Essays on Empirical Industrial Organization

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Abstract

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This dissertation consists of two essays in the field of empirical industrial organization. In the essays, I analyze the economic policies of a government's treasury department, and firms' strategies in the franchise industry by respectively using structural models and real data.

In chapter 1, I examine the effectiveness of a hybrid treasury auction mechanism in terms of government revenue and efficiency. Most countries issue treasury securities using traditional mechanisms, such as uniform pricing or discriminatory pricing. On the other hand, Korea has implemented a unique 'Korean-style' auction that has the characteristics of both uniform-price and discriminatory auctions, a switch from a simple uniform-price mechanism. I use individual bid level data from Korean treasury auctions before and after the issuance mechanism changes. Based on these bid data, I construct the distribution of market-clearing prices and estimate each bidder's underlying marginal valuations under each auction mechanism, uniform-price, and hybrid format respectively. I estimate the total surplus of a hypothetical benchmark auction calculated on the assumption that bidders bid truthfully without shading their demand by the estimated marginal valuation. By comparing the revenue and efficiency of each realized mechanism with the hypothetical benchmark, I indirectly measure the performance of a hybrid auction against that of a uniform-price

auction. I find that the hybrid method works more effectively than the uniform-price auction in terms of government revenue and efficiency. The government's additional absorption of bidders' surplus and the limited bidders' bid shading in hybrid auctions outweigh the effects of possible aggressive bidding in uniform-price auctions.

In chapter 2, by using Korean burger chain market data, I analyze the effects of ownership and revenue-cost sharing contracts on how franchise firms determine their stores' locations. I extend firms' static entry models in the oligopolistic market by setting up franchise headquarters' profit functions reflecting stores' ownership. By using equilibrium conditions linking the firms' observable actions and their profits, I construct a probability equation which generates a certain market equilibrium status. Using maximum likelihood estimation, I find the profit functions' parameters that maximize the probability of the observed market status. The greater the extent to which the headquarters take franchisees' variable revenues and the less that fixed costs are covered by franchisees, the more likely it is that headquarters allocate franchised stores in a manner similar to their company-owned stores. On the other hand, if franchise headquarters take less in variable revenues from franchised stores and focus on reducing fixed costs more, their location choices for franchised stores are quite different from those for company-owned stores. When it comes to the effect of other stores' presence on location choices, the cannibalization effect from the same brand stores is bigger than the competition effect from other brands' stores. Market characteristics such as population and housing prices also affect the burger chains' preferred store locations.

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DEDICATION

To my love Honglae and Yujin, who are always on my side

Chapter 1

ANALYZING THE EFFECTIVENESS OF HYBRID TREASURY AUCTION MECHANISM - EMPIRICAL EVIDENCE FROM KOREA -

1.1 Introduction

Most countries issue treasury securities by auction. Since many governments issue tremendous amounts of treasury securities, the importance of effective treasury auction mechanisms has been heavily emphasized. The traditional, commonly used methods for treasury auctions are uniform-price and discriminatory mechanisms. In a uniform-price auction, each bidder winning an auction pays the same market-clearing price for all units won. On the other hand, in a discriminatory price auction, each winning bidder pays her actual bid prices for the winning quantities. Comparisons of the effectiveness of these two representative mechanisms, the uniform-price and the discriminatory, have been studied abundantly, both theoretically and empirically.

In this paper, I analyze the effectiveness of a non-traditional hybrid treasury auction mechanism based on the data of the Korean government. It is a modified method based on the two traditional methods and has the combined characteristics of a uniform-price auction and a discriminatory auction. Few studies have been conducted on auction mechanisms other than the two traditional types of auctions, and few countries use auction methods other than those two methods. Spain and Korea are almost the only countries that use treasury auction methods that differ from the traditional ones. The reason that non-traditional methods are not used much may be because there are not many studies that demonstrate the effectiveness of these methods. On the other hand, there may not be much research, because the experiences of countries using these methods are so rare that not much data has been generated. This paper is meaningful in that it fills this gap in the literature by analyzing the effectiveness of a type of non-traditional auction that has hitherto not well been studied. If this paper demonstrates the effectiveness of a hybrid auction, an unprecedented auction type, the results may be used as the basis for introducing new types of auctions in lieu of the traditional ones.

The Korean government switched from a uniform-price auction to a 'Korean-style' hybrid auction, known as a 'differential-pricing auction,' in September 2009. In the differential-pricing auction, each bid price is sorted from high to low, divided into groups based on the market-clearing price and the preset interval increment, and the lowest price in the group is applied equally within the same group.[1] It has the characteristics of a uniform-price auction in that the lowest price of the group applies equally to all the bids within the same group, and it also has the characteristics of a discriminatory auction in that each different group pays a different price. I examine the effectiveness of the hybrid auction in terms of government revenue and efficiency by comparing it with the previously used uniform-price auction.

Since bidders' underlying values and bidding conditions —such as supply quantities and financial market circumstances —vary by auction, it is not enough simply to compare the revenues before and after the mechanism change with the observed bids. Therefore, I introduced a structural approach and conducted counterfactual simulations. A direct counterfactual approach, which calculates the government revenue of the alternative auction directly with recovered parameters, is not feasible due to computational issues. Instead, I used an indirect method that introduces a common benchmark and compares the two mechanisms through their relative differences from the benchmark. First, I estimated the bidders' marginal values of each auction that are not observable by using the bid shading model and the resampling

[1] In treasury bond auctions, the bid yields are used for bidding instead of the bid prices, and in bonds, the bid prices and the bid yields are inversely related. In practice, bid rates are aligned from low to high and divided into groups at a preset interval increment of 3 basis points (i.e., 0.03%). All successful bidders are awarded the highest winning rate within the group.

approach. Using the estimated values, I calculated the hypothetical benchmark, the total surplus of a Vickrey auction, which is the maximum surplus that a society can achieve through the auction. By comparing each mechanism's realized revenue and total surplus with the hypothetical benchmark, I indirectly compared the performance of the mechanisms. The closer it is to the benchmark, the better the performance of the auction is said to be. On the other hand, the further it is from the benchmark, the more room there is for improvement.

The main finding in this paper is that the hybrid auction can bring in more government revenue than the uniform-price auction. Based on the data, hybrid auctions perform better than uniform auctions for all maturities. In a uniform-price auction, all bids are applied at the lowest price, but in a hybrid auction, some bids are applied at higher prices, which allows the government to absorb the bidders' additional surpluses. Additionally, bidders' bid shading, which reduces their true demand to lower the market-clearing price, is limited in the hybrid auction, because of the risk of belonging to the higher-priced level due to the interval level change. These effects outweigh the possible aggressive bidding in uniform-price auctions. With respect to efficiency, both auctions are close to being efficient, but the efficiency loss of hybrid auctions is less than that of uniform-price auctions. Inefficiency occurs when the objects of an auction are allocated to the bidders with lower values, and it often happens when bidders with high values reduce their demand a lot to lower the market-clearing price. In hybrid auctions, the bid shading incentive that causes bidding to be different from real value order is more limited than in uniform-price auctions.

The key contribution of this paper is that it analyzes the effectiveness of a new type of mechanism, hybrid auctions, differentiating this study from most of the existing literature, which focuses on the effectiveness of such traditional mechanisms as uniform-price or discriminatory auctions. Furthermore, to the best of my knowledge, this paper is the first empirical study of a hybrid treasury bond auction using authentic individual bid-level data. Although there are studies on Spanish hybrid treasury auctions that are different from Korea's auctions, they use data from laboratory experiments instead of actual data or use public aggregated data on supply and demand of treasury bonds in auctions. In contrast, this paper uses actual individual bid-level auction data before and after the auction mechanism changes obtained from the Korean government. Lastly, this paper is meaningful in that it proposes a method for analyzing a new type of auction by establishing a modified model from an existing model.

