WP/04/179

IMF Working Paper

Quota Brokers

Susumu Imai, Kala Krishna,
Abhiroop Mukhopadhyay, and
Ling Hui Tan

INTERNATIONAL MONETARY FUND

 WP/04/179

IMF Working Paper

IMF Institute

Quota Brokers

Prepared by Susumu Imai, Kala Krishna, Abhiroop Mukhopadhyay, and Ling Hui Tan[1]

Authorized for distribution by Eric V. Clifton

September 2004

Abstract

This paper examines the role of middlemen (brokers) in an imperfect secondary market for quota licenses. Middlemen facilitate trade when markets are thin, as potential buyers and sellers find it difficult to meet and transact directly. However, in thin markets, middlemen also have the ability to influence the terms on which trades occur, and the wedge they create between the buying and selling price limits the extent to which they facilitate trade. We develop and simulate a model of quota broker behavior to examine their welfare implications.

JEL Classification Numbers: D45, D40

Keywords: Quota licenses, middlemen

Author(s) E-Mail Address: simai@alcor.concordia.ca; kmk4@psu.edu; axm359@psu.edu; ltan@imf.org

---

[1] Concordia University, Pennsylvania State University, Indian Statistical Institute, and IMF Institute, respectively. This work was initiated while Kala Krishna and Susumu Imai were visiting scholars at the IMF Institute.

Contents Page

I. Introduction 3

II. Middleman Behavior 4

III. Simulation Results 6
A. Changing the Mean of Endowments 7
B. Changing the Mean of Order Size 8
C. Changing the Mean of Valuations 8
D. Changing the Standard Deviation of Valuations 9

IV. Conclusion 9

Tables
1. Simulation Parameters: Sample Mean and Standard Deviation of q^e, q^o and u 10
2. Welfare Calculations 11

Figures
1. Welfare Effect of a Middleman 12
2. Demand and Supply: Increasing the Mean of q^e 13
3. Demand and Supply: Increasing the Mean of q^o 14
4. Demand and Supply: Lowering the Mean of u 15
5. Demand and Supply: Increasing the Standard Deviation of u 16

References 17

I. Introduction

This paper looks at the role played by middlemen in an imperfect secondary market for quota licenses. 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 trade is facilitated by middlemen.

The purpose of this paper is to develop a simple model of middleman behavior in the market for quota licenses to understand the extent of the effects described above and the welfare costs imposed by such thin markets. We focus on the market for quota licenses because quantitative restrictions are used in many countries to control emissions, agricultural output, and fishing catches, among other things; in many cases, these restrictions are implemented by issuing quota licenses which are tradable, to some extent, in a limited secondary market. In such circumstances, it is not uncommon to find middlemen (quota brokers) whose sole business is to buy and sell quota licenses, without being involved in the trade of the final product itself.

The nature of the middleman's product—quota licenses—plays an important role in our analysis. Quota licenses have several special characteristics that set them apart from most conventional products. For example, there are no physical storage costs for quota licenses; only the opportunity cost of funds tied up in the licenses is relevant. Also, quota licenses are perishable commodities, valid only for a certain period of time (e.g., 12 months) and worthless once that period expires. Krishna and Tan (1996) show that, in a dynamic setting with uncertainty, the market price for a quota license is made up of a number of components. First, there is a scarcity value, which depends on the restrictiveness of the quota. (This exists in a static setting as well.) Then there is an asset value component, as a license holder could have invested his money elsewhere and earned interest instead of holding the quota license—this component would make the price of a quota license rise at the rate of interest. In addition, there is an option value component, as the license holder can choose, at any point during the life of the license, whether to use the license or to hold it in order to use it on better terms later on. The option value component falls in value as the expiration date approaches.

As a result of these special characteristics of quota licenses, 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 stationary bid-ask prices. By contrast, since quota licenses expire after a certain period, the problem of quota brokers is inherently nonstationary.

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 markup. 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. As steel is not "perishable," the problem is inherently stationary. Also, in contrast to their case, there is no wholesale market for quota licenses, so bulk-breaking is not a major function of the quota broker. And unlike the steel market, there is no observable spot price for quota licenses. Finally, as mentioned earlier, the inventory holding cost, which is an important variable for the steel intermediary, is negligible in the case of a quota broker.

