\ln q_t^B - \mu_q^B)$ Define the matrix Ψ such that $\Psi^B = \begin{bmatrix} e_p' e_p & e_p' e_q \\ e_p' e_q & e_q' e_q \end{bmatrix}$. Then $(\Sigma^B)^{-1} \sim Wishart[\Psi^B, B]$. Analogously $(\Sigma^S)^{-1} \sim Wishart[\Psi^S, S]$.

Step 5

Given everything else, $\mu_B \sim N\left(\begin{bmatrix} \frac{1}{B}\sum_{t=1}^{B} \ln p_t^B \\ \frac{1}{B}\sum_{t=1}^{B} \ln q_t^B \end{bmatrix}, \frac{1}{B}\Sigma_B\right)$

[17] If the importer did not meet the middleman, there is no data (like decision of Yes or No) that gives us information additional to that contained in φ . However there is a need to draw them from the distribution because when Z is drawn in Step 1 , we need information on prices and quantity even if I was 0 in the previous iteration.

and $$\mu_S \sim N\left(\begin{bmatrix} \frac{1}{S}\sum_{t=1}^{S}\ln p_t^S \\ \frac{1}{S}\sum_{t=1}^{S}\ln q_t^S \end{bmatrix}, \tfrac{1}{S}\Sigma_S\right)$$

Step 6

With everything else known, σ_δ has an inverted gamma distribution. Since

$$\delta t = Z_t - p_t q_t - \theta_1^*(t+1)(-q_t^{'}) - \theta_2^*(-q_t^{'}) - \theta_3^*\left[(S_t - q_t^{'})^2 - S_t^2\right] - \mu_\delta,$$

$$\frac{\sum_{t=1}^{T^*}\delta_t^2}{\sigma_\delta^2} \sim \chi^2(T^*)$$

We draw a χ^2 variate with T^* degrees of freedom. and calculate $\sigma_\delta^2 = \frac{\sum_{t=1}^{T^*}\delta_t^2}{\chi^2 \text{ variate}}$.

Step 7

With everything else known, λ^B follows a Beta distribution with $\alpha = \left(\sum_{i=1}^{T} I_t^B\right) + 1$ and

$\beta = T - \left(\sum_{i=1}^{T} I_t^B\right) + 1$

Step 8

With everything else known, λ follows a Beta distribution with $\alpha = \left(\sum_{i=1}^{T} I_t\right) + 1$ and

$\beta = T - \left(\sum_{i=1}^{T} I_t\right) + 1$

Appendix B

Let **0** be a vector of 0*s*. Let us approximate the function around $X^0=(0,0,\mathbf{0})$. Let Q^0 denote the function evaluated at X^0 Therefore

$$F(S-q',t+1,\Omega)=Q^0+(S-q' \quad t+1 \quad \Omega')(Q_s \quad Q_t \quad Q_\Omega)'$$

$$+\frac{1}{2}(S-q' \quad t+1 \quad \Omega')\begin{pmatrix} Q_{ss} & Q_{st} & Q_{s\Omega} \\ Q_{tS} & Q_{tt} & Q_{t\Omega} \\ Q_{\Omega S} & Q_{\Omega t} & Q_{\Omega\Omega} \end{pmatrix}\begin{pmatrix} S-q' \\ t+1 \\ \Omega \end{pmatrix}$$

Expanding and collecting terms:

$$=Q^0+(S-q')Q_S+(t+1)Q_t+\Omega' Q'_\Omega+\frac{1}{2}\left\{Q_{ss}(S-q')^2+Q_{tt}(t+1)^2+Q_{\Omega\Omega}\Omega'\Omega\right\}$$

$$+\left\{Q_{st}(S-q')(t+1)+Q_{s\Omega}\Omega(S-q')+Q_{t\Omega}\Omega(t+1)\right\}$$