The remainder of the paper is organized as follows. Section 1.2 presents a literature review. Section 1.3 explains the institutional features of the Korean treasury auction market and provides descriptive statistics of the data used in this paper. Section 1.4 suggests the model and methodology for the estimation. Section 1.5 shows the estimation results, and Section 1.6 offers a conclusion.

1.2 Literature Review

Studies on effective auction mechanisms can be largely divided into two main categories: theoretical and empirical. While theoretical studies on single-unit auctions, such as first- and second-price auctions, have been studied in abundance, studies on multi-unit (i.e., share or divisible) auctions have not been carried out as extensively as single-unit auctions. Wilson (1979) introduced a share auction framework, in which bidders submit smooth and continuous demand schedules as their bids. This framework was developed by subsequent authors such as Back and Zender (1993), Wang and Zender (2002), and has been used by many studies thus far. Recent theoretical studies such as Ausubel et al. (2014) demonstrate that bidders' differential bid shading across units causes inefficiencies in both uniform-price and discriminatory auctions. They also show that, in general, the revenue and efficiency rankings of the two mechanisms are ambiguous but in settings with symmetric bidders, the discriminatory auction often outperforms.

Most early empirical studies focus on 'natural policy experiments,' which compare different auction formats used in different periods without proper controls. Umlauf (1993), Simon (1994), Nyborg and Sundaresan (1996), Malvey and Archibald (1998) compare the market-clearing prices of auctions with resale or forward (i.e., when-issued) prices. By comparing the differences in each format, uniform-price, and discriminatory auction, they analyze the effectiveness of the auction mechanisms indirectly. However, this approach has a disadvantage in that it relies on a strong assumption that the bidders' information is fixed between the primary and the secondary market. In other words, new information released after the bidding may change the bidder's valuations, but comparing the data from different periods does not the change take into account.

Many recent empirical studies use a structural approach. Researchers construct structural models, recover structural parameters such as the bidders' marginal valuation distributions, and do counterfactual simulations with a set of bidders' prior information fixed. Guerre, Perrigne, and Vuong (2000) suggested the seminal methodology to identify and estimate the valuation distribution for the first-price single-unit auction. They assumed that bidders have private independent values and play the Bayesian-Nash equilibrium of the game for optimization. Structural model estimation methodologies for multi-unit auctions, such as treasury auctions, have also been developed based on Guerre et al. (2000).

As a way to conduct structural analysis, there are parametric or nonparametric methods. Fevrier, Préget, and Visser (2004) use a parametric model to find equilibrium strategies for the discriminatory French treasury securities under the common value assumption. For the nonparametric method, many papers use the 'resampling approach' suggested by Hortaçsu (2002). This is a method of estimating marginal valuations of bidders while reducing the computational burden and alleviating the problems of setting many prior assumptions of the parametric method. Hortaçsu (2002) applies this method to discriminatory Turkish T-bill auctions, assuming strictly downward sloping continuous bid functions and the bidders' independent private values. I also use the 'resampling approach' to estimate bidders' underlying true values for the counterfactual analysis in this paper.

Hortaçsu and McAdams (2010) and Kastl (2011) developed Hortaçsu's (2002) nonparametric method considering discreteness. In reality, bidders' bidding functions are not strictly downward sloping continuous ones but rather step functions that bid the same price over a range of quantities, because there is usually a limitation of bidding numbers per bidder or a bidding cost exists. Hortaçsu and McAdams (2010) show through a model considering discreteness that introducing a uniform price or Vickrey auction instead of a discriminatory auction would not significantly increase the government's revenue. Kastl (2011) extended the discrete method and applied it to the uniform-price treasury bill auction in the Czech Republic. He demonstrated that under the discrete step function, bidders may bid above their marginal valuation, and the marginal value can be overestimated significantly in a uniform-price auction if discreteness is not considered. Hortaçsu and Kastl (2012), Hortaçsu et al. (2018) also applied Kastl's (2011) method to the Canadian treasury auction and U.S treasury auction each, and this paper also follows and modifies Kastl's (2011) model.

Kang and Puller (2008) analyzed the former auction mechanism changes in Korea. They used Korean auction data of 1999-2002 and compared the effectiveness of discriminatory and uniform-price auctions and concluded that discriminatory auctions perform better than uniform-price auctions.[2] Their contribution was in analyzing the efficiency attributes of each mechanism using data from both formats, while most other studies used data from only one type of format. Like Kang and Puller (2008), my data set also includes the data from both types of comparable auction formats, so I was able to analyze not only the revenue effectiveness but also the efficiency properties of uniform-price and hybrid auction mechanisms.

1.3 The Korean Treasury Auction Market and Data

1.3.1 The Korean Treasury Auction Market

The Korean government has auctioned treasury securities since 1997. Prior to 1997, treasury securities were distributed to several financial institutions and acquired in an uncompetitive manner. The Primary Dealer system was also introduced in 1997. For the first year, from

[2] Before Korea introduced the uniform-price auction format in 2000, it had used discriminatory auctions for a year.

July 1999 to July 2000, the discriminatory auction mechanism was used. In July 2000, the Korean government introduced a uniform-price auction to encourage bidders' participation. After using the uniform-price auction format for nine years, the Korean government introduced a hybrid auction, known as a differential-price auction, in September 2009 and has continued to use it.

Korean Treasury Bonds (KTBs) are issued as fixed-rate bonds and inflation-linked bonds. Fixed-rate KTBs are issued in six maturities: 3, 5, 10, 20, 30 and 50-year bonds, and inflation-linked KTBs are issued in 10-year bonds. All fixed-rate KTBs are coupon bonds, and the interest is paid every six months. Among them, I analyze 3, 5, 10 and 20-year fixed-rate bond auctions, which were implemented between February 2009 and July 2010, the period before and after the auction system was changed.

KTB auction dates are fixed for the investor's predictability. 3-year KTBs are auctioned on the first Monday of every month, 5-year KTBs on the second Monday, 10-year KTBs on the third Monday and 20-year KTBs on the fourth Monday. Competitive bidding is held between 10:40 am and 11:00 am on the auction day through the electronic bidding system, BOK-wire.[3] In instances when Monday is a public holiday, the auction is held on the next business day. The Korean government announces annual and monthly KTB issuance plans to enhance market predictability. The annual issuance plan for the following year is released at the end of the year. It includes information on the total annual issuance volume, the issuance proportion of KTBs with different maturities, major policies newly introduced or revised, etc. The monthly issuance plan is usually released by the last Thursday of every month. It includes details on new issuance, buy-backs, auction dates, issuance volume, etc. For market stability, the Korean government tries to maintain the monthly issuance volume evenly throughout the year.