The rest of the paper is organized as follows. Section II sets out a basic framework for the quota broker's problem. Section III presents simulation results for the model and suggests when welfare losses from quota brokers are likely to be large. Section IV concludes.

II. Middleman Behavior

The objective of this section is to develop a simple model where the middleman sets his buying price and his selling price (taking into account the nonstationary and dynamic nature of the problem), and his customers behave in an economically rational manner. The model captures the role of time and other factors affecting the agents' behavior, but abstracts from the search aspect.

Let us refer to the middleman's potential customers as importers. There are many importers and one middleman. The middleman sets a bid (buying) price P_t^B, and an asking (selling) price P_t^S for quota licenses at each point in time t.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. Each importer has an endowment of licenses, q^e. These licenses may have been allocated to him based on his historical performance, or they may have been purchased by him in an official auction held prior to the start of the quota period; how he got them has no bearing on his behavior in this model. Assume that each importer is matched to a buyer only quite rarely. As a result, when an importer receives an order, he treats it as if it is the only order he will get for the quota period (say, 12 months). Suppose he receives an order of size q^o units and value u. Assume u, q^o, and q^e are drawn from the distribution, $f(u,q^o,q^e \mid Z_t)$ where Z_t denotes a set of market conditions that affect the distributions of u, q^o, and q^e. Upon receiving the order, the importer must decide what to do: he can buy licenses from the middleman at the asking price, P_t^S; sell licenses to the middleman at the bid price, P_t^B; or not trade with the middleman at all. He chooses the option with the greatest payoff:

- If $u < P_t^B$, he will sell all q^e licenses to the middleman. Denote this combination of (u, q^o, q^e) by $X_1(P_t^B)$.
- If $u > P_t^B$ and $q^e > q^o$, he will use q^o licenses and sell the remaining $(q^e - q^o)$ licenses to the middleman. Denote this combination of (u, q^o, q^e) by $X_2(P_t^B)$.
- If $u > P_t^S$ and $q^o > q^e$, he will buy $(q^o - q^e)$ licenses from the middleman. Denote this combination of (u, q^o, q^e) by $X_3(P_t^S)$.
- If $P_t^B < u < P_t^S$ and $q^o > q^e$, he will not trade with the middleman (that is, he will only partially fill the order). Denote this combination of (u, q^o, q^e) by $X_4(P_t^B, P_t^S)$.

Now let us turn to the middleman's problem. The middleman's probability of meeting an importer is λ_t.[2] Knowing all of the above, and given Z_t and his current stock of licenses (S_t), the middleman sets P_t^B and P_t^S each period so as to maximize his expected profit, or the value of his stock. Let $V_t(S_t, Z_t)$ denote the value of his stock given Z_t:

$$\begin{aligned}
V_t(S_t, Z_t) = \max_{P_t^B, P_t^S} \lambda_t \{ & \int_{X_1(P_t^B)} f(u, q^e, q^o \mid Z_t) \left[E_{Z_t} V_{t+1}(S_t + q^e, Z_{t+1}) - P_t^B q^e \right] \\
+ & \int_{X_2(P_t^B)} f(u, q^e, q^o \mid Z_t) \left[E_{Z_t} V_{t+1}(S_t + (q^e - q^o), Z_{t+1}) - P_t^B (q^e - q^o) \right] \\
+ & \int_{X_3(P_t^S)} f(u, q^e, q^o \mid Z_t) \left[E_{Z_t} V_{t+1}(S_t - (q^o - q^e), Z_{t+1}) + P_t^S (q^o - q^e) \right] \\
+ & \int_{X_4(P_t^B, P_t^S)} f(u, q^e, q^o \mid Z_t) \left[E_{Z_t} V_{t+1}(S_t, Z_{t+1}) \right] \} + (1 - \lambda_t) E_{Z_t} V_{t+1}(S_t, Z_{t+1})
\end{aligned} \tag{1}$$

The terminal condition is:

$$V_T(S_T, Z_T) = 0 \quad \forall \quad S_T, Z_T \tag{2}$$

The first order conditions give P_t^B and P_t^S as functions of S_t and Z_t.

---

[2] We can think of the middleman setting his buying and selling prices (based on his knowledge of the distribution of his potential customers' valuations) and then sitting by his telephone waiting for customers to call, i.e., waiting for a "meeting." At any given time, there is always the chance that no one will call, so the probability of a meeting is less than one.

