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Subject: **Rationing Rules and Outcomes: The Experience of Singapore's Vehicle Quota System**

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CORRIGENDUM

The following equations were not printed clearly and needs to be printed again.

Page 5, equation (1)

$$\left(\begin{array}{c} \text{Total} \\ \text{motor vehicle} \\ \text{quota} \end{array} \right)_{qv} = g \cdot \left(\begin{array}{c} \text{Motor} \\ \text{vehicle} \\ \text{population} \end{array} \right)_{y-1} + \left(\begin{array}{c} \text{Projected} \\ \text{deregistrations} \end{array} \right)_y + \left(\begin{array}{c} \text{Unallocated} \\ \text{quota} \end{array} \right)_{qv-1} \quad (1)$$

Page 10, equation (2)

$$\left(\begin{array}{c} \text{Category } i \\ \text{quota} \end{array} \right)_{qv} = g \cdot \left(\begin{array}{c} \text{Category } i \\ \text{population} \end{array} \right)_{y-1} + \alpha \cdot \left(\begin{array}{c} \text{Projected} \\ \text{category } i \\ \text{deregistrations} \end{array} \right)_y + \left(\begin{array}{c} \text{Unallocated} \\ \text{category } i \\ \text{quota} \end{array} \right)_{qv-1} \quad (2)$$

Page 11, equations (3) and (4)

$$\left(\begin{array}{c} \text{Category 7} \\ \text{quota} \end{array} \right)_{qv} = (1 - \alpha) \left(\begin{array}{c} \text{Projected} \\ \text{total} \\ \text{deregistrations} \end{array} \right)_y \quad (3)$$

$$\begin{aligned} V_{i1} &= gQ_{i0} + \alpha R_{i1} = (g + \alpha\delta_i)Q_{i0} \\ V_{7,1} &= (1 - \alpha)R_1 \end{aligned} \tag{4}$$

Page 17, equation (8)

$$\begin{aligned} L_1^T &= F^{-1} \left(1 - \frac{V_1}{N_1} \right) \\ L_0^T = L_2^T &= G^{-1} \left(1 - \frac{V_2 + V_0}{N_2} \right) \end{aligned} \tag{5}$$

Page 19, equation (12)

$$L_0^{NT} = G^{-1} \left(1 - \frac{V_0}{N_2 - V_2} \right) \tag{6}$$

(The quota year starts in May.) Since the change in the total motor vehicle population is given by the number of new registrations minus the number of deregistrations, and any unallocated quota in a given year may be carried over to the following year, the quota formula is as follows:

$$\left(\begin{array}{c} \text{Total} \\ \text{motor vehicle} \\ \text{quota} \end{array} \right)_{qy} = g \cdot \left(\begin{array}{c} \text{Motor} \\ \text{vehicle} \\ \text{population} \end{array} \right)_{y-1} + \left(\begin{array}{c} \text{Projected} \\ \text{deregistrations} \end{array} \right)_y + \left(\begin{array}{c} \text{Unallocated} \\ \text{quota} \end{array} \right)_{qy-1}. \quad (1)$$

Each year, the quota is set to allow for a targeted g percent growth in the total motor vehicle population, plus additional quota licenses to cover the number of motor vehicles that will be deregistered during the (calendar) year, plus any unallocated quota licenses from the previous quota year. The rate of growth, g , was initially fixed at 4.3 percent, then reduced to 3 percent. In the formula above, the subscript y denotes calendar year and the subscript qy denotes quota year (which runs from May to April). Initially, projected deregistrations for (calendar) year y were simply taken to be equal to actual deregistrations in $y-1$ but from quota year 1999–2000 onwards, the authorities have employed a formula to project the number of deregistrations in year y . The formula is not disclosed; only the result is published.

At the beginning of each month, approximately one-twelfth of the quota is auctioned to the public. Prospective motor vehicle buyers have to obtain a quota license in the appropriate category before they are allowed to make their purchase. Any unallocated licenses are added to the quota in the next auction.