Many financial institutions such as banks, pension funds, insurers, securities companies

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[3] The Ministry of Economy and Finance holds comprehensive authority on KTBs, and the Bank of Korea is in charge of such practical matters as the issuance and redemption process.

and investment trust companies are KTB investors. Individuals or foreign investors can also invest in KTBs. However, only Primary Dealers (PDs) can participate in the KTB competitive auction directly. Other investors can participate in the auction via PDs or purchase KTBs in the secondary market. PDs are designated financial firms that have the exclusive right to participate in KTB auctions. At the same time, PDs take on market-making obligations. They are required to offer bid-ask prices in the secondary market and maintain sufficient trading volume and strong financial standing. The government conducts an assessment of PDs on their KTB underwriting and market-making performance every six months and provides incentives or penalties based on the results. The Korean government has continued to manage the number of primary dealers at around 20. At the end of 2018, the number of PDs (including the preliminary primary dealers (PPDs)) was 22. Ten are banks and twelve are securities firms. To apply for a KTB PD, a financial institution must meet strict requirements, such as the legal qualification to trade government bonds, financial soundness, staffing, etc. After operating as a PPD, it can be designated as a PD based on the results of the government's assessment.

The minimum bid amount is 1 billion Korean won (approximately 0.8-0.9 million dollars), and PDs can bid in multiples of 1 billion Korean won. The minimum bidding yield unit is 0.005%, and bidders can submit up to seven price-quantity bid points. Before June 2013 the minimum bidding yield unit was 0.01%, and the maximum number of price-quantity bid points was five. These old rules were applied to the data used in this paper, because I use the data of auctions that were implemented prior to 2013.

1.3.2 The Korean hybrid auction mechanism

The Korean government's goal was to combine the strengths of the uniform-price and the discriminatory auctions. By combining the characteristics of the discriminatory auction with the uniform-price auction, the Korean government tried to induce treasury bond Primary Dealers (PDs) to bid with reasonable yields to form reliable benchmark rates for the Korean capital market. Its intention was also to motivate the PDs to acquire market information and to develop their business abilities. The Korean government judged that PDs didn't have a lot of incentive to take an active role, since the winning rates were equal for all the winners under the uniform-price auction mechanism, and the government considered that this situation was not desirable for the development of the bond market. Also, compared to a uniform-price auction, a hybrid auction offers the possibility of the Korean government's obtaining an additional amount of the bidders' surplus.

At the same time, by retaining the characteristics of a uniform-price auction, the Korean government tried to curb a possible demand reduction that might happen. In a discriminatory price auction, since winners need to pay the price they bid, there is the concern that bidders can reduce their actual demand to increase surplus. Therefore, to maintain stable funding, the Korean government's action could be an alternative to a complete discriminatory pricing scheme in terms of preventing concern about excessive demand decline. In the hybrid method, the government aligns bid yields from lowest to highest and divides them into different groups at intervals of, for example, three basis points (3bp: 0.03%). The highest bid yield (i.e., the lowest bond price) of each group becomes the winning yield for that group. This means that bidders can, with a high probability, win government securities at prices lower than their bids, similar to a uniform-price auction.

Table 1.1: Comparing auction mechanisms (Example of $10 billion auction)

Bidders	Bids	winning yield		
		Uniform	Discriminatory	Differential*
A	4.99% $3 billion	5.05%	4.99%	4.99%
B	5.00% $2 billion	5.05%	5.00%	5.02%
C	5.02% $3 billion	5.05%	5.02%	5.02%
D	5.03% $1 billion	5.05%	5.03%	5.05%
E	5.05% $1 billion	5.05%	5.05%	5.05%
F	5.07% $2 billion	Failed	Failed	Failed

* Group 1: [5.05%-5.02%), Group 2: [5.02%-4.99%), Group 3: [4.99%-4.96%)

Table 1.1 shows a simple example of each issuance mechanism. For example, if the government issues $10 billion worth of government bonds and six bidders submit different bids, the market-clearing yields for each mechanism are decided as follows. The government determines the winners by sorting the bidders in order, starting with the lowest bidding yields, until the total sum of the winning bids reaches the issue amount. The government prefers bidders who bid at lower yields, because discounting with lower yields makes the bond's present value more expensive. Under the uniform-price auction, the highest winning yield (i.e., the lowest winning price) of 5.05% applies to all the winners from A to E, while under the discriminatory auction, each different winning rate applies to each different winner. Under a hybrid auction of 3 basis point intervals, three different winning rates apply to three groups, for example, 5.05% for D and E, 5.02% for B and C and 4.99% for A. This is a very simple example only to show how winning prices are determined by the auction type when the bids are the same for all auction types. In reality, the bidders' strategies will change with each mechanism. Also, in this example, each bidder bids only one price-bid quantity set, but in reality, each bidder can bid multiple price-quantity sets.

1.3.3 Description of the Data

My data set consists of data for 66 auctions of Korean Treasury Bonds. The period is from 2/16/2009 to 7/5/2010, before and after the auction mechanism change that took place in September 2009. I use a structural model to control for other outside factors effectively, but to minimize any potential economic environment changing effect, I reduced the period analyzed to one and a half years and chose the sequential auction data in this period. It was a period when the central bank's base rate, one of the key indicators of the overall picture of the financial market, remained the same at 2.00%.

The first 26 auctions between 2/16/2009 and 8/24/2009 were conducted with a uniform-price mechanism, and the last 40 auctions between 9/7/2009 and 7/5/2010 were conducted with a hybrid auction mechanism. The data consists of all the bidding information, including each bidder's identity, bidding yields, bidding quantities, winning yields, winning quantities, etc. Since the 66 auctions consist of 3, 5, 10, 20-year bond auctions, it is also possible to compare the auction mechanisms' effect by maturity. Korean Treasury Bonds are coupon bonds, and the yields in the data, such as coupon yields, bidding yields and winning yields, are based on the annual interest rates. To express a bid function with price and quantity, I converted the bidding yields to the prices according to the formula announced by the Bank of Korea, which is used to calculate the issuing unit price per face value of 10,000 Korean Won (KW, approximately \$8-9). This issuing unit price formula is a variation of the usual bond price formula because, in a KTB auction, the coupon yields and the auction winning yields are usually different due to the 'fungible issuance policy'[4] of Korea. After the auction, the winners pay the government their winning amounts multiplied by the issuing unit price, divided by 10,000. The issuing unit price formula is given by:

$$\left[\left(\sum_{t=1}^{n} \frac{10,000 \times \frac{R}{m}}{\left(1+\frac{r}{m}\right)^{t-1}}\right) + \frac{10,000}{\left(1+\frac{r}{m}\right)^{n-1}}\right] \times \left(\frac{1}{1+\frac{r}{m} \times \frac{a}{b}}\right)$$

n: Remaining number of interest payment

R: Coupon rate (Annual)

r: Winning rate (Annual)

m: Annual number of interest payments

a: Number of days left until the end of interest payment period

b: Number of days of interest payment period

Summary statistics of uniform price and hybrid auction formats by each maturity are shown in Table 1.2. Since the Korean government has continued to maintain the number of PDs at around twenty, the average number of bidders per auction did not change much. Also,

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[4]The Korean government introduced the fungible issuance policy to increase the supply volume and liquidity of each bond type and to form credible benchmark rates. By using fungible issuance, the bonds issued within a set period, even with different auction days, have the same terms (e.g., maturities, coupon rates, etc.) and are treated as a single bond.

