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Expectations Formation and Forecasting of Vehicle Demand: An Empirical Study of the Vehicle Quota Auctions in Singapore*

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Abstract

This paper studies the expectations formation and forecasting of vehicle demand in Singapore under the vehicle quota system. Under the system, a car buyer must first bid for a vehicle license in monthly auctions in order to purchase a new car. We construct an econometric model to test the hypothesis that past bid distributions of the license auctions contain information that car buyers can use to update their expectations about the intensity of market demand, forecast the license premiums and formulate their bidding strategies in future auctions. Our empirical analysis indicates that past bid distributions have a good degree of predictive power for the license premiums.

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1. Introduction

Auctions are used in the allocation of a wide variety of goods and services, including treasury bills, art and antiques, oil drill leases, fishing rights, houses, agricultural produce, radio spectrum and 3G mobile phone licenses. In the case of Singapore, monthly auctions of quota licenses have been conducted since May 1990 to allocate the rights to own motor vehicles. Governments also frequently procure supplies and services through tenders and award contracts to the lowest-cost bidder. Most auctions are also not one-off affairs. In fact, like the vehicle quota license auctions in Singapore, many auctions take place regularly and involve the sale of multiple units of the same object. Other examples of repeated auctions with multiple units of identical or closely substitutable objects are auctions of flowers (e.g. in The Netherlands), wine auctions (e.g. in France and California, USA), auctions of real estate properties (e.g. New Zealand) as well as Treasury bills (e.g. in USA) and initial public offerings (e.g. Taiwan). Many participants in these auctions interact repeatedly, and new players may enter the auctions while other players leave.

In all these auctions, bidders must form expectations about the market demand for the objects to be allocated, the consequent competition that they will face in the auction, as well as forecast the winning bids. Although the underlying economic conditions fluctuate over time and the set of participants in each auction may vary, participants in these repeated auctions can often gather useful information from the bid distributions and winning bids of preceding auctions. Based on this information, they will update their beliefs about current and future market demands, the competition they face, as well as revise their expectations about the valuation of the objects to be allocated.

A rich theoretical literature on auctions, developed since the 1980s (see Klemperer (1999) for a recent survey), had furthered our knowledge of the optimal design of auctions, the properties of different auction formats and their welfare implications, the strategic interactions between auction participants and the optimal bidding strategies they will use to compete effectively. In particular, Milgrom and Weber, (1982) has shown that when bidders'

valuations are affiliated,[1] it is in the interest of the seller to make available as much relevant information as possible before each auction, as this is likely to raise expected proceeds from the auction, as bidders utilize the information optimally in formulating their expectations.

In the context of repeated affiliated-value auctions such as Singapore's vehicle license auction, the bid distributions of previous auctions contain useful information about bidders' expectations about market demands and trends. This information could still be relevant in future license auctions, particularly if they point to a trend in the demand for new vehicles. While the theory behind affiliated-value auctions is well established, and experimental research have illuminated the strategic aspects of these type of auctions and the "winners' curse" phenomenon (see for instance, Kagel and Levin (1986), Levin, Kagel and Richard (1996)), there have been few empirical studies on the expectation formation process and the use of past bid distributions in forecasting market demand and the market-clearing bids. This provides the motivation for this paper, which aims to study the expectations formation process and the forecasting of vehicle demand under Singapore's vehicle quota license auction, which is an example a repeated multiple-object uniform price auction with a second-price bidding format.

Our objective in this paper is to study how car buyers, or more commonly, distributors acting on behalf of car buyers, bid for the licenses and whether it is possible to forecast quota license premiums (i.e. the lowest successful bids) with good accuracy and improve one's success of securing a vehicle license. To our knowledge, the present study is the only one of its kind in forecasting vehicle demand in the setting of a quota license auction.

Our study focuses on the period from September 1994 to December 1997 (altogether 40 auctions), when data on the bid distributions for the sealed-bid auction format was available. The sealed-bid auction format in Singapore' vehicle license auction offers us a unique opportunity to study the expectations formation and demand-forecasting game as

[1] Roughly speaking, bidders' private information or signals are affiliated if a high value of one bidder's signal makes high values of other bidders' signals more likely.

participants in the repeated auctions use bid distributions of previous auctions to update their valuations and predict future license premiums.[2]

Under the current online-open bid format (since May 2002), each license auction takes place over three days at the beginning and middle of each calendar month, and bidders can see, in real time, the market clearing bids at each point in time before the auction closes. Bidders can update their valuations in real time, enter or drop out of the auction, or revise their bids. However, bidders with valuations lower than the market clearing bids will not enter the license auction. Thus, the bid distributions for an open auction format are necessarily truncated distributions since they do not capture the data from the participants who did not enter the auction. Understanding the expectations formation and demand-forecasting process in the open-bidding auction is a much more challenging task.

Our analysis is as follows. We construct an econometric model to test the hypothesis that in Singapore's vehicle license auction, past bid distributions contain significant information that bidders can use to revise their expectations about the intensity of market demand (as measured by the ratio of available monthly quota over the number of bidders participating in the auction), forecast the quota license premiums and formulate their bidding strategies. The results of our econometric analysis support this hypothesis. Specifically, we found that the mean, variance and ratio of quota over number of submitted bids of past bid distributions have a good degree of predictive power for quota license premiums.