III. Simulation Results

Since we cannot obtain a closed-form solution to the model, we use numerical simulations to get a better understanding of the behavior of the middleman's buying and selling prices. The simulations are based on the following assumptions: (i) the middleman's initial stock of licenses is zero;[3] (ii) importers' endowments are drawn from a lognormal distribution, $\log q^e \sim N(\mu_e, \sigma_e^2)$;[4] (iii) importers' orders less endowments are drawn from a normal distribution, $q = q^o - q^e \sim N(\mu_q, \sigma_q^2)$, conditional on the drawing of q^e and conditional on implied orders $q + q^e$ being positive; (iv) the implied mean of q^o is greater than the mean of q^e;[5] (v) importers' valuations are drawn from a lognormal distribution, $\log u \sim N(\mu_u, \sigma_u^2)$, truncated at 10.00;[6] (vi) λ is chosen to be 0.83; and (vii) Z is fixed in each simulation. Each simulation was run for 30 time periods, with 50 simulations for each parameter value.

The objective of the simulations is to find out how the middleman's buying and selling prices behave in response to changes in the means of q^e and q^o, and the mean and variance of u (one at a time), and the implications for welfare loss relative to perfect competition. The presence of a middleman with some market power results in a deadweight loss compared with the situation of perfect competition. In static or stationary infinite horizon problems, the wedge between the selling and buying price represents the market power and the deadweight loss is given by the standard loss triangle. (Figure 1.) In a dynamic finite horizon problem, the analysis is not so straightforward. Since the quota licenses expire after a certain period of time, both the buying and selling prices of the middleman fall towards the end of the license validity period. In the terminal period, the buying price is zero. Thus the path of the spread between the two prices need not be monotonic and has a pure market power component and a component linked to time. This nonstationary characteristic of the spread complicates its use for welfare analysis. Just as the shape of the demand curve limits the extent to which a monopolist can extract

---

[3] In other words, the middleman receives no initial allocation of licenses, either directly from the government or by purchase (e.g., through a quota auction).

[4] The lognormal distribution was chosen because endowments cannot take negative values.

[5] Given our earlier assumption that importers receive orders very infrequently, an importer with $q^o < q^e$ will fill his order, q^o, and dispose of the excess for free. Knowing this, the middleman will find it in his interest to just wait for these costless licenses, so his buying price will be zero. In order to avoid this scenario, we make the assumption that q^o is greater than q^e, on average.

[6] The reason for the truncation is that we consider prices between 0 and 10, and prices are determined by valuations.

monopoly rent, in our model the distribution of importer valuations and the time remaining for which the licenses are valid limit the middleman's ability to exploit his market power.

To separate the market power component from the time component, we consider only the middleman's buying and selling prices in the earlier part of the quota year, the idea being that the buying and selling prices tend to be relatively stable in the first few periods, as the terminal period effect has not yet set in. Drawing from the distribution of valuations, endowments, and orders, we generate a demand curve and a supply curve for licenses. The intersection of demand and supply gives the market clearing price and quantity that would result under perfect competition (P^C and Q^C in Figure 1).

In order to get an idea of the wedge between the buying and selling price arising due to the middleman, we repeatedly simulate the middleman's behavior over the entire 30 periods specified in the model and calculate a proxy for Q in Figure 1 using the first nine periods.[7] The middleman's buying price and selling price (P^B and P^S) are read off the demand and supply schedules. Using these, we can calculate the welfare loss associated with having a middleman relative to a competitive market—this is equivalent to the ratio of the shaded triangle to the larger triangle bounded by the y-axis, the demand curve, and the supply curve in Figure 1.

Table 1 shows the distribution parameters used in the simulations.[8] Table 2 summarizes the results of these simulations on welfare. As expected, the buying and selling price bracket the competitive price and the quantity traded by the middleman is smaller than the market clearing quantity under competition.

A. Changing the Mean of Endowments

Figure 2 plots the middleman's demand and supply curves: D1 and S1 are the demand and supply curves in the base case (Simulation 1 in Table 1), and D2 and S2 are the demand and supply curves when the mean of q^e is increased (Simulation 2 in Table 1). Higher average

[7] To be precise, we first calculated the buying and selling prices for each period by simulating the 30-period model repeatedly. We then took the average of the first nine periods' buying and selling prices, and obtained the corresponding quantities from the demand and supply schedules, respectively. Finally, we averaged these two quantities to get a proxy for Q.