Table 1.2: Summary statistics of auction data

Maturity	3-year		5-year		10-year		20-year	
Format	Uni	Hyb	Uni	Hyb	Uni	Hyb	Uni	Hyb
Number of auctions	6	10	6	10	7	10	7	10
Avg. number of bidders per auction	18.8	19.3	19.3	19.3	19.2	19.0	18.0	19.2
Avg. number of bid points per bidder	4.49	3.98	4.58	4.29	3.91	4.17	3.53	3.81
Avg. Max-Min bidding prices of a bidder (KW)	22.0	8.8	35.5	15.4	70.1	27.6	126.1	47.4
Avg. Max-Min bidding prices of an auction (KW)	56.3	47.3	159.9	25.3	198.7	57.0	360.5	89.5
Avg. bid quantity per auction (bil.KW)	2,890.3	3,952.6	3,467.2	5,362.9	1,516.6	3,825.0	782.1	2,146.4
Avg. issue quantity per auction (bil.KW)	2,339.6	1,435.0	2,532.3	2,263.4	1,125.3	1,719.1	593.4	888.2
Avg. bid price/winning price among total bids (%)	100.12	99.97	100.18	99.98	100.29	99.96	100.53	99.89
Avg. rank percentage of winning bids from the top (%)	81.49	49.46	63.19	53.56	70.16	52.19	74.05	45.40

* Bid prices and winning prices are quantity weighted average prices.

the average number of bidding points per bidder does not show a marked change, because it has decreased for 3-year and 5-year bond auctions but has increased for 10-year and 20-year bond auctions. However, we can see that there are some characteristic changes after the mechanism changes. The most noticeable change is in the average differences between the maximum and the minimum bid prices, which show a deviation between the bid prices. The differences have been reduced significantly both for each bidder and within an auction.

Another feature is the significant increase in bid volume compared to the government supply. The change in government supply depends on bond maturity, but bid volumes increased for all maturities. The Korean government explained the reason as follows. Under the uniform-price auction, some bidders bid too high prices to secure the amounts for their own customers. For them, the probability of paying their bid was very slight because they only needed to pay the market-clearing price, the lowest winning price. However, market-clearing prices were often set at a high level, and sometimes it exceeded secondary market prices. Bidders were increasingly reluctant to participate in the auctions for fear of a loss and preferred to buy the bonds from the secondary market rather than from the primary market. However, under the new mechanism, the bidders expected that other bidders would also bid reasonable prices, and the probability that the market prices between the primary and secondary market would become upside-down decreased. This is why the bidders were more actively involved under the new hybrid mechanism proposed by the government.

Lastly, the winning prices in the hybrid auctions tend to be higher than the overall bid prices, compared to the uniform-price auctions. If we sort the bid prices from high to low and then rank the winning prices by percentage, the ranking percentages of the winning prices in the hybrid auctions are much smaller than in the uniform-price auction. In other words, in the hybrid auctions, the ranks of the market-clearing prices are higher than in the uniform-price auctions and closer to the highest bid price.

It is clear that there were changes before and after the auction mechanism change, but it is not clear how these have affected government revenue or efficiency. For example, the reduced price range between the maximum and the minimum bid itself does not provide information about the revenue level change. Also, even though the winning prices in the hybrid auctions tend to be higher, since the bidders' underlying bidding schemes may change depending on the mechanism, we cannot simply conclude that the hybrid auction mechanism allows the government to take in more revenue. Therefore, further analysis through modeling is required in order to consider the bidding schemes.

1.4 Modeling and Identification Methodology

1.4.1 The Model

To analyze the effectiveness of the new hybrid mechanism in Korea, it is necessary to compare government revenue and efficiency with the previous uniform-price auction mechanism. As shown in Figure 1.1, I visually represented government revenues in the uniform-price auction and hybrid auction, respectively.[5] Market-clearing quantities (Q^c) and prices (P^c)

[5]For the sake of simplicity, I assume the price-quantity bid functions are linear functions represented by the straight dotted lines here. However, in reality, bid functions would be step functions, because there is a limit to the maximum number of price-quantity bids per bidder.

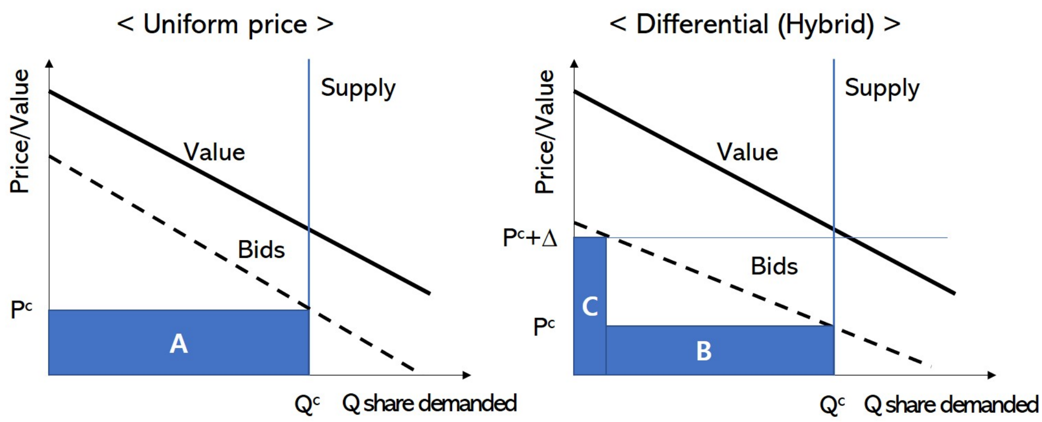


Figure 1.1: Government revenue comparison

are determined where accumulated bids and the total supply meet. The government revenue under uniform-price auction is the space of 'A,' which is the rectangle calculated by the product of P^c and Q^c. The government revenue under the hybrid auction is the sum of the two rectangles, determined by the bids and the predetermined interval increment (Δ). The government can earn as much as 'C' from the bids above the $P^c + \Delta$ and 'B' from the bids between P^c and $P^c + \Delta$. However, it is not enough to compare those spaces directly (i.e., A vs. $B + C$) using the observable bids data for the revenue comparison due to the following reasons.

First, a lot of conditions of the auctions under each mechanism, such as supply quantities, number of bidders, financial market circumstances, were different because each mechanism was implemented for different periods. Just comparing the realized government revenues without controlling for other factors is not appropriate. Second, simply observing the realized bids cannot measure how much the bidders shaded their true value. If the other conditions are the same, the mechanism by which bidders make the bids closer to the actual valuations will be more favorable to increase government revenue. For example, even if the government can absorb more of the bidder's surplus in one auction than in another, if the bidder shades more of the valuation in the auction, then we cannot prejudge that one auction method is more effective than another. Bid shading incentives of bidders vary by auction mechanism, and to analyze them we need to figure out the true valuations. For these reasons, this paper introduces a structural approach to identify bidders' true valuations and conducts a counterfactual simulation to compare the effectiveness of the two mechanisms.

The analysis strategy of this paper is as follows. First, I estimate the marginal valuations of all bidders in every auction of each format. As mentioned earlier, incentives for shading bids vary depending on the auction mechanism, so we cannot directly compare government revenues through the observed bids. To estimate a bidder's marginal valuation in an auction, we need a distribution of market-clearing prices for the auction, conditional on the bidder's bid vector. The distribution of market-clearing prices can be estimated by constructing the residual supplies that a bidder can face in the auction. Once marginal valuations of all bidders are estimated, we can calculate the hypothetical benchmark. I use the total surplus of Vickrey auction as a benchmark. By comparing the revenue and the total surplus of each realized mechanism with the hypothetical benchmark, we can compare the performance of the mechanisms indirectly through their relative differences.