The plan for the rest of this paper is as follows. Section 2 provides a brief description of the main features of Singapore's Vehicle Quota System. In Section 3, we discuss the main elements of game-theoretic modeling of the vehicle quota license auctions. This forms the basis for the construction of an econometric model in Section 4 to study the expectations formation and demand forecasting process in the vehicle license auction. While our econometric model is applied to the vehicle license auctions in Singapore, the methodology of

[2] Although data from January 1998 to June 2001 are available, we have chosen not to include them in the study, for the reasons that we discussed in Section 4.

our model is broadly applicable to auctions of other types of goods in a sealed-bid format. We conclude our study in Section 5 with a discussion and comments on future research.

2. Singapore's Vehicle Quota System

The Vehicle Quota System ("VQS") was implemented in May 1990 to complement existing fiscal tax measures to control the growth in vehicle population. Under the VQS, each car buyer must first bid for a vehicle quota license – officially referred to as the Certificate of Entitlement (or more commonly, COE). Each quota license allows a vehicle to be on the road for ten years. At the end of this period, the owner may either de-register the vehicle or renew the license for a further five-year or ten-year period, by paying a "prevailing quota license premium". Over the past decade, there have been a number of studies that assessed the mechanics, equity and efficiency of the VQS (among them, Phang (1993), Koh and Lee (1994), Chin and Smith (1997), Chu (1998, 2002), Chu and Goh (1997), Toh and Phang (1997), Tan (2001), and Koh (2003)).

Until June 2001, the allocation of vehicle quotas licenses was conducted via a sealed-bid auction where successful bidders pay the lowest successful bid.[3] Following a government review of the VQS, the auction format switched to an online open-bid format in several phases, beginning in June 2001. Since May 2002, there are two auctions conducted twice a month (the beginning and the middle of the month). The bidding is carried out online, at the website of the Land Transport Authority of Singapore ("LTA"), at http://www.lta.gov.sg.

Every quota year (beginning in May), the quota for new motor vehicles is determined in accordance with a targeted rate of growth in the motor vehicle population, and taking into account the projected de-registration of vehicles. At present, the LTA releases on its website the exact calculations for the target vehicle population and the number of vehicle quota

[3] When there are many participants in the auctions, the distribution of bids is approximately continuous, so that the lowest successful bid will be close to the highest rejected bid. Hence, the vehicle quota license auction is approximately a second-price auction format.

licenses available for auction each month. The projected quota for each category is allocated almost equally over twelve months.

Motor vehicles are classified into several categories under the VQS, with a separate license quota for each category. Prior to 1999, there were seven quota categories.[4] To allow changes in consumer tastes to influence the composition of the vehicle population over time, 25% of the deregistered vehicles in each category are allotted to an "Open" category, where the quota licenses can be used to register motor vehicles belonging to any of the quota categories. "Open" category licenses are transferable once. Beginning in July 2001, bidding for quota licenses shifted gradually from a sealed-bid format to an on-line open-bid format.

In each quota license auction, each bidder is allowed to submit only one bid in one category, and must furnish a deposit equal to half the bid amount. Successful bidders pay the lowest winning bid, and must pay the difference between the winning bid and their deposit at the time of the registration of the vehicle. Although the license auctions are over-subscribed (with one exception, to be discussed in Section 4.1), not all the quota licenses are allocated in each auction. This is because there is no tie-breaking procedure for identical bids at the cutoff level. These bids are treated as unsuccessful bids, and the license premium for the auction is the next higher bid. The unallocated licenses are carried over to the next monthly auction in the same category.

As originally conceived, each car buyer is supposed to bid for a quota license directly and then places an order for a car when a license is obtained. In practice, it is the car distributors that bid for the licenses on behalf of car buyers, since car distributors typically

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[4] When the VQS was first introduced in 1990, there were 7 categories; these are: Category 1 for cars of 1000 cc and below; Category 2 for cars of 1001-1600 cc and below, and taxis; Category 3 for cars of 1601-2000 cc and below; Category 4 for cars above 2000 cc; Category 5 for goods vehicles and buses; Category 6 for motorcycles; Category 7, an "Open" category for registration of all types of vehicles. An eighth category for "weekend cars" was introduced in May 1991, but discontinued in September 1994. In May 1999, Categories 1 and 2 were merged into one category, as was the case for Categories 3 and 4. The other categories were unchanged.

offer bundled packages where the quoted car price already includes a "subsidized" quota license, sometimes with provisions to raise the car price if there are substantial fluctuations in the license premiums. These pricing policies discriminate against buyers who obtain quota licenses on their own, rather than through the distributors. In fact, some car distributors would not entertain car buyers who attempt to bid and obtain quota licenses on their own.

3. Modeling the Vehicle License Auction

To provide the setting for the econometric model we shall use in this study, we first discuss the main elements of game-theoretic models of the vehicle license auctions.[5] The vehicle license auction is an example of an affiliated-values repeated multiple-object auction (for a precise definition of affiliated values, see Milgrom and Weber (1982)). Therefore, the valuations of bidders and the sealed bids that they submit have a common-value element. The participants in these auctions form expectations about the intensity of demand in each auction. The objective is to submit bids higher than the forecast quota license premiums.