[8] For clarity, Table 1 reports only the means and standard deviations of q^e, q^o, and u, instead of the underlying parameters, $\mu_e, \sigma_e^2, \mu_q, \sigma_q^2, \mu_u, \sigma_u^2$. Note changing the mean of q^e involves changing more than one of the underlying parameters, since q^e is log normally distributed—in Simulation 2, where only the mean of q^e is changed relative to Simulation 1, both σ_e^2 and μ_q also had to be changed in order to keep the variance of q^e and the mean of q^o the same as in Simulation 1. The same is true for changes in the mean or variance of u.

endowments reflect a market where there is a greater availability of licenses (in the hands of the importers), so there are fewer importers wanting to buy licenses from the middleman. Thus, the demand for licenses falls, and the middleman has to lower his selling price. At the same time, potential sellers, on average, have larger quantities to sell, so supply rises and the middleman can lower his buying price.[9] Thus, the greater the supply of licenses held by importers, the lower will be the middleman's buying and selling price, except for the terminal period when the buying price is always zero. Simulation results verify this intuition.

What is the consequence of these price changes on welfare? It is hard to make a definite statement since the competitive price is also lower.[10] In our simulations, society's welfare losses go up by a small amount (compare Simulation 1 and Simulation 2 in Table 2).

B. Changing the Mean of Order Size

Figure 3 plots the middleman's demand and supply curves in the base case (D4 and S4, from Simulation 4 in Table 1) and when the mean of q^o is increased (D5 and S5, from Simulation 5 in Table 1). If the average order size is larger (for given endowments), then $(q^o - q^e)$ increases on average, so the demand for licenses goes up. But there will be fewer importers with endowments greater than order size (i.e., fewer importers with excess licenses to sell), thus supply from this source falls. Consequently, while the middleman can now charge a higher selling price, he also has to pay more to buy licenses. Simulations verify that a higher mean of orders leads to higher buying and selling prices at any given point in time, except for the terminal period when the buying price is always zero. In our simulations, welfare losses for society go down (compare Simulation 4 and Simulation 5 in Table 2).

C. Changing the Mean of Valuations

Figure 4 plots the middleman's demand and supply curves in the base case (D1 and S1, from Simulation 1 in Table 1) and when the mean of u is lowered (D3 and S3, from Simulation 3 in Table 1). Shifting the distribution of u leftward increases the supply of licenses to the middleman (as more importers will find it worth their while to sell their entire endowment) and reduces demand for licenses (as fewer importers will find it worth their while to purchase additional licenses to complete their order). Thus one would expect the middleman

---

[9] The middleman's supply of licenses comes from importers with low u who wish to sell their entire endowment, and (a small number of) importers with $q^e > q^o$ who wish to sell their excess licenses. Hence, all else being the same, the larger endowments are on average, the greater will be the quantity available for sale to the middleman.

[10] In other words, the welfare loss triangle caused by the middleman is smaller but the total surplus under perfect competition is also smaller so the comparison of the welfare loss relative to perfect competition is not obvious.

to charge a lower buying and selling price when average valuations are lowered, except for the terminal period, when the buying price is always zero. Simulations verify this intuition and show smaller welfare losses for society (compare Simulation 3 and Simulation 1 in Table 2).

D. Changing the Standard Deviation of Valuations

Figure 5 plots the middleman's demand and supply curves in the base case (D6 and S6, from Simulation 6 in Table 1) and when the standard deviation of u is increased (D3 and S3, from Simulation 3 in Table 1). The simulations show that a higher standard deviation of valuations leads to a lower buying price and a higher selling price at any given point in time, except for the terminal period, when the buying price is always zero. The middleman can charge a higher selling price as there is a chance of meeting a buyer who values the license very highly. On the flip side, his buying price is now lower as there may be sellers with very low valuations who want to get rid of their endowments. Thus the greater the dispersion of the value of the license, the greater will be the wedge between the middleman's selling and buying prices, and hence, the greater will be the welfare loss (compare Simulation 3 and Simulation 6 in Table 2).

IV. Conclusion

Resale markets are an under-researched area in economics. Yet in a world with exogenous uncertainty, resale is a critical part of how markets operate. This is particularly true for the market for quota licenses. In reality, such resale markets tend to be thin, and their economic and welfare implications need to be better understood.