Meanwhile, unlike single-unit auctions, in the case of multi-unit auctions, a direct approach involving converting the estimated valuations into bid equilibria in an alternative auction and comparing the revenue of the alternative auction with the revenue of the original mechanism is known to be very difficult. The first reason is the 'Theoretical vacuum.' The equilibrium mapping of multi-unit auctions from values to bids is not clearly characterized. The first-order condition that can be derived from the profit maximization problem is a necessary condition for a Bayesian-Nash equilibrium, not a sufficient condition. Since bidders' bid shading incentives vary by auction, we need to know each bid function in order to measure it, but we don't have enough knowledge of the features of bid functions of all the alternative formats. Also, the issue of multiple equilibria has been raised in uniform price auctions. To deal with this problem, strong assumptions, such as a linear equilibrium, are needed, but imposing additional prior assumptions can hinder correct estimation. Finally, there is the problem of computational difficulties. Bidders' bidding strategies in a multi-unit auction are high-dimensional. Because of the 'Curse of Dimensionality,' the computational cost will be huge. For these reasons, most existing literature[6] takes the indirect approach used in this study.

I follow Wilson's (1979) set up of the share auction model for divisible goods auctions. I assume, like Kang and Puller (2008), that the bidders have Independent Private Value (IPV).[7] The basic characteristics of the Korean government bond market have not changed significantly since then, and it is reasonable to make such assumptions in light of market participants' statements and related studies. Under IPV, bidders play symmetric bidding strategies, and the strategies constitute a Bayesian-Nash equilibrium. Bidder i's valuation (v) on quantity (q) satisfies $v(q, s_i, s_{-i}) = v(q, s_i)$ because the valuation depends on private information s_i known only to i and does not depend on other bidders' information s_{-i}. I also assume that bidders' valuations are continuous and weakly decreasing (i.e., non-increasing) in bid quantity q.

Bidder i's bid function can be expressed as $y_i(p)$. Each bidder decides how many quantities to bid according to a given price (p). Similar to a normal downward demand curve, the lower the price, the larger the bid quantity will be. If the total supply is Q and the number of bidders is N, the market-clearing price (p^c) is determined at

$$y_i(p^c) = Q - \sum_{j \neq i}^{N} y_j(p^c) \tag{1.1}$$

[6]Hortaçsu (2002), Kang and Puller (2008), Hortaçsu and McAdams (2010), Kastl (2011), etc.

[7]Kang and Puller (2008) assumed Korean treasury auctions to be IPV auctions for the following reasons.

> First, each bidder may have a different reserve requirement for treasury bills or a different availability of liquidity which is not known to their rivals. Second, primary dealers serve as intermediaries to purchase securities for other firms, and each primary dealer may have a different level of commitment to place orders for customers. The terms of the purchase arrangements can make winning units in the auction more valuable to some PDs than to others. Finally, each bidder may have different forecasts of long-run interest rates which generate different values to holding government securities. (p.298)

The left side of the equation is the demand of bidder i at a certain price p and the right side is the residual supply at p, the total quantity supplied minus the total of other bidders' demand. The price at which the demand and residual supply meet becomes the market-clearing price.

The cumulative distribution function of market-clearing price ($G(.)$) conditional on bidder i's bid function $y_i(p)$ is

$$\begin{aligned} G(p, y_i(p)) &= Pr\{y_i(p) \leq Q - \sum_{j \neq i}^{N} y_j(p)\} \\ &= Pr\{p^c \leq p | y_i(p)\} \end{aligned} \tag{1.2}$$

If the residual supply is greater than or equal to the demand for a specific price p, the market-clearing price p^c is less than or equal to the price. The function G(.) indicates the probability that the market-clearing price is less than or equal to a certain price p.

Uniform-price auction In a uniform-price, the profit of bidder i, who submits a bid schedule $y_i(p)$, conditional on a particular realization of a market-clearing price p^c, is given by

$$\int_0^{y_i(p^c)} v(q, s_i)dq - p^c y_i(p^c) \tag{1.3}$$

The first term is the sum of bidder i's valuations up to the winning quantity, and the second term is bidder i's payment, which is calculated by the market-clearing price times the winning quantity. In a uniform-price auction, regardless of the bidder's bids, the unit price per quantity is fixed at the market-clearing price. Bidder i's expected profit is determined by the probability of winning as well as the profit when the bidder wins. Since the market-clearing prices conditional on bidder i's bid function are distributed by $G(.)$, the bidder's expected profit maximization under the uniform-price auction becomes,

$$\max_{y_i(\cdot)} \int_0^{\infty} \{\int_0^{y_i(p^c)} v(q, s_i)dq - p \cdot y_i(p)\} dG(p, y_i(p)) \tag{1.4}$$

$dG(p, y_i(p))$ is a probability distribution function of market-clearing prices. It indicates the probability that a bid price is equal to the market-clearing price.

Hybrid auction In Korea's hybrid auction, bidder i's expected profit depends not only on the market-clearing price distribution but also on the likelihood that the bidder's bid price is higher than the sum of the market-clearing price (p^c) and the preset interval increment (Δ)[8]. If every winning bid of bidder i falls in between p^c and $p^c + \Delta$, her expected profit, conditional on p^c, is equal to that of a uniform-price auction, as reflected in equation (1.4). However, if some of her winning bids are included in upper intervals that are greater than $p^c + \Delta$, her expected payoff becomes different from the uniform-price auction case. If at a certain bid price p, when p is equal to the market-clearing price p^c and some bids of bidder i fall one level higher from the lowest interval, the bidder needs to pay $\Delta \cdot y_i(p^c + \Delta)$ in addition to $p^c \cdot y_i(p^c)$. Likewise, for the bids in t-th higher interval from the lowest interval, the bidder needs to pay $\Delta \cdot y_i(p^c + t\Delta)$ additionally. T_i, the total number of additional intervals of bidder i, is a rounded-down integer determined by the difference between the highest bid price and the market-clearing price (i.e., $T_i = [\frac{y_i^{-1}(0) - p^c}{\Delta}]$). The profit of bidder i, who bids $y_i(p)$ at p and whose bid function has T_i additional intervals, conditional on a particular realization of market-clearing price p^c, is given by

$$\int_0^{y_i(p^c)} v(q, s_i)dq - p^c y_i(p^c) - \mathbb{1}(T_i \geq 1)\Delta \cdot \sum_{t=1}^{T_i} y_i(p^c + t\Delta) \tag{1.5}$$

If we define the cumulative distribution of the market-clearing price of a hybrid auction, conditional on bidder i's bid vector $y_i(p)$ as $H(p, y_i(p))$, the bidder's expected profit maximization becomes

$$\max_{y_i(.)} \int_0^{\infty} \{\int_0^{y_i(p^c)} v(q, s_i)dq - p \cdot y_i(p) - \mathbb{1}(T_i \geq 1)\Delta \cdot \sum_{t=1}^{T_i} y_i(p + t\Delta)\} dH(p, y_i(p)) \tag{1.6}$$

[8] 3bp (0.03%) was used as the interval increment during the analysis period. During this time, 3bp was worth about 7-8 KW (Korean Won) for the 3-year maturity bond and 12-13 KW for the 5-year maturity bond, based on a 10,000 KW face value. The longer the maturity, the more coupons you receive, so the same yield increment creates different price increments.