Consider the demand problem from the perspective of car distributors. We note that in practice, car distributors typically act on behalf of car buyers to bid for quota licenses. As car distributors share a common objective to generate sales while minimizing cost of operations (particularly if they had to offer bundled packages with "guaranteed" quota licenses), their valuations of the quota licenses – and the bids they submit as a result – will be affected by each other's expectations. More generally, for all bidders in the license auction, their valuations of licenses will be influenced by the intensity of market demand in the current auction, as well as by the anticipated demands in future auctions. Finally, to the extent that car buyers can choose the timing of their car purchases, the quota licenses in different

[5] Formal game-theoretic models of Singapore's vehicle quota license auctions can be found in Koh and Lee (1994), Tan (2001) and Koh (2003). Each of these studies focuses on a different aspect of the vehicle quota license auction, and formulates different models to address the issues. In particular, Koh (2003) constructed a model to study the impact of the vehicle quota system on the market competition in the car distributorship industry.

auctions are substitutable; hence, bidders' valuations and their resultant demands in each license auction would be influenced by the license premiums in earlier auctions. Since bidders also have the option not to participate in the current auction but in future auctions, their valuations in the current auction will be affected by their expectations and forecasts of future license premiums, as well as their beliefs regarding the expectations of rival bidders concerning future market demands. Finally, the beliefs and forecasts of the auction participants may be based on both public and private information.

In summary, each bidder will possess private information that influences his expectations of market demand and his valuation of the vehicle licenses. He may also acquire additional information, as well as use the relevant public information to revise his valuations and formulate his bidding strategy. Specifically, for the prospective car buyer, the private information will include the stream of utilities he can derive from owning and using a passenger car. He may also have some private information regarding future car demand. For the company executive, his private information will include the vehicle's contribution to the company's business operations, as well as his expectations of future demand for licenses, etc. For car distributors, the private information that affects their valuations would include the companies' profit margins, the competition's car pricing policies, and forecasts of future car demand. For a speculator who bids in the "Open" category, and who is only interested in reselling the quota license in the secondary market, the private information would include the level of demand for "Open" category transferable licenses as well as his forecasts of secondary market prices. Finally, if a bidder decides to bid for a non-transferable quota license in a specific category, rather than buy a transferable ("Open" category) license, the bidder's private information would include his forecast about the license premiums in the resale market for Open category licenses.

Besides private information, auction participants have access to public information (e.g. news reports about economic outlook, announcements of changes in government policies, etc) that may also affect their expectations about market demand and valuations of

the licenses. For instance, the number of quota licenses available in each auction is public knowledge, since this is determined a year in advance and made public on the website of the LTA. Changes in future license quotas will lead to revision in the expectations of future quota premiums, and this will affect bidders' decision to participate in a particular auction – either postponing participation or bringing forward the participation. Auction participants can also evaluate the bid distributions of previous auctions, which are made available by the LTA, to learn about the valuations of other bidders. Such ex-post public information regarding competition in the license auctions may provide useful information about the competition in subsequent auctions, particularly if it points to a market trend. Another piece of public that may be relevant is the price of "Open" category quota licenses in the secondary market.

Conditional on the public information and their private information, each bidder forms expectations about the intensity of demand, calculates his valuations for the quota licenses in the current auction, and formulates his bidding strategies accordingly. It is well-established in auction theory that Nash equilibrium bidding strategies exist for auction games with affiliated valuations: each player's optimal strategy is to bid as if as he is the marginal successful bidder (see, for instance, Milgrom and Weber (1982), Koh and Lee (1994) and Klemperer (1999)), based on his beliefs and expectations of market demand. For our study, the practical implication of the Nash equilibrium bidding strategy in Singapore's market for new motor vehicles is that bidders in the vehicle license auction will try to forecast the winning bid and bid higher than the forecast bid. Furthermore, bidders will optimally use the information contained in previous bid distributions to form their expectations about car demand and the degree of competition in the current auction (specifically, the number of bidders, as well as the expected value of the rivals' bids) in order to forecast the license premium (i.e. the lowest successful bid).

4. Econometric Analysis

In this section, we present an econometric model to study the expectations formation and demand forecasting process in Singapore's vehicle license auctions. In particular, we seek to understand whether it is possible to forecast the intensity of market demand as well as the quota license premiums in each auction, utilizing the information contained in previous license auctions. If there are significant learning effects, the informational content of bid distributions will have a high degree of predictive power for future car demands and the quota license premiums.

The following notations will be used in our econometric model: P_t = quota license premium (i.e. the lowest successful bid), Q_t = available licenses in the quota, and B_t = number of bids submitted. For a randomly selected participant in the license auction (which, in our sample, was conducted on a monthly basis), we denote his bid by $\tilde{P}_t$. Since each bidder cannot observe the bids of other participants in the sealed-bid auction, each bidder may consider his bid $\tilde{P}_t$ as a random variable with mean μ_t and variance σ_t^2. We allow μ_t and variance σ_t^2 to vary over time, in order to reflect changes in the bidding strategies of existing participants (say, in response to new public information or new private information) or the participation of new bidders in the license auctions, as well as changing demand conditions.

As the number of successful bids is fixed at Q_t, the available monthly quota, we define $R_t = Q_t / B_t$ as the quota-bid ratio. This measures the market demand for vehicles and the resultant degree of competition in the current auction. Figure 1 in the Appendix shows the inverse of the quota-bid ratio (i.e. $1/R_t = B_t / Q_t$) for the four passenger car categories (Categories 1 to 4) and the Open Category (Category 7). It is clear from Figure 1 that the bid-quota ratios are volatile, and appear to be correlated across different categories. Also, the bid-quota ratios are generally above 100%, indicating oversubscription in the license auctions.