This paper developed a basic model of middleman pricing behavior and used numerical simulations to obtain comparative statics results, as well as potential welfare implications of thin markets brokered by middlemen relative to competitive markets. Middlemen have been portrayed as providers of a valuable service by bringing buyers and sellers together. At other times, they have been vilified as rentiers who live off the fruit of others' labor. Our simulation results suggest the outcome with a middleman comes closer to the competitive outcome when order sizes are large or valuations are low. On the other hand, when valuations are widely dispersed or when importers hold abundant quota licenses, the outcome with a middleman seems to diverge further from the competitive outcome.

Table 1. Simulation Parameters: Sample Mean and Standard Deviation of q^e, q^o and u

Simulation	Mean of q^e	S.D. of q^e	Mean of q^o	S.D. of q^o	Mean of u	S.D. of u
A. Simulation 1 (Base A)	1.6	2.1	3.6	2.3	3.1	2.3
Simulation 2: Higher mean of q^e	1.9	2.1	3.6	2.3	3.1	2.3
Simulation 3: Lower mean of u	1.6	2.1	3.6	2.3	1.5	2.2
B. Simulation 4 (Base B)	1.0	1.2	3.0	1.6	3.0	2.2
Simulation 5: Higher mean of q^o	1.0	1.2	4.4	1.6	3.0	2.2
C. Simulation 6 (Base C)	1.6	2.1	3.6	2.3	1.5	1.5
Simulation 3: Higher S.D. of u	1.6	2.1	3.6	2.3	1.5	2.2

There are three base cases: A, B, C. Different bases were chosen to bring out the effect of the changes in parameters more sharply.

Table 2. Welfare Calculations

	Average selling price	Average buying price	Average quantity transacted	Price under perfect competi-tion	Quantity under perfect competi-tion	Welfare loss
A. Simulation 1 (Base A)	5.26	1.29	3,785	2.73	9,043	10,437
Simulation 2: Higher mean of q^e	5.07	1.19	3,688	2.30	9,086	10,472
Simulation 3: Lower mean of u	4.10	0.26	4,599	0.64	9,205	8,883
B. Simulation 4: (Base B)	5.58	1.43	3,048	3.46	6,770	7,723
Simulation 5: Higher mean of q^o	5.89	1.73	4,083	4.57	7,690	7,503
C. Simulation 6: (Base C)	2.81	0.56	3,709	1.11	9,100	6,068
Simulation 3: Higher S.D. of u	4.10	0.26	4,599	0.64	9,205	8,844