1.4.2 Marginal Valuation Identification

Continuously Differential Bid Function Case

To compare the effectiveness of the two mechanisms with counterfactual analysis, we need to identify and estimate the marginal valuations of each bidder in every auction. In the uniform-price auction mechanism with a symmetric IPV assumption, a Bayesian-Nash equilibrium $y(\cdot)$ has to meet the following necessary condition for all bids. Using the Euler–Lagrange equation, the first-order condition in a uniform-price auction becomes,

$$v(y_i(p), s_i) = p - \frac{G_y(p, y_i(p))}{G_p(p, y_i(p))} \cdot y_i(p) \tag{1.7}$$

G_p and G_y are the derivatives of $G(.)$ with respect to p and y, respectively. The optimal bid price (p) for $y_i(p)$ unit is equal to the bidder's marginal valuation for that unit minus the shading factor $-\frac{G_y(p,y_i(p))}{G_p(p,y_i(p))} \cdot y_i(p)$. The numerator and the denominator of the shading factor refer to how much the cumulative market-clearing price distribution changes due to quantity changes and price changes, respectively. The numerator represents the effect of quantity shading on the market-clearing price distribution, and the denominator represents the probability distribution of the market-clearing prices. A bidder has an incentive to engage in bid shading, which is the incentive of reducing a demand quantity of a marginal unit, if there is a probability of lowering the expected market-clearing price by shading. Lowering the market-clearing price that applies to all other winning quantities can reduce the bidder's payment. If a bidder reduces some bid quantities by shading, the market-clearing price will decrease or remain the same. The probability that the market-clearing price will be lower than the bid price (i.e., $\Pr(p^c \leq p | y_i(p))$) becomes higher by quantity (y) shading, in other words, G_y is less than or equal to 0 (i.e., $G_y \leq 0$). The higher the bid price (p), the greater the probability that the market-clearing price will be lower than the bid price, so G_p is positive (i.e., $G_p \geq 0$). Since the shading factor is weakly positive, bidders bid less than or equal to their true valuations in the continuous differential model.

When $H(p, y_i(p))$ is the distribution of market-clearing price conditional on bidder i's bid function in a hybrid auction, and T_i is the total number of additional intervals of bidder i, the first-order condition of the expected profit maximization problem in the Korean hybrid auction becomes,

$$v(y_i(p), s_i) = p - \frac{H_y(p, y_i(p))}{H_p(p, y_i(p))} \cdot y_i(p) - \mathbb{1}(T_i \geq 1)\Delta \cdot \sum_{t=1}^{T_i} y_{ip}(p + t\Delta) \frac{H_y(p, y_i(p))}{H_p(p, y_i(p))} \qquad (1.8)$$

This is similar to the first-order condition of the uniform-price auction except for the last additional term of the shading factor. The shading factor is equal to the difference between the valuation and the price $(v - p)$. (i.e., The shading factor: $-\frac{H_y}{H_p} \cdot y_i(p) - \mathbb{1}(T_i \geq 1)\Delta \cdot \sum_{t=1}^{T_i} y_{ip}(p + t\Delta)\frac{H_y}{H_p}$). The first term of the shading factor is positive, as in the uniform case, but the second term is negative, since the derivative of the quantity of an upper interval with respect to price $(y_{ip}(p + t\Delta))$ is negative. If bidder i submits bidding schedules using the same bid function in both auctions and the market-clearing price distributions in both auctions are the same (i.e., $G(p, y_i(p)) = H(p, y_i(p))$), the shading factor of a hybrid auction is likely to be smaller than that of a uniform-price auction.

Discrete Step Bid Function Case

In reality, the bidders' bid functions are not continuously differentiable. In most treasury auctions, bidders are limited in the number of bids that they can submit, and bidders who participate in the Korean treasury auction can submit up to 5 bid points (price-quantity sets) per auction. Due to the limitation, a consecutive quantities range may be bid at the same price, and the bid function with a quantity on the X-axis and price on the Y-axis becomes a non-differentiable step function. Kastl (2011) suggested a model for discrete step bid functions instead of continuous downward sloping bid functions. He proved that the marginal value will be overestimated significantly in a uniform-price auction if discreteness is not taken into account.

If the maximum number of bid points that bidders can submit is K (e.g., in the Korean case, K=5), each bidder has a left-continuous step function with a maximum of K steps. Bidder i's k-th step ($k \leq K$) bid point is (y_{ik}, p_{ik}), when y_{ik} stands for the share of total bid quantity accumulated up to the k-th step ($y_{ik} \in [0, 1]$), and p_{ik} is the bid price at the k-th step. The larger k, the lower the auction price and the larger the quantity (i.e., $p_{ik} \geq p_{ik+1}, y_{ik} \leq y_{ik+1}$). Each bidder would have a marginal valuation per every quantity share with a continuous, weakly decreasing valuation function. However, since the exact forms of the valuation functions are unknown, I estimate the marginal valuations of the bid steps (e.g., $V(y_k)$) based on the submitted bid points.

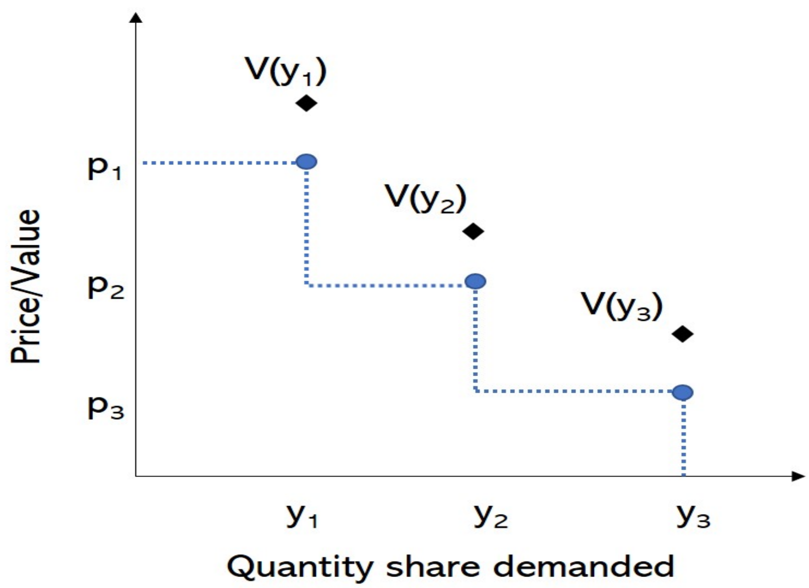


Figure 1.2: Illustration of a step bid function example

Kastl (2011) characterizes a necessary condition in a uniform-price auction that strategies played by bidders at all equilibria must satisfy. In every k-step of a bidder, if there is the probability of changing the expected market-clearing price by bid shading (i.e., reducing a bit of demand quantity at a marginal point), the bidder's strategy is determined at the point that the marginal benefit of shading and the marginal cost of shading are the same. A bidder has the incentive to shade on the last unit of the step k, when the market clearing price is between the bidder's two bid steps (i.e., $p_{ik} < p^c < p_{ik+1}$). In other words, when the residual supply crosses a vertical part of the bidder's demand function and the bidder can win the full quantity that she bid (y_{ik}) at step k.[9]

In any Bayesian-Nash equilibria, any local deviation should not be profitable. Therefore, in uniform-price auctions, the following condition needs to be satisfied:

$$Pr(p_{ik} > p^c > p_{ik+1})[v_i(y_{ik}, s_i) - \mathbb{E}_{S_{-i}|s_i}(p^c | p_{ik} > p^c > p_{ik+1})] \\ = y_{ik} \frac{\partial \mathbb{E}_{S_{-i}|s_i}(p^c; p_{ik} \geq p^c \geq p_{ik+1})}{\partial y_{ik}} \tag{1.9}$$

$$\text{(Where} \quad \mathbb{E}_{S_{-i}|s_i}(p^c; p_{ik} \geq p^c \geq p_{ik+1}) = \mathbb{E}_{S_{-i}|s_i}(p^c \mathbb{1}(p_{ik} \geq p^c \geq ip_{ik+1}))$$