The quota licenses are sold through sealed-bid, uniform price auctions. Each individual is allowed to submit only one bid. Each bidder is required to leave a deposit equal to half his bid amount. The minimum bid is \$1, and bids must be in multiples of \$1.⁸ Successful bidders pay the lowest winning bid; the difference between the quota premium and the deposit amount is due at the time of registration of the motor vehicle. (If the deposit exceeds the quota premium, the difference is applied toward the buyer's registration fees). Unsuccessful bidders are refunded their deposits.

Initially, the government planned to hold quarterly auctions of quota licenses: the first auction took place in April 1990 and the quota licenses issued during that auction were valid for six months from May 1990 to October 1990, i.e., they had to be used to register a new motor vehicle within that time period. Hence, the quota system is considered to have taken effect from May 1990. After the first auction, the frequency of the auctions was increased to once a month, and the validity period of the quota license shortened to three months. In

⁸ References to \$ are to Singapore dollars. The average exchange rate per US\$1 was:

1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
1.81	1.73	1.63	1.62	1.53	1.42	1.41	1.48	1.67	1.69	1.72

October 1991, the validity period of the quota license for certain categories was lengthened to six months (see Section V below).

The quota license has a life span of ten years. At the end of this period, the motor vehicle owner may either deregister the vehicle—export it or scrap it—or renew the license for a further five or ten years by paying what is called the “prevailing quota premium”.⁹ If the motor vehicle is sold (within the country) before the expiry of its quota license, the quota license will be transferred to the buyer together with the vehicle; the seller will have to bid for a new quota license if he wishes to purchase a new vehicle. If a motor vehicle is deregistered before the expiry of the quota license, the owner is entitled to a rebate on the quota premium paid, pro-rated to the remaining life span of the license.

Under the VQS, motor vehicles are divided into several different categories, with a separate quota for each category. Prior to May 1999, there were seven quota categories:

- Category 1: Small cars with engine capacity of 1,000 c.c. and below;
- Category 2: Medium-sized cars with engine capacity of 1,001 to 1,600 c.c., and taxis;
- Category 3: Large cars with engine capacity of 1,601 to 2,000 c.c.;
- Category 4: Luxury cars with engine capacity of 2,001 c.c. and above;
- Category 5: Goods vehicles and buses;
- Category 6: Motorcycles and scooters; and
- Category 7: “Open”.

Category 7 (“open”) quota licenses may be used to purchase any type of motor vehicle.¹⁰ In May 1999, the number of categories was reduced to five: categories 1 and 2 were merged and redesignated category A; categories 3 and 4 were merged and redesignated category B; and categories 5, 6, and 7 were renamed categories C, D, and E respectively. Subcategorization is discussed further in Section IV.

III. AUCTION OUTCOMES: PRELIMINARY EVIDENCE

Has the VQS been successful in controlling the rate of motor vehicle growth? The average annual motor vehicle growth rate during 1975–89 (prior to the introduction of the VQS) was 4.4 percent, with a standard deviation of 4.24 percent. The average annual motor vehicle growth rate during 1990–99 (under the VQS) was 2.9 percent, with a standard

⁹ The prevailing quota premium for a given quota category is computed as a three-month moving average of the quota premium of that category. (Prior to November 1998, a twelve-month moving average was used.)

¹⁰ Bidders of motorcycles in the open category paid one third of the quota premium in that category.

equilibrium allocation of category 1 and 2 licenses under competitive market conditions, subject to the total quota, V . Denote these equilibrium quantities as q_1 and q_2 respectively, and the equilibrium quota premium as L . This is illustrated in Figure 2 where the number of category 1 cars is measured rightward from the O_1 axis and the number of category 2 cars is measured leftward from the O_2 axis, where the distance between O_1 and O_2 is V .