Figure 1. Welfare Effect of a Middleman

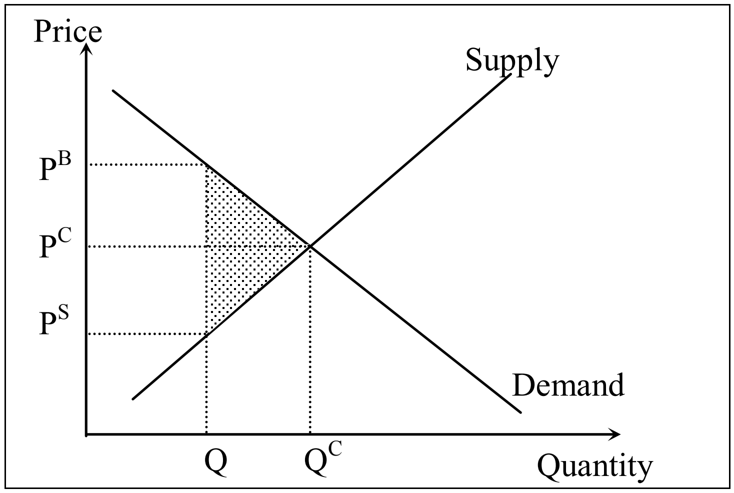
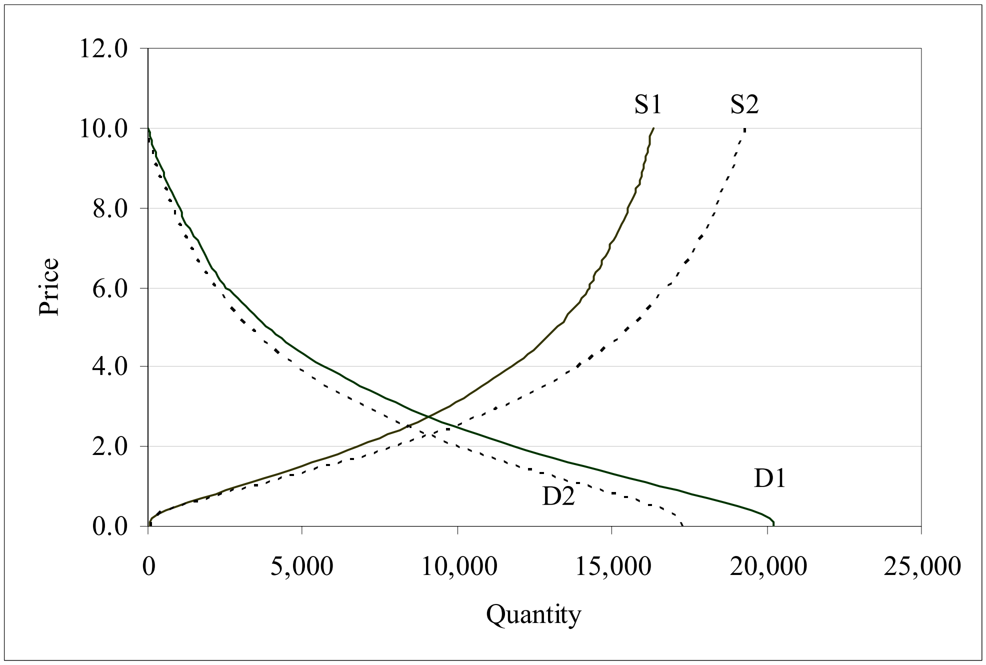
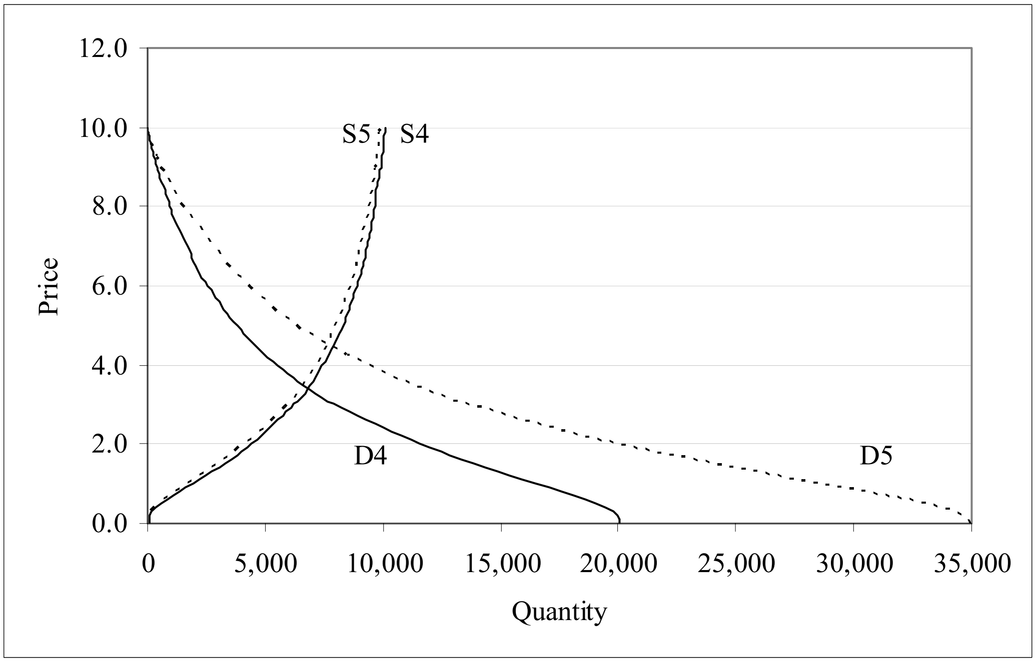