By construction, the probability of successfully obtaining a vehicle license is given by

$$\Pr\left(\tilde{P}_t \geq P_t\right) = \frac{Q_t}{B_t} = R_t \tag{1}$$

For our analysis, we shall assume that the standardized bid, $(\tilde{P}_t - \mu_t)/\sigma_t$, has a distribution function $F(\,.\,)$. Therefore, we obtain the following relationship:

$$\begin{aligned} \Pr\left(\tilde{P}_t < P_t\right) &= \Pr\left(\frac{\tilde{P}_t - \mu_t}{\sigma_t} < \frac{P_t - \mu_t}{\sigma_t}\right) \\ &= F\left(\frac{P_t - \mu_t}{\sigma_t}\right) = 1 - R_t \end{aligned} \tag{2}$$

Taking the inverse transformation, we obtain

$$\frac{P_t - \mu_t}{\sigma_t} = F^{-1}(1 - R_t) \tag{3}$$

so that

$$P_t = \mu_t + \sigma_t F^{-1}(1 - R_t) \tag{4}$$

The expression in (4) shows that the market-clearing quota license premium depends on (i) the mean μ_t and variance σ_t^2 of the distribution of the submitted bids, (ii) the distribution function $F(\,.\,)$, and finally (iii) the quota-bid ratio R_t, which reflects the intensity of market demand in each quota license auction.

As the various quantities in the econometric model are not observable *ex-ante*, our approach is to use proxies in its empirical estimation. Firstly, we approximate $F^{-1}(\,.\,)$ by a low-order polynomial. For our purpose, it suffices to approximate $F^{-1}(1 - R_t)$ by a quadratic function in R_t.[6] Secondly, we use R_{t-1} as the proxy for R_t. This is in line with our theoretical hypothesis that bidders would use the bid distributions of previous auctions in formulating their expectations and beliefs in future auctions. Thirdly, we assume that the mean μ_t of the bid distribution in the current auction is the quota license premium in the preceding auction, i.e., $\mu_t = P_{t-1}$. This is a practical assumption and corresponds to the situation where each bidder believes that expected value of the rivals' submitted bids is the quota license premium

[6] Note that this approximation is local to the sample data that we consider in our study.

of the preceding auction.[7] Finally, we use the moving average of the standard deviation of the bid distributions of the three preceding auctions, denoted by $\sigma^*_{t-1} = (\sigma_{t-1} + \sigma_{t-2} + \sigma_{t-3})/3$, as the proxy for σ_t. The choice of σ^*_{t-1} is to smooth out the effect of fluctuations in the bid distributions caused by the participation of speculators who submit random bids to try their luck and other short-term market perturbations.[8]

With these assumptions and proxy measures in mind for the estimation process, we will consider the following regression equation[9]

$$P_t - P_{t-1} = \beta_0 + \beta_1 \sigma^*_{t-1} R_{t-1} + \beta_2 \sigma^*_{t-1} R^2_{t-1} \tag{5}$$

Thus, we obtain an econometric model with the first-order price differences $(P_t - P_{t-1})$ as the dependent variable.

Our preliminary data analysis indicates that the data series of the quota license premiums P_t for all the quota license categories possess a unit root and are therefore non-stationary. The non-stationary property of P_t is not surprising, since the vehicle quota system has undergone different policy changes and the underlying economic environments have also changed significantly between May 1990 and December 1997. By contrast, we have found that the data series of the price differences $(P_t - P_{t-1})$ are stationary. (The details will be given in Section 4.2.) Hence, for the purpose of uncovering the learning and expectations formation processes in the quota license auctions, our approach of modeling the price difference of the license is appropriate.

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[7] For Categories 1 and 7, which we will discuss in Section 4.2, the correlations between μ_t and P_{t-1} are 0.93 and 0.91, respectively. Thus, this assumption is justified statistically.

[8] Other moving-average orders have been considered in the empirical analysis. The three-month moving average, however, provides the best results for the regression analysis.

[9] Note that an explanatory variable σ^*_{t-1} may be included in the regression due to the constant term in the quadratic approximation of $F^{-1}(\,.\,)$. However, the variable σ^*_{t-1} has been found to be statistically insignificant, due the presence of multicollinearity, and is therefore excluded in the regression analysis.

4.1 Auction Data

For our study, data on license premiums, the monthly quota, the number of submitted bids, from May 1990 onwards, were obtained from LTA's website (at http://www.lta.gov.sg). However, data on bid distributions in the sealed-bid license auctions were available only from September 1994 to June 2001 (when the auction format switched to an online open-bidding format). This information was previously disseminated primarily to car distributors and the motoring associations (such as the Automobile Association of Singapore and the Motor Traders Association of Singapore), and is not available on LTA's website.

Unfortunately, the bid distribution data that was disseminated were not individual bids, but bids grouped and summarized into bands of price relatives above and below the market-clearing bids (see Figure 2 for a sample of the bid distributions). Thus, the bid distribution data are somewhat less informative that what we would have liked. Nonetheless, the available information suffices for our purpose of calculating the means and standard deviations in the license auctions.

Our study focuses on the period from September 1994 to December 1997 (altogether 40 auctions). While bid distribution data from January 1998 to June 2001 are available, we have elected not to use these data for the following reasons. From January 1998 onwards, our preliminary data analysis uncovered the persistent presence of lottery seekers (to be defined shortly) in all the categories of the quota license auctions.[10] This occurred after the January 1998 license auction for Category 3. In that auction, there were only 315 bids for 336 available licenses. The resulting quota license premium was S$50 (the lowest ever), and this was the only time that the quota license auction was ever undersubscribed.