Similarly,

$$F(S,t+1,\Omega)=Q^0+SQ_S+(t+1)Q_t+\Omega' Q'_\Omega+\frac{1}{2}\left\{Q_{ss}S^2+Q_{tt}(t+1)^2+Q_{\Omega\Omega}\Omega'\Omega\right\}$$

$$+\left\{Q_{st}S(t+1)+Q_{s\Omega}\Omega S+Q_{t\Omega}\Omega(t+1)\right\}$$

Subtracting one from the other and canceling out common terms, we get

$$F(S-q',t+1,\Omega)-F(S,t+1,\Omega)=Q_S(-q')+\frac{1}{2}Q_{ss}\left\{(S-q')^2-S^2\right\}$$

$$+\left\{Q_{st}(-q')(t+1)+Q_{s\Omega}\Omega(-q')\right\}$$

$$=\left\{Q_S+Q_{S\Omega}\Omega\right\}(-q')+\frac{1}{2}Q_{ss}\left\{(S-q')^2-S^2\right\}+Q_{st}(-q')(t+1)$$

TABLES

Table 1.1: Unit Values

Cat: Year	Unit Value
601: 1989	8.3
601: 1992	6.9
602: 1989	2.9
602: 1992	2.55
603: 1989	5.15
603: 1992	4.4
604: 1989	20.95
604: 1992	22.5
606: 1989	6.9
606: 1992	6.7
610: 1989	5.8
610: 1992	4
616: 1989	17.25
616: 1992	14.2

Table 1.2: Parameter estimates

Cat/Years	Theta*(1)	Theta*(2)	Theta*(3)	Constant
601: 1989	**-0.89**	**1.46**	**-0.25**	**-0.05**
	0.47	*0.13*	*0.08*	*0.01*
1992	**-0.38**	**0.42**	0.01	**-0.02**
	0.11	*0.02*	*0.01*	*0.005*
602: 1989	0.36	**0.57**	**-0.06**	**-0.04**
	0.37	*0.06*	*0.05*	*0.008*
1992	**-0.19**	**0.31**	**-0.02**	**-0.02**
	0.08	*0.03*	*0.007*	*0.005*
603: 1989	**-0.91**	**0.73**	**-0.23**	-0.02
	0.32	*0.12*	*0.22*	*0.471*
1992	**-0.06**	**0.33**	**-0.02**	**-0.006**
	0.10	*0.03*	*0.03*	*0.002*
604: 1989	**-4.25**	**4.58**	0.62	**-0.02**
	2.58	*1.14*	*5.79*	*0.004*
1992	**-1.23**	**1.72**	**0.32**	**-0.013**
	0.23	*0.10*	*0.20*	*0.003*
606: 1989	**-0.30**	**0.69**	**0.16**	**-0.04**
	0.30	*0.20*	*0.06*	*0.006*
1992	**-0.14**	**0.43**	**-0.01**	**-0.01**
	0.11	*0.03*	*0.02*	*0.002*
610: 1989	**-0.40**	**0.81**	0.04	**-0.01**
	0.23	*0.09*	*0.04*	*0.005*
1992	**-0.17**	**0.41**	**-0.02**	**-0.01**
	0.16	*0.04*	*0.01*	*0.003*
616: 1989	-0.12	**4.43**	1.33	**-0.10**
	2.07	*0.78*	*1.38*	*0.012*
1992	0.15	**0.85**	**0.15**	**-0.03**
	0.43	*0.13*	*0.06*	*0.01*

Note: Bold values represent that 0 does not lie in 5-95% interval
The values in italics are the standard errors calculated from 25000 draws