Figure 2. Demand and Supply: Increasing the Mean of q^e



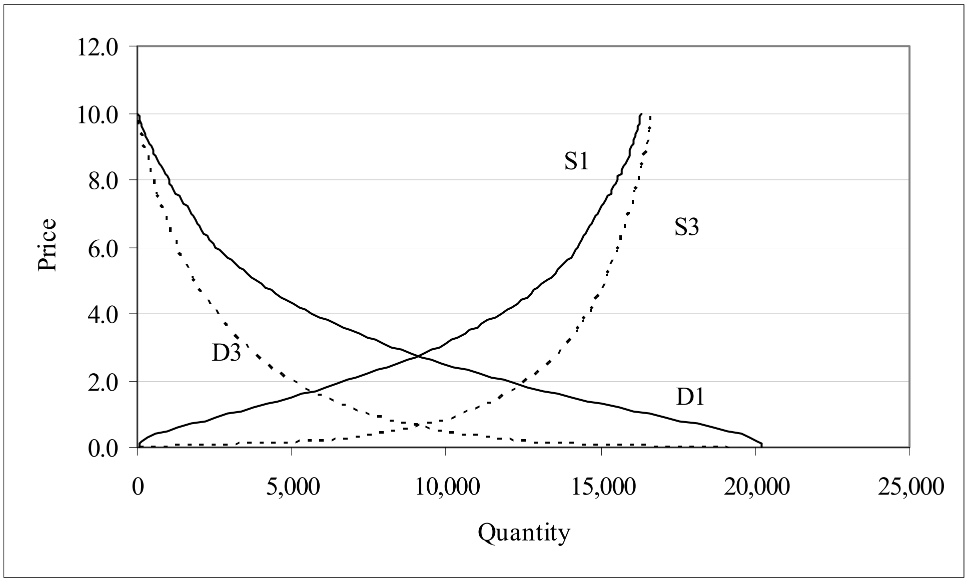
D1, S1: Simulation 1
D2, S2: Simulation 2

Figure 3. Demand and Supply: Increasing the Mean of q^o



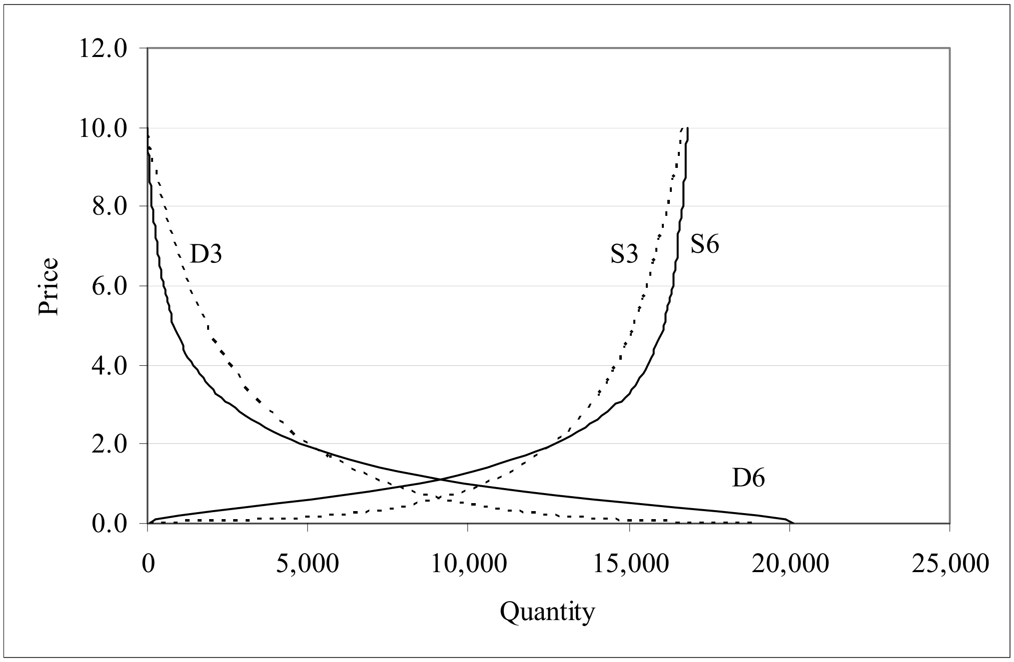
D4, S4: Simulation 4
D5, S5: Simulation 5

Figure 4. Demand and Supply: Lowering the Mean of *u*



D1, S1: Simulation 1
D3, S3: Simulation 3

Figure 5. Demand and Supply: Increasing the Standard Deviation of *u*



D6, S6: Simulation 6
D3, S3: Simulation 3

References

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.

Spulber, Daniel F., 1996, "Market Making by Price Setting Firms," *Review of Economic Studies,* Vol. 63, No. 4 (October), pp. 559–80.