The sharp drop in market demand for cars and the consequent under-subscription in the January 1998 Category 3 auction had to do with the events of December 1997. Then,

[10] By lottery seekers, we refer to participants in the quota license auctions who submit bids that are unrealistically low, in the hope that if the auction is undersubscribed (i.e. fewer bidders than available licenses), they may be able to pick up a license at a bargain.

South Korea almost defaulted on its sovereign debt, as foreign capital retreated from Asian economies following the currency devaluations in Thailand, Indonesia and the Philippines that sparked Asian Financial Crisis in mid-1997. Although the International Monetary Fund pulled together a rescue debt-restructuring package over Christmas to stave off a potential sovereign debt default, consumer sentiment took a sharp dive across Asian economies. In Singapore, the sharp decline in consumer sentiment was the cause of the weaker participation in the quota license auctions.

The occurrence of the S$50 license premium contrasted with a peak of S$95,000 (in November 1994) and prompted many lottery seekers to participate in the subsequent quota license auctions and try their luck.[11] In turn, this led to the presence of a concentration of bids at the lower end of the bid distribution. As is evident in Figure 1 in the Appendix, the bid-quota ratios for all the passenger car categories shot up significantly after January 1998, and persisted for many months before subsidizing, but still remained above the levels of December 1997 and January 1998. Since our objective in this paper is to study the formation of expectations in forecasting vehicle demand where the auction participants are bona fide car buyers (i.e. not lottery seekers), we restrict our sample to the period before the December 1997 bidding.

4.2 Research Findings

We apply the econometric model to all seven license categories for passenger cars, for the period September 1994 through December 1997. To recapitulate, our hypothesis is that in Singapore's vehicle quota license auction – an example of a repeated multiple-object auction where the objects have a common value to the bidders – the bid distributions contain information for bidders to update their expectations about the intensity of market demand

[11] Since the bidding format was a sealed-bid auction, bidders had no way of finding out that the January 1998 Category 3 auction was going to be undersubscribed. If they had known, more bids would have been submitted, or lower bids would have been submitted.

(i.e. R_t the quota-bid ratio), make forecasts about the vehicle license premiums and formulate their bidding strategies.

This hypothesis is supported by our econometric analysis, which shows that the bid distributions of previous license auctions have a good degree of predictive power for license premiums. We found that the predictive power appears to be the strongest for Category 1 and the Category 7 (the "Open" category), and weaker for the other categories. In these two categories, we tallied a total of 62,549 bids for the 29,622 licenses available over 40 auctions. Table 1 summarizes the results of the econometric analysis for Category 1 and Category 7.

Table 1: Estimation of the Econometric Model

	Category	
	Cat 1: 1000 cc and below	**Cat 7: Open, Transferable**
β_0	11306.96 (3.609)	–4734.939 (–1.071)
β_1	–8.465 (–4.328)	3.451 (2.101)
β_2	9.639 (4.357)	–5.189 (–2.887)
R^2	0.360	0.302
Durbin-Watson	2.200	1.977
ADF for P_t	–1.9473 (0.3096)	–2.2471 (0.1936)
ADF for $P_t - P_{t-1}$	–7.1255 (0.0000)	–4.3167 (0.0015)
No of Observations	37	37

Notes: ADF = augmented Dickey-Fuller statistic. The null hypothesis for the ADF test is that there is a unit root. For the estimates of the parameters β, the figures in the parentheses are the *t*–ratios. For the ADF statistics, the figures in the parentheses are the *p*–values.

The augmented Dickey-Fuller statistics show that P_t is non-stationary (as we discussed earlier), while the $\left(P_t - P_{t-1}\right)$ series is stationary.[12] The regression slope parameters are all significant at the 5 percent level. Both regressions explain more than 30 percent of the variations in the quota license premiums. For regressions based on price differences, the high R^2 coefficient is quite remarkable, and supports our hypothesis that the bid distributions in the vehicle quota license auctions contain significant information for learning and expectations formation in subsequent auctions.

We believe that the stronger results for these two categories are due to the fact that there is little substitution in demand for vehicles in these two categories, resulting in more stable distribution of the bids $\tilde{P}_t$. Category 1 is for passenger cars of 1000 cc and below. Prospective car buyers in this category are unlikely to switch to purchase a car in the other (more expensive) car categories if quota license premiums increased (as was the case during most of the period from 1994 to 1997). However, for Categories 2 to 4, prospective car buyers have the option to switch to a lower (cheaper) car category if quota license premiums rose so much as to affect their overall budget for car purchase. In other words, there is a greater degree of substitutability in the other categories, so that the bid distributions are less stable than in Category 1. In the case of Category 7, this is the category for transferable licenses, and the bidders who participate in this category are the car distributors. Thus, the set of participants are stable over time. In the Appendix, Figures 3 and 4 provide graphical representations of the key features of the vehicle quota license auctions for Categories 1 and 7, respectively.

From Table 1, we also note that the estimated values of β_1 and β_2 have opposite signs in the regressions for Categories 1 and 7. Hence, the net effect of R_{t-1} on the change in P_t is mixed. This conclusion is, however, not surprising. First, an increase in R_{t-1} would lead to a decline in P_{t-1} (see equation (4)), which has the effect of encouraging more bidders to

[12] See MacKinnon (1991) for the use of the augmented Dickey-Fuller test.

participate in the auction.[13] In other words, B_t is likely to increase. As B_t increases, this causes R_t to decline and P_t to increase. Second, when bidders form expectations for μ_t based on P_{t-1}, an increase in R_{t-1} would reduce P_{t-1} and μ_t, and hence P_t. As these two effects of R_{t-1} on P_t are in opposite directions, the net effect is uncertain.