Table 1.3: Distribution of selling price

Cat/Years	μ_p^S	μ_q^S	σ^{2S}_p	σ^{2S}_q	Cov.
601: 1989	**-0.16**	**-3.73**	**0.14**	**3.64**	**0.0010**
	0.09	*0.41*	*0.04*	*1.1421*	*0.03*
1992	**-0.79**	**-4.87**	**0.03**	**2.88**	**0.0003**
	0.03	*0.26*	*0.01*	*0.5310*	*0.01*
602: 1989	**-0.55**	**-4.20**	**0.10**	**4.17**	**0.0004**
	0.06	*0.38*	*0.03*	*1.0217*	*0.03*
1992	**-1.42**	**-3.94**	**0.12**	**4.66**	**0.0010**
	0.05	*0.29*	*0.03*	*0.8866*	*0.04*
603: 1989	**-0.44**	**-5.39**	**0.10**	**2.85**	**0.0009**
	0.06	*0.30*	*0.03*	*0.6764*	*0.03*
1992	**-1.06**	**-4.73**	**0.05**	**2.01**	**0.0004**
	0.02	*0.14*	*0.01*	*0.2568*	*0.01*
604: 1989	**1.20**	**-6.22**	**0.12**	**1.85**	**0.0007**
	0.06	*0.22*	*0.03*	*0.4016*	*0.02*
1992	**0.42**	**-5.64**	**0.05**	**1.86**	**0.0005**
	0.03	*0.16*	*0.01*	*0.2766*	*0.01*
606: 1989	**-0.01**	**-4.31**	**0.15**	**3.12**	**0.0009**
	0.05	*0.22*	*0.03*	*0.5040*	*0.03*
1992	**-0.70**	**-5.17**	**0.05**	**2.22**	**0.0006**
	0.02	0.16	0.01	0.3151	0.02
610: 1989	**-0.14**	**-4.71**	**0.08**	**2.87**	**0.0005**
	0.04	*0.23*	*0.02*	*0.5270*	*0.02*
1992	**-0.96**	**-4.47**	**0.09**	**2.50**	**0.0005**
	0.03	*0.16*	*0.01*	*0.3649*	*0.02*
616: 1989	**1.31**	**-4.64**	**0.20**	**1.28**	**0.0009**
	0.08	*0.19*	*0.05*	*0.28*	*0.0228*
1992	**0.21**	**-4.25**	**0.07**	**2.73**	**0.0005**
	0.03	*0.19*	*0.01*	*0.42*	*0.02*

Note: Standard errors are italicized.

Table 1.4: Distribution of buying price

Cat/Years	μ_p^B	μ_q^B	σ^{2B}_p	σ^{2B}_q	Cov
601: 1989	**0.001**	**-2.74**	**0.05**	**0.0012**	**0.007**
	0.057	*0.01*	*0.01*	*0.001*	*0.0031*
1992	**-0.862**	**-2.60**	**0.01**	**0.0002**	**0.001**
	0.019	*0.003*	*0.0016*	*0.0001*	*0.0003*
602: 1989	**-0.467**	**-2.47**	**0.10**	**0.0012**	**-0.010**
	0.075	*0.01*	*0.02*	*0.001*	*0.0039*
1992	**-1.484**	**-1.65**	**0.04**	**0.0007**	**0.005**
	0.046	*0.01*	*0.01*	*0.0004*	*0.0016*
603: 1989	**-0.482**	**-3.69**	**0.16**	**0.0020**	**-0.017**
	0.119	*0.01*	*0.05*	*0.002*	*0.0075*
1992	**-1.212**	**-3.18**	**0.02**	**0.0003**	**-0.002**
	0.024	*0.003*	*0.004*	*0.0001*	*0.0006*
604: 1989	**0.901**	**-5.64**	**0.57**	**0.0042**	**0.046**
	0.173	*0.01*	*0.17*	*0.003*	*0.0206*
1992	**0.395**	**-4.35**	**0.01**	**0.0002**	**-0.002**
	0.021	*0.003*	*0.003*	*0.0001*	*0.0004*
606: 1989	**0.052**	**-2.83**	**0.04**	**0.0007**	**0.005**
	0.048	*0.01*	*0.01*	*0.0003*	*0.0017*
1992	**-0.779**	**-3.12**	**0.03**	**0.0005**	**-0.004**
	0.042	*0.01*	*0.01*	*0.0002*	*0.0012*
610: 1989	**-0.155**	**-3.49**	**0.05**	**0.0008**	**0.006**
	0.054	*0.01*	*0.01*	*0.0005*	*0.0020*
1992	**-0.852**	**-2.92**	**0.11**	**0.0012**	**0.011**
	0.073	*0.007*	*0.03*	*0.0007*	*0.0038*
616: 1989	**1.337**	**-3.80**	**0.53**	**0.0029**	**0.037**
	0.138	*0.01*	*0.13*	*0.002*	*0.0139*
1992	**0.269**	**-2.94**	**0.07**	**0.0010**	**0.008**
	0.049	*0.006*	*0.016*	*0.001*	*0.003*