As mentioned before, (y_{ik}, p_{ik}) is bidder i's k-th bid point and $Pr(p_{ik} > p^c > p_{ik+1})$ is the probability that a market-clearing price is between two adjacent bid steps. $v_i(y_{ik}, s_i)$ is bidder i's marginal valuation of y_{ik}, based on the bidder's information s_i. $E_{S_{-i}|s_i}(p^c|p_{ik} > p^c > p_{ik+1})$ is the expected market-clearing price under the condition that it is located between the two bid steps based on the expected other bidders' information S_{-i}, conditional on bidder i's information s_i. $\frac{E_{S_{-i}|s_i}(p^c; p_{ik} \geq P^c \geq p_{ik+1})}{\partial y_{ik}}$ is the ratio of the expected market-clearing price change to bid quantity change at the k-th step. The left-hand side (L.H.S.) of the equation represents the losing surplus or expected marginal cost of shading on the marginal unit, while the right-hand side (R.H.S.) represents the marginal benefit of quantity shading. They are illustrated graphically in Figure 1.3. When there is a possibility that the market-clearing price will fall in between the two price bid steps of the bidder, p_k and p_{k+1}, the bidder has the incentive of to shade her bid. If the bidder slightly reduces the bidding quantity, she loses

[9]If the market-clearing price is equal to the bid step price (i.e., $p^c = p_{ik}$), except for the knife-edge cases when the residual supply curve overlaps the bid function vertically at y_{ik} at p_{ik}, the residual supply curve crosses vertically the horizontal part of the bidder's bid function. That means that there is no bid shading incentive for the bidder, because there is excess demand at p_{ik}, and even if the last quantity unit of y_{ik} is shaded, it cannot affect the market price. Kastl (2012) stated that if there is a tie at p_{ik} or p_{ik+1}, that is, when more than one bidder is rationed, a bidder's bid shading can affect the bidder's allocation or the market-clearing price. For the sake of brevity and clarity, this paper excludes tie cases.

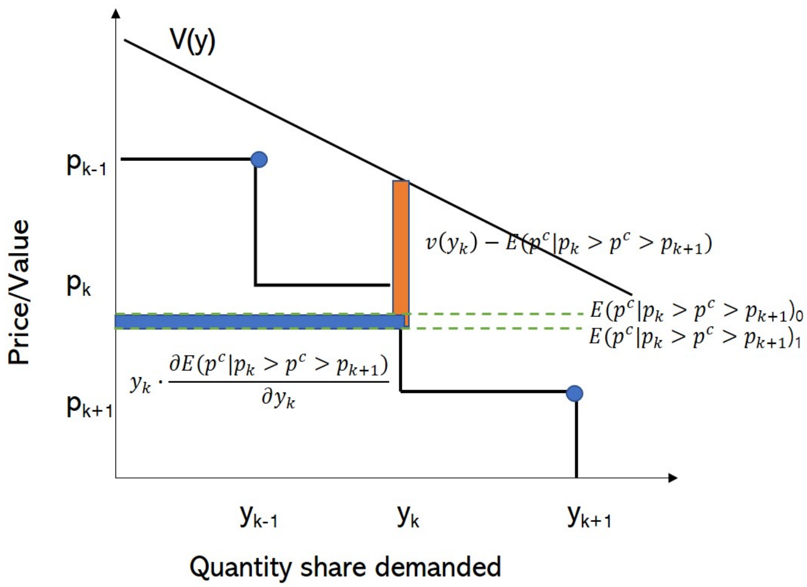


Figure 1.3: Bidder's problem in the uniform-price auction

the marginal profit on the final unit of the bid bundle at the k-th step to the extent of the difference between the marginal value and the expected market-clearing price. On the other hand, quantity shading can lower the market-clearing price that affects the payment for all the bidding quantities by that step, which enhances the bidder's benefit. By rearranging equation (1.9), the marginal valuation at the k-th step can be identified as follows:

$$v_i(y_{ik}, s_i) = \mathbb{E}_{S_{-i}|s_i}(p^c|p_{ik} > p^c > p_{ik+1}) + \frac{y_{ik}}{Pr(p_{ik}>p^c>p_{ik+1})} \frac{\partial \mathbb{E}_{S_{-i}|s_i}(p^c;p_{ik}\geq p^c\geq p_{ik+1})}{\partial y_{ik}} \quad (1.10)$$

Similar intuition can be applied to the Korean hybrid treasury auction. The market-clearing price (p^c) is determined in the same way for the uniform-price auction. The other differential prices are automatically determined by the sum of the market price and the integer multiple of the preset interval increment. If the preset interval increment is Δ, the prices applied to the bids in each interval are set as p^c, $p^c + \Delta$,... until the highest bid is included in an interval. Since the other differential prices are automatically determined by the market-clearing price, we only need to take into account the bidder's strategic action on the market-clearing price. Similar to the uniform-price auction, a bidder in the Korean hybrid auction has an incentive to engage in bid shading when the market-clearing price is strictly between the adjacent bid steps. Any local deviation should not be profitable in any Bayesian-Nash equilibria. In all equilibria, the expected marginal costs and benefits should be equal to each other, and the following condition needs to be satisfied in hybrid auctions:

$$\begin{aligned} &Pr(p_{ik} > p^c > p_{ik+1})[v_i(y_{ik}, s_i) - \mathbb{E}(p^c | p_{ik} > p^c > p_{ik+1})] \\ &= y_{ik} \frac{\partial \mathbb{E}(p^c; p_{ik} \geq p^c \geq p_{ik+1})}{\partial y_{ik}} \\ &\quad - Pr(p_{ik} > p^c > p_{ik+1}) \mathbb{1}(T_i \geq 1) \Delta \sum_{t=1}^{T_i} \sum_{j=1}^{k} \mathbb{1}[\mathbb{E}(p^c | p_k > p^c > p_{k+1}) + t\Delta - \delta \\ &\qquad \leq p_{ij} < \mathbb{E}(p^c | p_{ik} > p^c > p_{ik+1}) + t\Delta)] \cdot (y_{ij} - y_{ij-1}) \end{aligned} \tag{1.11}$$

As mentioned before, T_i, the total number of additional intervals of bidder i, is a rounded-down integer which is determined by the difference between the highest bid and the market-clearing price (i.e., $T_i = [\frac{y_i^{-1}(0) - p^c}{\Delta}]$). And δ is the expected market-clearing price change by the perturbation, which is the symbol that I use for brevity (i.e., $\frac{\partial \mathbb{E}_{S_{-i}|s_i}(P^c; p_k \geq P^c \geq p_{k+1})}{\partial y_k} = \delta$). As in the uniform-price auction, the L.H.S. of equation (1.11) represents the expected marginal cost, and the R.H.S. represents the expected marginal benefit of shading in the Korean hybrid auction. The expected marginal cost of shading is the same as in the uniform-price auction, as shown in the L.H.S. of equation (1.9). If the market-clearing price is between the two price bid steps of bidder i, the expected marginal cost of shading is the difference between the marginal value and the expected market-clearing price of the quantity (i.e., $v(y_{ik}) - E(p^c | p_{ik} > p^c > p_{ik+1})$).