5. Summary and Discussion

The objective of this paper is to study the expectations formation and demand forecasting in Singapore's vehicle license auction. We construct an econometric model to demonstrate that in Singapore's vehicle license auction, participants can improve their chances of success by utilizing the information in past auctions to formulate their bidding strategies. Specifically, we show that the mean, variance and quota-bid ratios of preceding auctions have a significant degree of predictive power for forecasting vehicle demand.

Although the data we used to calculate the means and standard deviations for our regression analysis was partially aggregated data (as discussed in Section 4.1), the results – particularly for Categories 1 and 7 – support our hypothesis that past bid distributions contain useful information about other bidders' private information that may continue to be relevant in the current auction. This is because in repeated multiple-object auctions, the objects being auctioned (in this case, quota licenses) are substitutable across auctions, and therefore bidders should update their expectations about the intensity of market demand in the current auction and revise their valuations and bidding strategies accordingly.

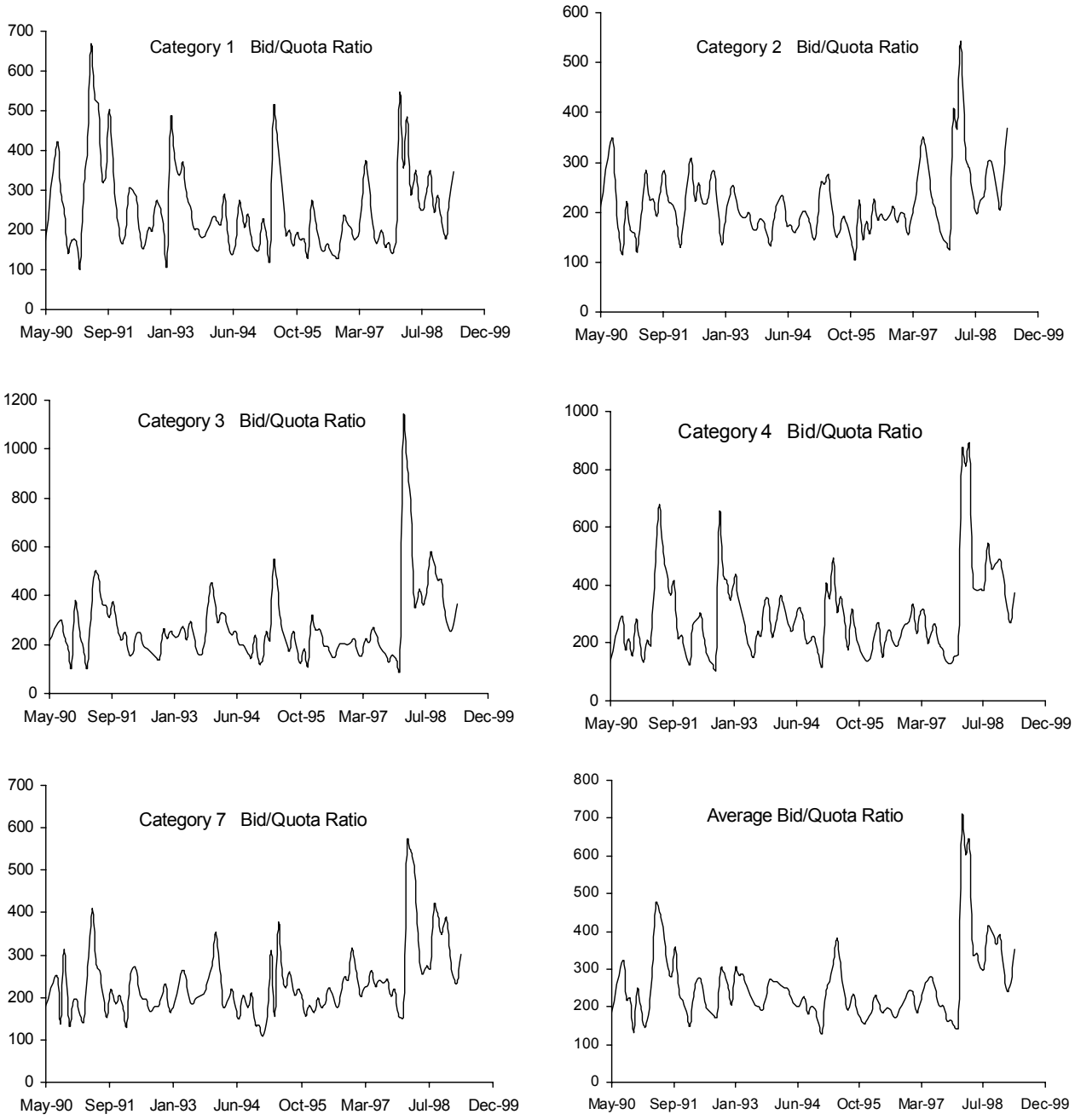
The econometric model we describe in Section 4 is the simplest model for our analysis. It is possible to refine the analysis further to strengthen the results, but the qualitative conclusions will remain unchanged. One promising avenue to refine the model is to consider a simultaneous-equation estimation setup. We noted in the discussion in Section 4.2 that number of bidders and the lagged license premiums are negatively correlated. A

[13] The correlation between $\left(P_{t-1} - P_{t-2}\right)$ and $\left(B_t - B_{t-1}\right)$ is –0.70 for Category 1 and –0.59 for Category 7.

more sophisticated means to incorporate this relationship and study its effects on the regression model is to explicitly model this process together with the demand-forecasting and price formation process described in Section 4.