Note: Standard errors are italicized

Table 1.5: Other parameters

Cat/Years	λ^B	λ	$\sigma^2_{\delta'}$
601: 1989	**0.76**	**0.98**	**0.0027**
	0.07	*0.02*	*0.0016*
1992	**0.43**	**0.98**	**0.0004**
	0.08	*0.02*	*0.0002*
602: 1989	**0.61**	**0.98**	**0.0015**
	0.08	*0.02*	*0.0006*
1992	**0.52**	**0.99**	**0.0008**
	0.07	*0.01*	*0.0003*
603: 1989	**0.57**	**0.98**	**0.0002**
	0.09	*0.02*	*0.0001*
1992	**0.26**	**0.99**	**0.0002**
	0.04	*0.01*	*0.0001*
604: 1989	**0.41**	**0.99**	**0.0005**
	0.07	*0.01*	*0.0002*
1992	**0.34**	**0.99**	**0.0002**
	0.05	*0.01*	*0.0001*
606: 1989	**0.36**	**0.99**	**0.0028**
	0.06	*0.01*	*0.0007*
1992	**0.35**	**0.99**	**0.0002**
	0.06	*0.01*	*0.0001*
610: 1989	**0.54**	**0.99**	**0.0003**
	0.07	*0.01*	*0.0003*
1992	**0.40**	**0.99**	**0.0006**
	0.06	*0.01*	*0.0002*
616: 1989	**0.30**	**0.98**	**0.0085**
	0.07	*0.02*	*0.0016*
1992	**0.49**	**0.99**	**0.0031**
	0.056	*0.008*	*0.001*

Note: Standard errors are italicized

Table 1.6: Comparison of means of actual prices and means of distributions

Cat: Years	Actual Buying Price Mean	Distribution: Buying Price Mean	Actual Selling Price Mean	Distribution: Selling Price Mean
601: 1989	0.94	1.03	1.02	0.91
601: 1992	0.42	0.42	0.47	0.46
602: 1989	0.54	0.66	0.68	0.61
602: 1992	0.21	0.23	0.29	0.26
603: 1989	0.53	0.67	0.72	0.67
603: 1992	0.30	0.30	0.37	0.35
604: 1989	2.25	3.27	3.90	3.50
604: 1992	1.45	1.49	1.69	1.56
606: 1989	1.00	1.08	1.16	1.07
606: 1992	0.44	0.47	0.53	0.51
610: 1989	0.79	0.88	0.98	0.90
610: 1992	0.36	0.45	0.42	0.40
616: 1989	3.77	4.96	5.05	4.12
616: 1992	1.21	1.36	1.35	1.28

Table 1.7: Welfare Loss as compared to Perfect Compt.

		No of Transactions	Welfare Loss/Welfare under Perf Compt
601:	1989	69	0.67
	1992	75	0.57
602:	1989	76	0.85
	1992	109	0.77
603:	1989	39	0.51
	1992	167	0.20
604:	1989	88	0.69
	1992	147	0.57
606:	1989	93	0.76
	1992	115	0.75
610:	1989	129	0.44
	1992	149	0.24
616:	1989	82	0.87
	1992	149	0.66