But will small car buyers necessarily be squeezed out of the market in the absence of subcategorization? Clearly, if $D_1(Q_1) - P_1$ is very low relative to $D_2(Q_2) - P_2$, then q_1 will be very small relative to q_2 ; at the extreme, a corner solution could obtain whereby $q_2 = V$ and $q_1 = 0$. To be sure, one would expect that at any given quantity, the inverse demand function for small cars will be lower than that for large cars, i.e., $D_1(Q_1) < D_2(Q_2)$, since one can think of large cars as being of a higher quality (or providing more "services") than small cars.¹⁴ But one would also expect that the world price of small cars will be lower than the price of large cars, i.e., $P_1 < P_2$. Hence, a priori there would be no reason to expect $D_1(Q_1) - P_1$ to be necessarily lower than $D_2(Q_2) - P_2$, and so no reason to expect q_1 to be necessarily smaller than q_2 . However, it will be true that $L/P_1 > L/P_2$ so the overall quota would be relatively unfair to small car buyers as it would result in a higher tax burden for them compared to large car buyers. By contrast, a fairer outcome could be achieved by subdividing the quota such that: $D_1(Q_1)/P_1 = D_2(Q_2)/P_2$, with $Q_1 + Q_2 = V$. The resulting allocation will be v_1 and v_2 , as shown in Figure 2, such that $L_1 < L_2$ and $L_1/P_1 = L_2/P_2$.

The above analysis assumed no substitution between the two car categories. If substitution is possible, then the equilibrium market allocation of category 1 licenses will be less than q_1 and the equilibrium allocation of category 2 licenses will be greater than q_2 . This is because the overall quota raises the price of small cars relative to large cars, resulting in substitution away from the former toward the latter. In this case, small car buyers are not being squeezed out but are voluntarily upgrading to larger cars. Falvey (1979) analyzes such a case.

A. Categories 1-4: Cars

Has quota subcategorization succeeded in achieving the objective of equity? The data indicate that the answer is no. Figure 3 plots the quota premiums of categories 1, 2, 3, and 4 on the same axis. If subcategorization worked as it should have, the line representing category 1 quota premiums should lie everywhere below the line representing category 2, which should in turn lie everywhere below the line representing category 3, and so on. This is evidently not the case—as can be seen in Figure 3, the lines intersect at several points.

Table 1 shows that of the 106 auctions between May 1990 and April 1999, category 1 premiums ranked the lowest of the four car categories in 86 auctions (81 percent of the time);

¹⁴ Following Swan (1970), the quality of a product may be thought of as the amount of services obtained from its consumption. These services are a homogeneous good with a uniform price. To the extent that two products embody unequal amounts of services, they will differ in quality and hence, in price.

category 2 premiums ranked second lowest in 62 auctions (58 percent of the time); category 3 premiums ranked second highest in 52 auctions (49 percent of the time); and category 4 premiums ranked highest in 57 auctions (54 percent of the time). But the desired outcome of $L_1 < L_2 < L_3 < L_4$ occurred in only 45 of the 106 auctions—in other words, over half of the auctions involved an instance where the quota premium for a smaller car exceeded that of a larger car. In 14 of these cases, category 1 quota licenses cleared at a higher price than category 4 quota licenses;¹⁵ in two instances (the November 1990 auction and the October 1998 auction), category 1 quota licenses were the most expensive of all the categories auctioned.

Even in those instances where the quota premiums for smaller cars turned out to be lower than those for larger cars, the relative tax burden still fell disproportionately more on small car buyers. For example, in January 1992, the quota premium was \$10,100 for category 1 cars; \$16,602 for category 2 cars; \$18,500 for category 3 cars; and \$19,666 for category 4 cars. During that period, the open market value averaged around \$8,500 for category 1 cars; \$13,500 for category 2 cars; \$24,500 for category 3 cars; and \$70,000 for category 4 cars. Thus, the implicit tax rate was approximately 119 percent for category 1 cars; 123 percent for category 2 cars; 75 percent for category 3 cars; and 28 percent for category 4 cars.

These results highlight the pitfalls of subcategorization. In practice, the shape and position of the demand curves are not known with any degree of precision, so that fixing separate quotas for each category becomes a guessing game. As evidenced by the data, over half of the time one or more of the guesses have been off the mark, with the quotas for small and medium sized cars set too low and the quotas for large and luxury cars have been set too high relative to their demands.