Finally, we believe that our econometric analysis is applicable to a wider setting. For instance, in countries such as New Zealand and Singapore, real estate properties or land parcels are sometimes sold via sealed-bid tenders, although the more commonly-used format is an open-bidding format. In the case of government procurement, however, sealed-bid tender is the predominant format. Although these auctions are, strictly speaking, not repeated multiple-object auctions, and the objects in one auction are not always perfectly substitutable with those in subsequent auctions, they do share the same characteristics that the same set of players interact repeatedly in successive auctions, and valuations are affiliated across bidders. Therefore, it is likely that learning effects are present in the price formation process of these other auctions, as bidders seek to infer from past distributions the valuations of other players, the private information they may possess, and then revise their own beliefs and expectations accordingly.

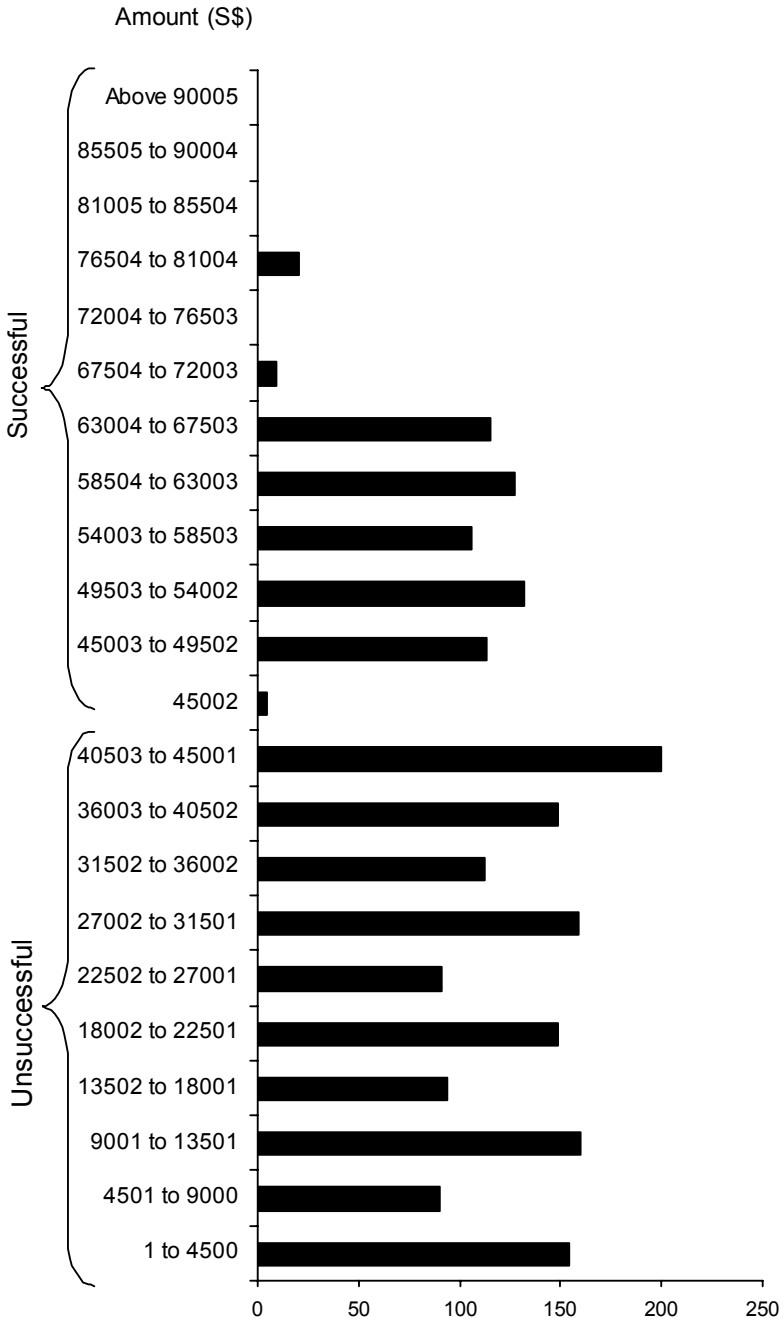
Figure 1: Bid-Quota Ratios: May 1990 to April 1999



Note: The Average Bid/Quota Ratio is the average for Categories 1, 2, 3, 4 and 7.

Figure 2: An Illustration of the Bid Distribution in Singapore's Vehicle Quota Auction

Category 7, March 1995



Notes: 1. The range of bid amounts is in increment/decrement of 10% from the Quota Premium (S$45,002)

2. The original source of the data is the Land Transport Authority of Singapore. The data is no longer available on its website.