Table 1.8: Minimum value of $\frac{\partial F}{\partial S}$

Cat: Year	$\frac{\partial F}{\partial S}$
601: 1989	0.21
601: 1992	0.23
602: 1989	0.51
602: 1992	0.12
603: 1989	0.17
603: 1992	0.26
604: 1989	5.88
604: 1992	1.18
606: 1989	1.08
606: 1992	-0.23
610: 1989	0.73
610: 1992	0.39
616: 1989	4.98
616: 1992	1.48

Table 1.9: Buying Prices and Selling Price Means net of Security Deposit

	Selling Price	Buying Price
601: 1989	0.08	0.20
601: 1992	0.11	0.08
602: 1989	0.32	0.37
602: 1992	0.13	0.10
603: 1989	0.16	0.16
603: 1992	0.13	0.08
604: 1989	1.41	1.18
604: 1992	0.43	0.37
606: 1989	0.38	0.39
606: 1992	0.18	0.13
610: 1989	0.32	0.30
610: 1992	0.20	0.25
616: 1989	2.39	3.24
616: 1992	0.57	0.65

Table 1.10: Mean of Valuations

	Mean of Buyers Valuation	Mean of Sellers Valuation
601: 1989	1.71	0.64
601: 1992	1.64	0.29
602: 1989	2.00	0.43
602: 1992	1.46	0.14
603: 1989	2.13	0.42
603: 1992	1.81	0.04
604: 1989	6.80	1.04
604: 1992	2.74	0.83
606: 1989	2.31	0.50
606: 1992	1.43	0.28
610: 1989	1.84	0.47
610: 1992	1.30	0.14
616: 1989	7.80	0.41
616: 1992	3.08	0.99

Table 1.11: Difference between valuation and price offered

Cat: Years	Sellers	Buyers
601: 1989	0.39	0.80
601: 1992	0.13	1.18
602: 1989	0.23	1.39
602: 1992	0.09	1.20
603: 1989	0.25	1.46
603: 1992	0.26	1.46
604: 1989	2.23	3.30
604: 1992	0.66	1.18
606: 1989	0.58	1.24
606: 1992	0.19	0.92
610: 1989	0.41	0.94
610: 1992	0.31	0.90
616: 1989	4.55	3.68
616: 1992	0.37	1.80