B. Category 7: The Open Category

The rationale for the open category was to introduce flexibility in the motor vehicle mix. Quotas for the different categories are based on their proportion in the total motor vehicle population at the end of the previous (calendar) year. It was thought that by allowing a portion of the total quota to be “open”, i.e., usable in any category, there would be some room for deviation from the previous year’s motor vehicle mix based on changes in demand.

In practice, the annual quota for each category is determined as follows:

$$\left(\text{Category } i \text{ quota} \right)_{gy} = g \cdot \left(\text{Category } i \text{ population} \right)_{y-1} + \alpha \cdot \left(\text{Projected category } i \text{ deregistrations} \right)_y + \left(\text{Unallocated category } i \text{ quota} \right)_{gy-1} \quad (2)$$

¹⁵ These 14 cases occurred between May 1990 and November 1998.

for $i = 1, \dots, 6$, where the subscripts y and qy are defined as before. The target growth rate, g , is the same for all categories; as mentioned earlier, it was 4.3 percent initially, later reduced to 3 percent. The parameter, α was initially set at 70 percent but raised to 75 percent in December 1992. So the quota for category i in, say, quota year 1998–99, would have been equal to 3 percent of the number of category i vehicles in December 1997 plus 75 percent of the number of category i vehicles deregistered in 1997 plus any unused category i quota licenses carried over from quota year 1997–98. The annual quota for category 7 is determined as follows:

$$\left(\begin{array}{c} \text{Category 7} \\ \text{quota} \end{array} \right)_{qy} = (1 - \alpha) \left(\begin{array}{c} \text{Projected} \\ \text{total} \\ \text{deregistrations} \end{array} \right)_y \quad (3)$$

where α is defined as above.

The following example illustrates how the quotas evolve over time. Let i denote vehicle category ($i = 1, \dots, 6$); category 7 is the open category. For simplicity, assume that: (i) all quotas are fully utilized every year so there is no carryover; (ii) a fraction δ_i of the previous year's population of category i vehicles is deregistered every year; and (iii) the deregistrations are evenly distributed throughout the year so the quota year is effectively equivalent to a calendar year (denoted by t). Denote quota by V_{it} , deregistrations by R_{it} , and vehicle population by Q_{it} .

The initial (year 1) quotas for the seven license categories will then be:

$$\begin{aligned} V_{i1} &= gQ_{i0} + \alpha R_{i1} = (g + \alpha\delta_i)Q_{i0} \\ V_{7,1} &= (1 - \alpha)R_1 \end{aligned} \quad (4)$$

where $R_1 = \sum_{i=1}^6 R_{i1}$, and g and α are defined as above. The total quota is $V_1 = \sum_{i=1}^6 V_{i1} + V_{7,1}$. Suppose a fraction λ_{it} of the open quota is utilized in category i , where $\sum_{i=1}^6 \lambda_{it} = 1$. Then during year 1, the population of each vehicle category will increase by the following amount:

$$\Delta Q_{i0} = V_{i1} + \lambda_{i1}V_{7,1} - R_{i1} = (g - (1 - \alpha)\delta_i)Q_{i0} + \lambda_{i1}(1 - \alpha)R_1 \quad (5)$$

Hence, the rate of population growth of category i vehicles may be greater or smaller than g , depending on the utilization of open licenses and the rate of deregistrations. Specifically, the rate of population growth for category i is greater than g if $\lambda_{i1}R_1 > R_{i1}$ (i.e., if the number of open category licenses used to register category i vehicles exceeds the number of category i deregistrations) and less than g if $\lambda_{i1}R_1 < R_{i1}$. The rate of total vehicle population growth is equal to g . If there is no open quota ($\alpha = 1$), then the rate of population

growth will be equal to g for all vehicle categories, meaning that the composition of vehicles will remain fixed at the year 0 configuration.