Figure 3: Vehicle Quota License Auction in Category 1

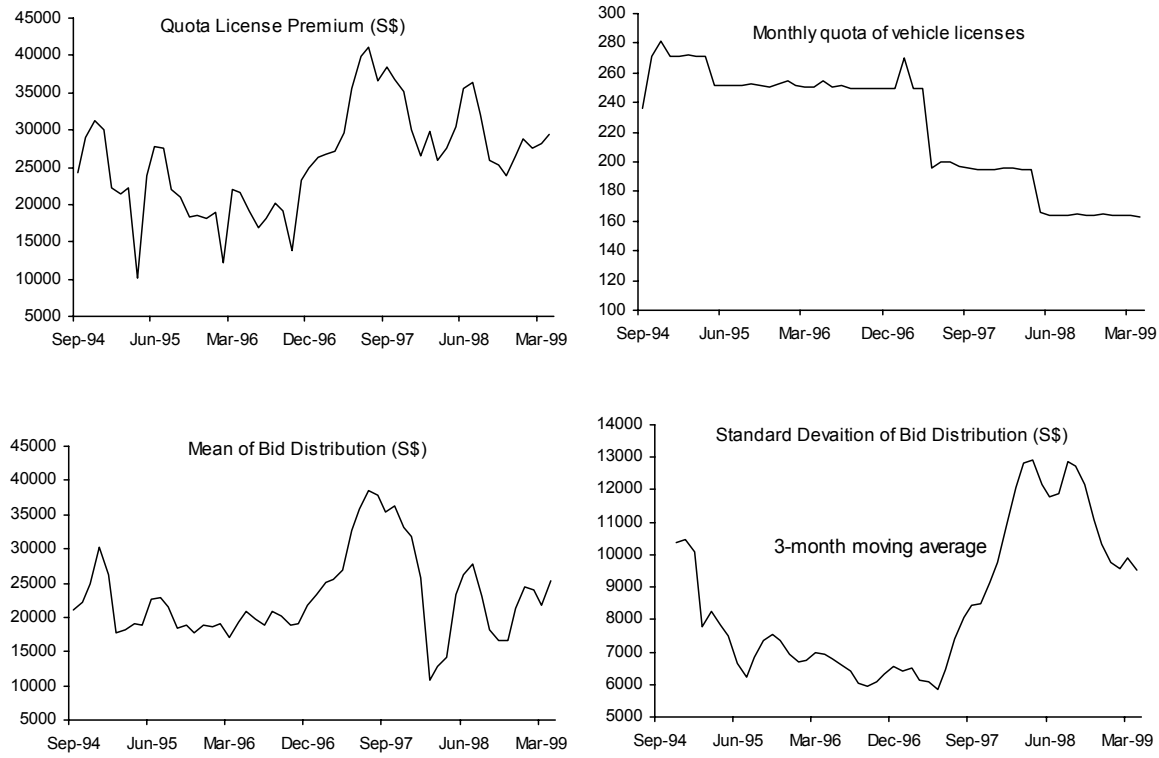
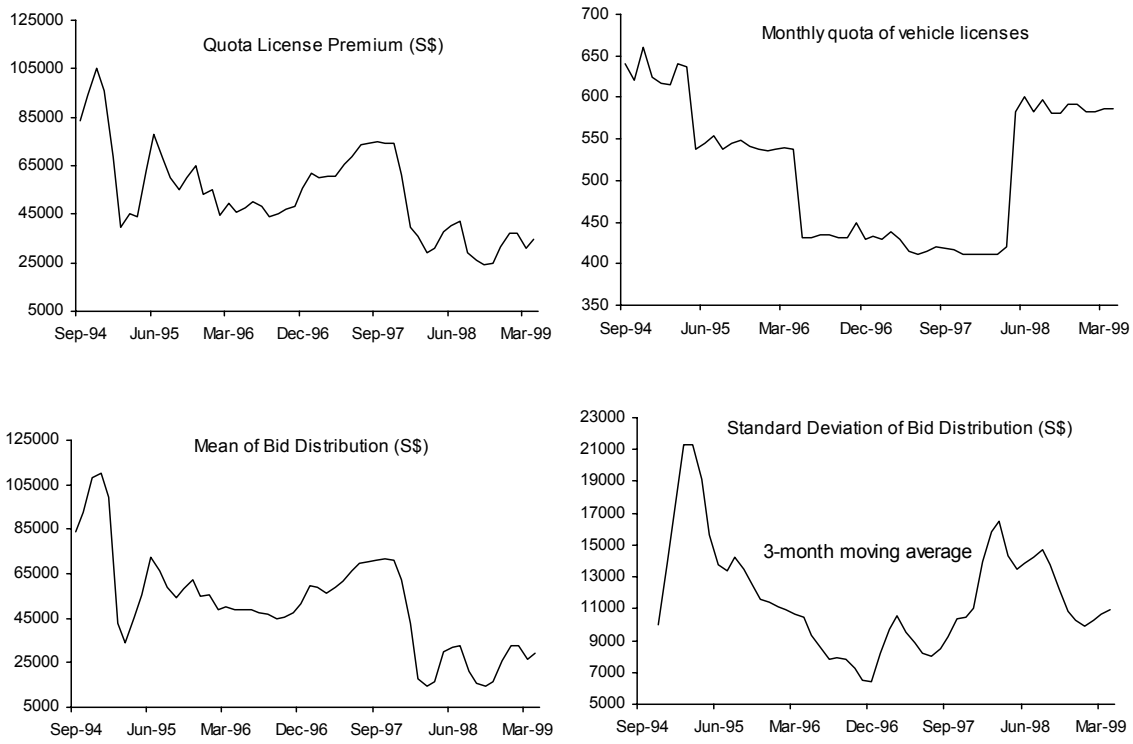


Figure 4: Vehicle Quota License Auction in Category 7



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