Figure 1.1: The Time Line

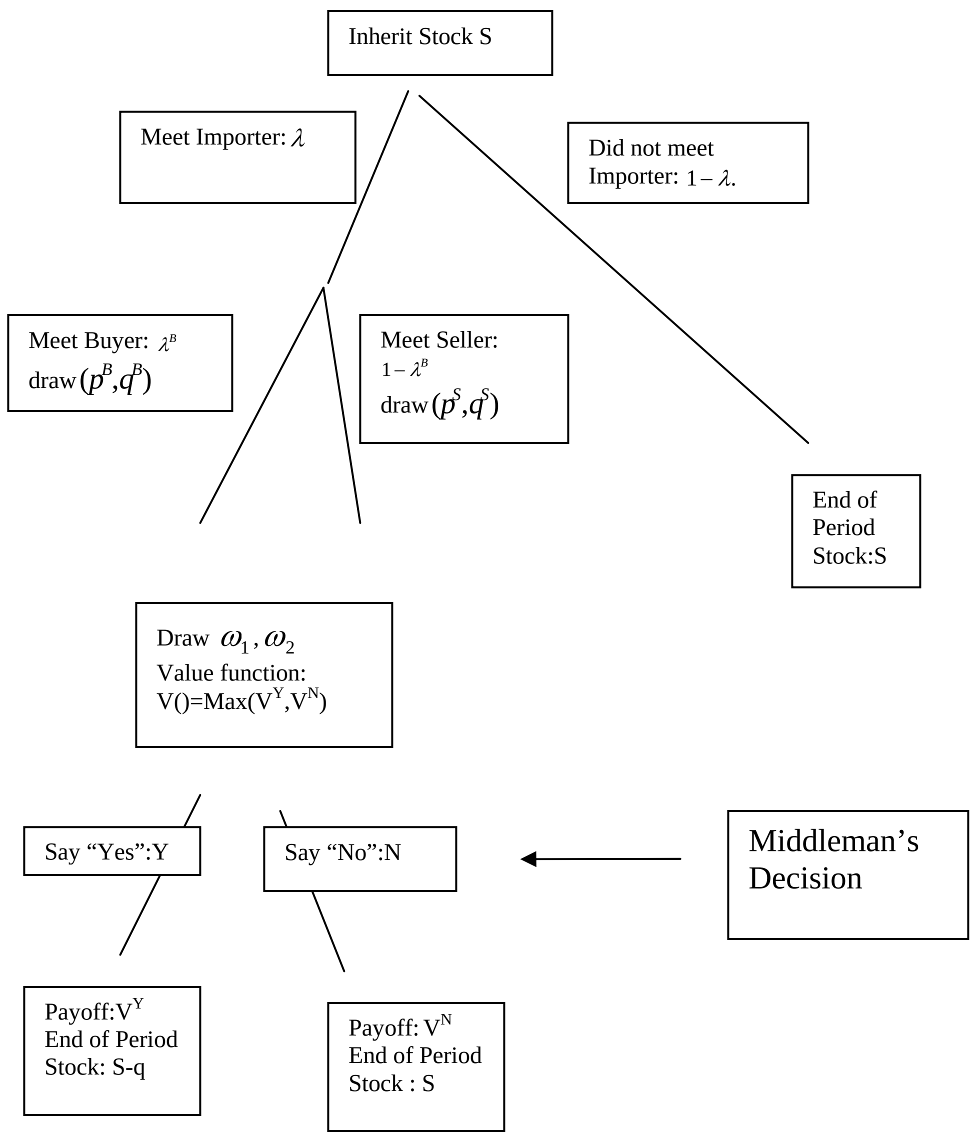