In year 2, the quota for category i will be:

$$V_{i2} = (g + \alpha\delta_i)Q_{i1} = (g + \alpha\delta_i)(Q_{i0} + \Delta Q_{i0}) \quad (6)$$

so the rate of quota increase for category i vehicles will be greater than g if $\lambda_{i1}R_1 > R_{i1}$ and less than g if $\lambda_{i1}R_1 < R_{i1}$. Hence, vehicle categories in which open licenses are heavily used will experience an above-average increase in quota for a given rate of deregistrations; vehicle categories in which open licenses are scarcely used will experience a below-average increase in quota.

But what determines the utilization of the open category licenses, i.e., the λ_{i1} s? Intuitively, one can think of the open quota as being imposed on the aggregate residual demand for quota licenses. Hence, as long as the open quota is not too large, one would expect that its quota premium would be close to the maximum quota premium in the other categories and that it would be used in the categories with the highest quota premiums (i.e., the categories with the most binding quotas). The pricing of open category licenses is considered further in Section V.

Data on the usage of category 7 quota licenses are not published, but data on new registrations indicate that the open licenses have been used mainly to purchase large cars. This is consistent with the information in Table 1 that category 3 or 4 quota premiums were the highest in 87 percent of the auctions.¹⁶ On average during 1990–99, the ratio of new registrations to quota level was 95 percent for category 1, 113 percent for category 2, 195 percent for category 3, and 260 percent for category 4. In other words, the number of new category 3 cars that were actually purchased during that period was almost double the amount set by the category 3 quota and the number of new category 4 cars purchased was over two and a half times the amount set by the category 4 quota. This would have been possible only through the use of the open quota.

The composition of the car population has indeed shifted over the last ten years toward larger cars and away from smaller cars. In 1990, the makeup of the car population was: 15 percent category 1 cars; 67 percent category 2 cars; 14 percent category 3 cars; and

¹⁶ During 1990–99, the correlation coefficients between the quota premiums in category 7 and those in the other categories were as follows:

<u>Category 1</u>	<u>Category 2</u>	<u>Category 3</u>	<u>Category 4</u>	<u>Category 5</u>	<u>Category 6</u>
0.7366	0.9097	0.9627	0.9808	0.9062	0.6456

(The correlation coefficient between category 7 and category 6 takes into account the rule that individuals using a category 7 license to register a category 6 vehicle pay only one-third of the category 7 quota premium.)

However, it is possible that if the open quota, V_0 , is relatively small, it may be insufficient to complete the arbitrage process. Suppose there is a corner solution and all the open licenses are applied toward large cars. Then the quota premiums will not be equalized and:

$$L_1^T = F^{-1} \left(1 - \frac{V_1}{N_1} \right)$$

$$L_0^T = L_2^T = G^{-1} \left(1 - \frac{V_2 + V_0}{N_2} \right)$$
(8)

where $L_2^T > L_1^T$. Hence the quota premiums of categories 1 and 2 (denoted L_1^T and L_2^T respectively) will be negatively related to the restrictiveness of their effective quota (defined as the number of licenses available for buying that car type relative to the number of potential buyers for that car type), and the open quota premium (denoted L_0^T) will be equal to the highest (category 2) quota premium. In practice, this is the outcome that is usually observed.

Now consider what happens when category 1 and 2 licenses are nontransferable but the open category is transferable. This means that individuals who purchased category 1 or 2 licenses in period 1 may not resell them in period 2, but individuals who purchased open licenses may do so. As usual, the problem is solved backward, beginning with period 2. In period 2, V_1 category 1 licenses and V_2 category 2 licenses have already been sold so holders of those licenses are effectively out of the market. The equilibrium interior solution for the open quota premium will be such that:

$$(N_1 - V_1)[1 - F(L_0^{NT})] + (N_2 - V_2)[1 - G(L_0^{NT})] = V_0$$
(9)

The above expression implicitly defines L_0^{NT} , the equilibrium open quota premium under nontransferability. Note that all else constant, L_0^{NT} is higher the smaller is the open quota, V_0 .