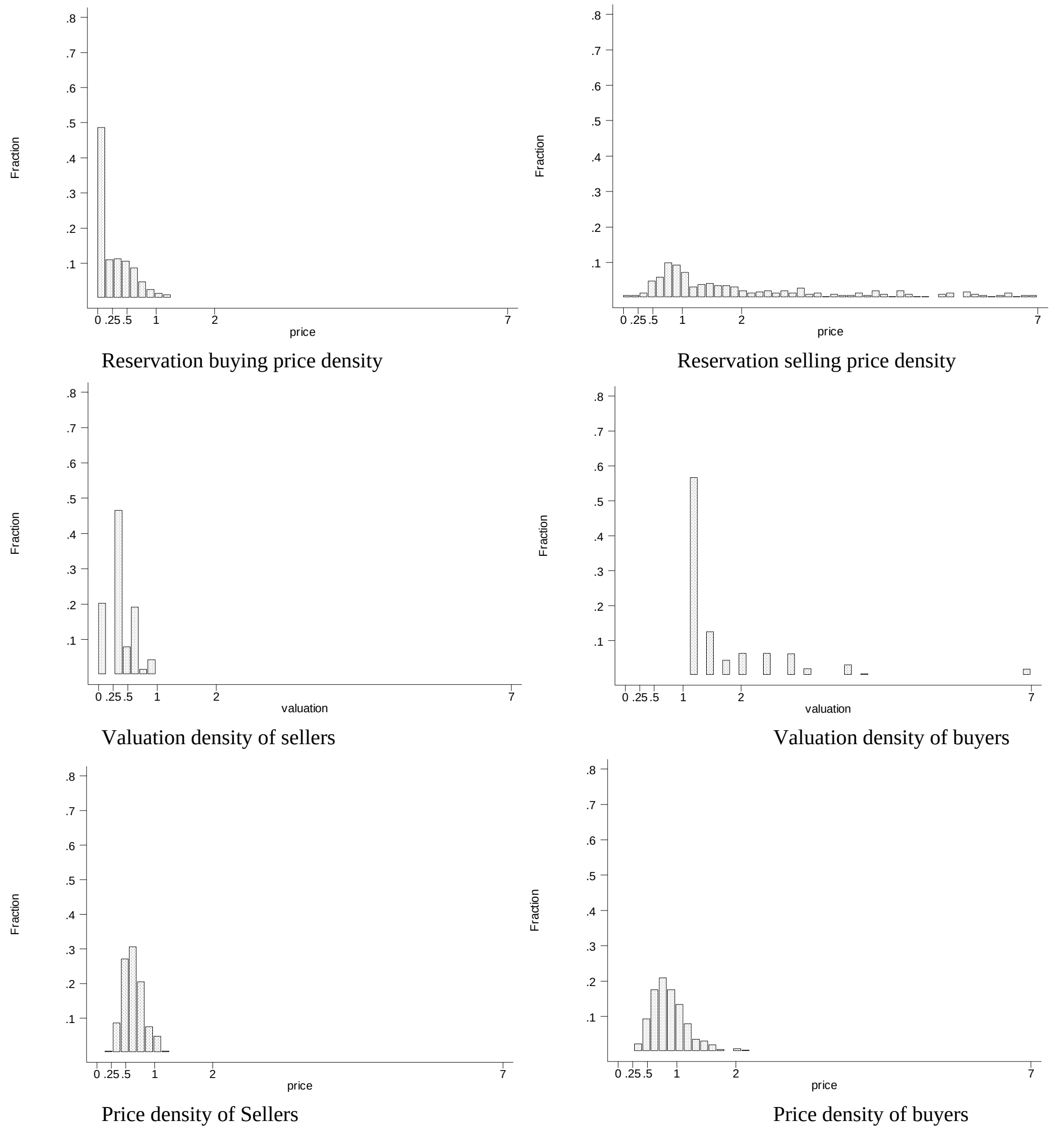
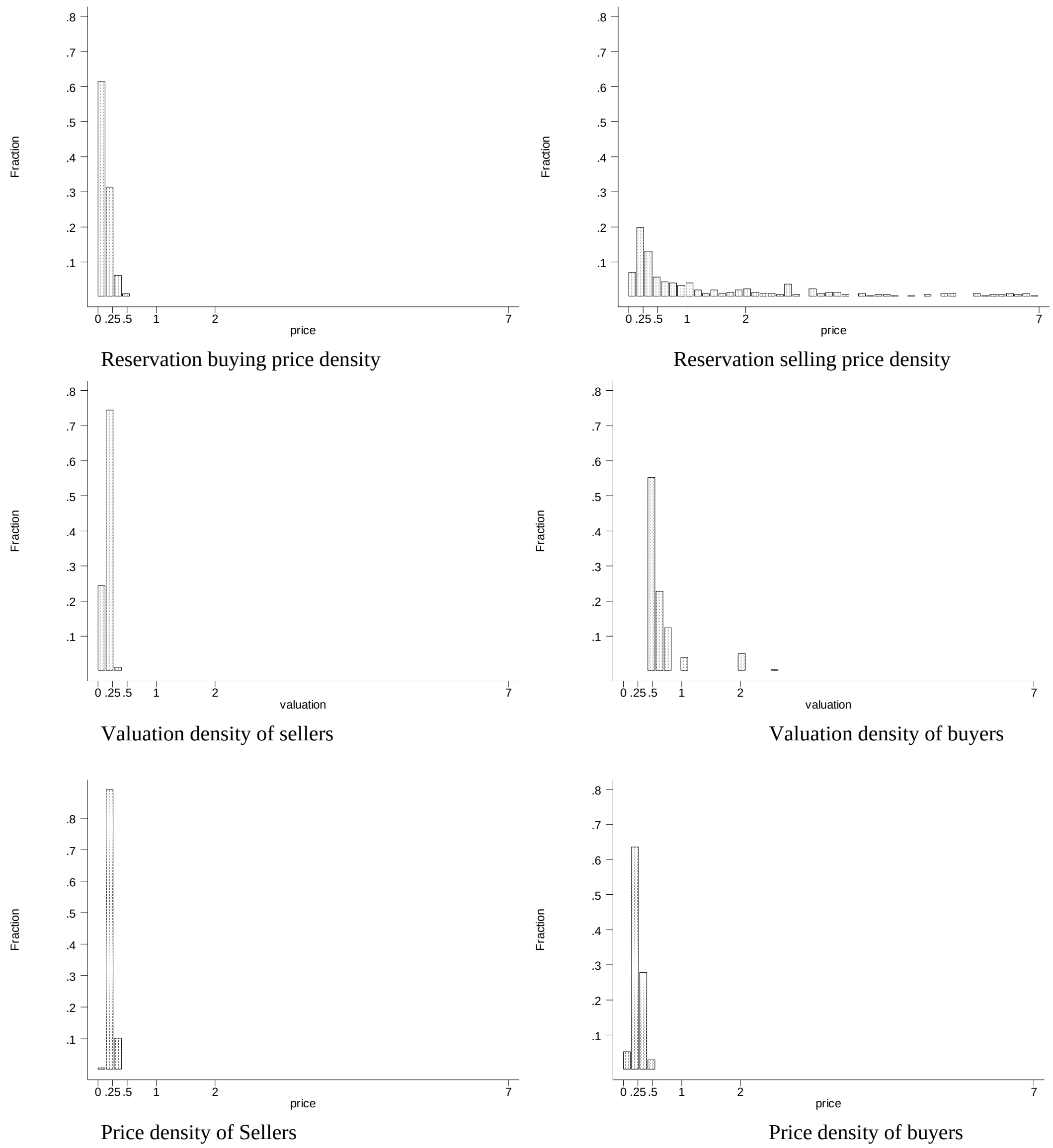


Figure 1.2: Simulations Category 602 Year1989



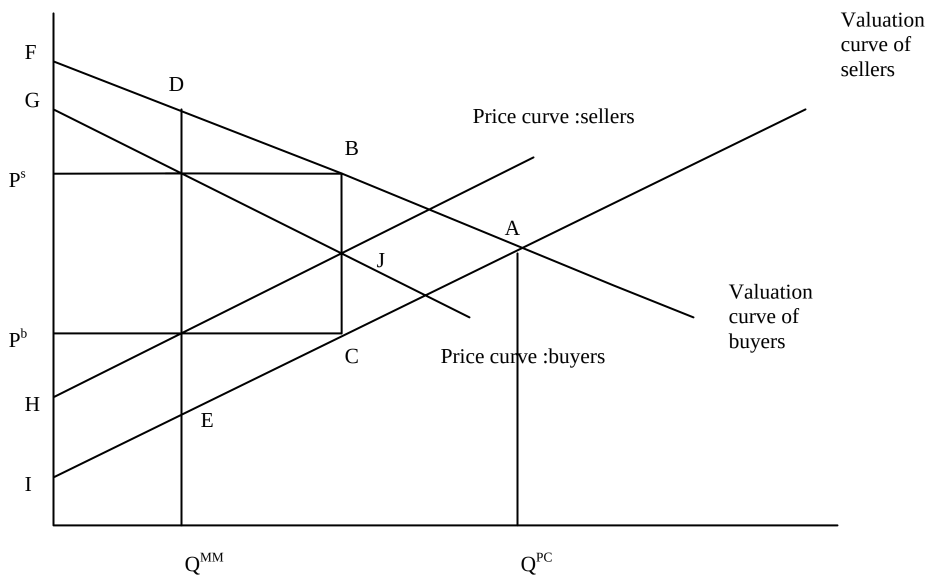
The densities have been drawn on different panels to distinguish them. They have been drawn to the same scale.

Figure 1.3 Category 602 Year1992



The densities have been drawn on different panels to distinguish them. They have been drawn to the same scale.

Figure 1.4: Welfare Loss



Welfare Loss: ADE