In period 1, individuals purchase category 1 and 2 licenses before knowing their true valuations. In the absence of open quota, since all small car buyers are identical ex ante, they will all be willing to pay the same amount for a category 1 license, namely $E(w_1)$. But if there are open licenses available then a potential small car buyer has the option of either buying a category 1 license in period 1 or buying an open license in either period 1 or period 2. If he purchases a category 1 license, he cannot resell it in period 2 if his realization turns out to be low; his expected surplus from this option is thus $E(w_1) - L_1^{NT}$, where L_1^{NT} denotes the nontransferable category 1 license price. But if he purchases an open license, he will use the license only if his realization turns out to be high (i.e., above L_0^{NT}) and he will resell the license if his realization turns out to be low (i.e., below L_0^{NT}); his expected surplus from this

option is thus $\int_{L_0^{NT}}^{\bar{w}_1} (w_1 - L_0^{NT}) f(w_1) dw_1$. Equating the expected surplus from the two options yields the equilibrium nontransferable category 1 license price:

$$L_1^{NT} = E(w_1) - \int_{L_0^{NT}}^{\bar{w}_1} (w_1 - L_0^{NT}) f(w_1) dw_1 \quad (10)$$

Note that $L_1^{NT} \leq E(w_1)$, so the nontransferable category 1 license price will be lower in presence of the open quota than without the open quota. Furthermore, note that $L_1^{NT} \leq L_0^{NT}$, so the transferable open category license will be more expensive than the nontransferable category 1 license.²³ Intuitively, this may be understood by noting that if the individual purchases a nontransferable category 1 license, his actual surplus may be positive (if his realization turns out to be above L_1^{NT}) or negative (if his realization turns out to be below L_1^{NT}), but if he purchases an open license, his actual surplus cannot be negative since he can always resell the license if his realization turns out to be below L_0^{NT} . Thus in order for him to be indifferent between the two options, the transferable open license will have to cost more than the nontransferable category 1 license.

The same reasoning holds for potential large car buyers, so:

$$L_2^{NT} = E(w_2) - \int_{L_0^{NT}}^{\bar{w}_2} (w_2 - L_0^{NT}) f(w_2) dw_2 \quad (11)$$

where $L_2^{NT} \leq E(w_2)$ and $L_2^{NT} \leq L_0^{NT}$

What if there is a corner solution? Again, suppose that all the open licenses are applied toward large cars. Then the open quota premium under nontransferability will be:

²³ To see this, subtract L_0^{NT} from both sides of the expression for L_1^{NT} :

$$\begin{aligned} L_1^{NT} - L_0^{NT} &= \int_{\underline{w}_1}^{\bar{w}_1} w_1 f(w_1) dw_1 - \int_{L_0^{NT}}^{\bar{w}_1} (w_1 - L_0^{NT}) f(w_1) dw_1 - \int_{\underline{w}_1}^{\bar{w}_1} L_0^{NT} f(w_1) dw_1 \\ &= \int_{\underline{w}_1}^{L_0^{NT}} (w_1 - L_0^{NT}) f(w_1) dw_1 \leq 0. \end{aligned}$$

$$L_0^{NT} = G^{-1} \left(1 - \frac{V_0}{N_2 - V_2} \right) \quad (12)$$

In this case, potential small car buyers know that there will not be any open licenses available for them, so they will bid $E(w_1)$ for category 1 licenses. Potential large car buyers will bid L_2^{NT} as given above. Hence, $L_1^{NT} < L_2^{NT} \leq L_0^{NT}$.

Comparing L_1^{NT} with L_1^T and L_2^{NT} with L_2^T shows that the transferability premium depends on the effective quota for that category (i.e., the quota for that category plus any open licenses that are used in that category). If the effective quota is very restrictive relative to demand, then the transferability premium is positive but if the effective quota is not very restrictive relative to demand, then the transferability premium may be negative.²⁴ For the open category, the open quota premium will be equal to the maximum of the category 1 and category 2 quota premiums under transferability (assuming incomplete arbitrage), but should exceed the maximum under nontransferability.

B. Empirical Analysis

Did the switch to nontransferability lower license prices in the affected categories? Casual observation of Figure 1 suggests that nontransferability raised rather than lowered the quota premiums in categories 1 through 4. According to the model above, this would imply that the effective quotas for those categories were not restrictive. However, there are other factors that may have affected the quota premiums such as the supply of quota licenses and demand shifts that were unrelated to nontransferability (possible factors may include income growth and road infrastructure development, among others). In fact, Figure 1 shows that the quota premiums for category 5 (which remained transferable throughout) were also higher after the third quarter of 1991.

In an earlier study, Koh and Lee (1993) estimate the impact of nontransferability on the quota premium by regressing the quota premium on a dummy variable for transferability and other variables such as the ratio of bids received to successful bids and the bid range, for categories 1, 2, 3, and 4 separately. They find that nontransferability was associated with a lower quota premium in category 1; had no significant effect in category 2; and was associated with a higher quota premium in categories 3 and 4.

This paper takes a different approach by looking at license prices in categories 1, 2, 3, and 4 relative to category 5. The rationale for doing this is to control for any exogenous

²⁴ Krishna and Tan (1998) show that relaxing the assumptions to allow for bidders' valuations to depend on the restrictiveness of the quota or to allow for heterogeneous bidders does not change the flavor of the basic result.

demand-shift factors that were common to all motor vehicles.²⁵ Category 5 was chosen as a base because it was not affected by the regime switch.²⁶

The regressions were based on the following very simple model. Denote the relative demand for category i licenses by: $D_{it} = D(L_{it}/L_{5t}, B_{it}/B_{5t}, Dummy)$ where L_{it} denotes the license price (in Singapore dollars) of category i at time t ; B_{it} denotes a demand shift parameter, such as the number of bids for category i licenses at time t ; and the dummy variable is equal to 0 for the transferability period (1990:9 to 1991:9) and 1 for the nontransferability period (1991:10 to 1999:04).²⁷ The relative demand for category i licenses should be negatively related to the relative price of category i licenses and positively related to the relative number of bids for category i licenses, but could be positively or negatively related to the dummy variable.²⁸ On the supply side, denote the relative quota of category i licenses by V_{it}/V_{5t} . Setting demand equal to supply in equilibrium yields a reduced form such as the following:

$$\ln(L_{it} / L_{5t}) = \beta_0 + \beta_1 Dummy_t + \beta_2 \ln(V_{it} / V_{5t}) + \beta_3 \ln(B_{it} / B_{5t}) + \varepsilon_{it}. \quad (13)$$

The log transformation was used as a means of removing growth over time of the variance of the data. Separate regressions were run for categories 1, 2, 3, and 4, using monthly auction data from September 1990 to April 1999.

If the switch to nontransferability had the desired effect, the estimated coefficient on the dummy variable, β_1 , should be negative and significant. The coefficient β_2 is expected to

²⁵ The assumption here is that the fundamentals driving the premium for category 5 are the same as those driving the premiums for categories 1 to 4. Robustness checks indicate that this is not unreasonable: the license price paths of categories 1 to 5 are quite closely related to movements in domestic asset prices in general (i.e., the stock market index).

²⁶ Also, one can reasonably assume no substitution effects between category 5 (goods vehicles and buses) and category 1–4 (cars). Category 7—the open category—was also unaffected by the regime switch, but as argued above, the quota premium for category 7 is determined jointly with the quota premiums of the other categories, so the inverse demand relative to category 7 would be harder to interpret.

²⁷ It is possible that transferability/nontransferability affects not only the intercept of the demand function but also the slopes. However, the data are insufficient to allow for this (there are only 14 observations during the transferable period).

²⁸ One may argue that the open market value of category i cars relative to category 5 vehicles should also be included as an independent variable in the inverse demand function for category i licenses. Unfortunately, while some information is available on these values, no consistent data series exists. This omission is not too serious if the world prices of the different categories of vehicles move in tandem so that their relative prices do not change much over time.