On the other hand, the expected marginal benefit of shading can differ from the one in the uniform-price auction. The first term on the R.H.S. of equation (1.11) is the same as the R.H.S of equation (1.9) for the uniform-price auction. It is because the effect of market-clearing price changes due to quantity shading at a step act equally on all quantities up to that step, as shown in Figure 1.4, even though the winning prices vary by each interval. However, if quantity shading changes the interval level and the corresponding winning price applied to some bids, there can be an additional effect shown in the second term in the R.H.S of equation (1.11).[10] The second term shows the possible reduced benefit when the winning prices applied to some ranges increase due to a downward revision of the price interval level. If there are T_i additional price intervals up to the marginal k-th step and there is a bid range $(y_{ij} - y_{ij-1})$ in which the corresponding winning price is changed to the price of the upper interval, then the cost for the range increases by multiplying the quantity by the price interval increment (e.g., $(y_{ij} - y_{ij-1}) \cdot \Delta$). This occurs when a bid step is near the boundary of a price interval (e.g., $E(p^c) + t\Delta - \delta \leq p_{ij} < E(p^c) + t\Delta$), as shown graphically in Figure 1.5. Before shading, the market-clearing price is p^c and the price for the upper interval is $p^c + \Delta$. This bidder wins y_{k-1} at $p^c + \Delta$ and $(y_k - y_{k-1})$ at p^c, respectively. After shading, the market-clearing price is lowered to $p^c - \delta$. In this example, since the bid price in the k-th step (p_k) is close to the price interval division line, not only the bids in the $k-1$-th step but also the bids in the k-th step, fall to the higher interval at this time. For the k-th step quantity $(y_k - y_{k-1})$, the bidder needs to pay $p^c - \delta + \Delta$ this time, which may be more than p^c. The blue regions reflect the benefit of lowering the market-clearing price by shading, and the yellow region shows the possible loss from price interval level changes. The net value is shown by subtracting the space of the yellow region from the space of the blue region, which becomes the expected marginal benefit in this case.

The marginal valuation at the k-th step in the Korean hybrid auction is identified as

[10] This happens only when $T_i \geq 1$ because if $T_i = 0$, it is the same as the uniform-price case. For the real data of the Korean treasury auctions, T_i is 0 or 1 for most cases.

follows:

$$
\begin{aligned}
v_i(y_{ik}, s_i) = {} & \mathbb{E}(p^c | p_{ik} > p^c > p_{ik+1}) \\
& + \frac{y_{ik}}{Pr(p_{ik} > p^c > p_{ik+1})} \frac{\partial \mathbb{E}_{S_{-i}|s_i}(p^c; p_{ik} \geq p^c \geq p_{ik+1})}{\partial y_{ik}} \\
& - \mathbb{1}(T_i \geq 1)\Delta \sum_{t=1}^{T_i} \sum_{j=1}^{k} \mathbb{1}[\mathbb{E}(p^c | p_{ik} > p^c > p_{ik+1}) + t\Delta - \delta \\
& \qquad \leq p_{ij} < \mathbb{E}(p^c | p_{ik} > p^c > p_{ik+1}) + t\Delta](y_{ij} - y_{ij-1})
\end{aligned}
\tag{1.12}
$$

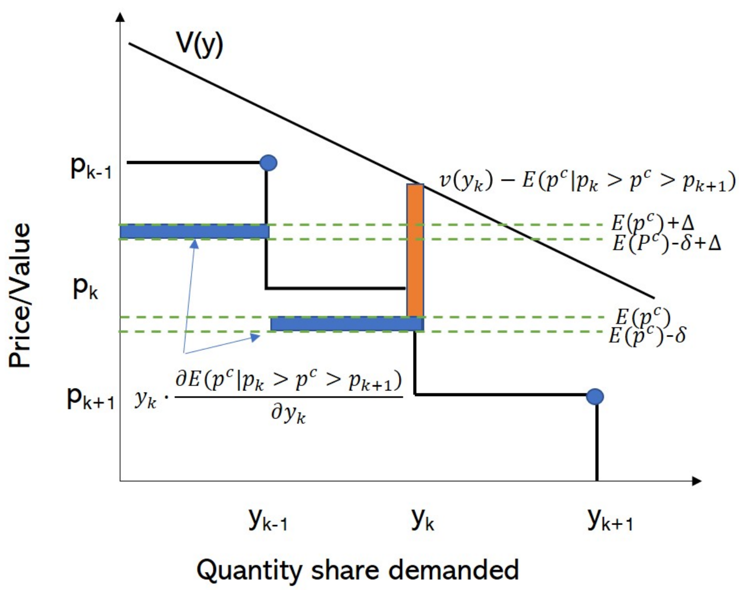


Figure 1.4: Bidder's problem in the hybrid auction 1 (No interval change in bid step)

1.4.3 Resampling approach

To compare the government revenue and efficiency between the two mechanisms, it is necessary to estimate the marginal valuations of each bidder in each auction. To do this, we first need to estimate the distributions of market-clearing prices conditional on each bidder's observed bid vectors. Once we have the distributions, we can calculate each bidder's expected

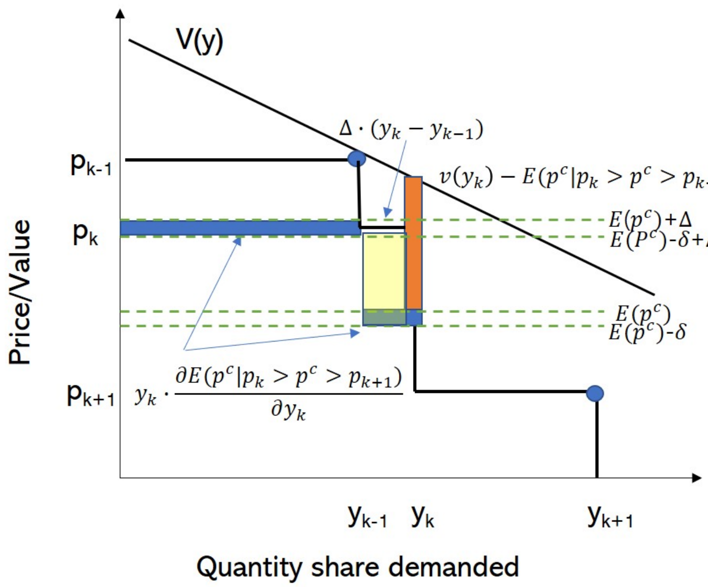


Figure 1.5: Bidder's problem in the hybrid auction 2 (Change of interval in bid step)

market-clearing price between the two bid steps, and the estimated change of the expected market-clearing price due to the quantity shading. Then, according to equation (1.10) and (1.12), we can estimate the marginal valuations. Hortaçsu (2002) suggested the 'resampling approach' for the estimation of the market-clearing price distributions and thereafter, Kang and Puller (2008), Hortaçsu and McAdams (2010), Kastl (2011), Hortaçsu and Kastl (2012), Hortaçsu et al. (2018), etc. used the method for auction mechanism analysis. The idea is to first fix a bidder's bid function and, second, randomly draw bid functions by the number of bidders who participate in the auction to form a residual supply that the fixed bidder may face. By intersecting the fixed bid function and a constructed residual supply function, we can find a market-clearing price. By repeating this process many times, we can obtain a lot of market-clearing prices, and from them, we can estimate the market-clearing price distribution that will be faced by each bidder empirically. The resampling process presented in previous literature and used in this paper is as follows:

1. Fix a bidder i and the bid vector made by this bidder among N_t bidders (i.e., N_t bid

vectors) in auction t.

2. Draw a random sample of $N_t - 1$ bid vectors with replacement giving an equal probability of $1/N_t$ from the N_t bid vectors in auction t.[11]

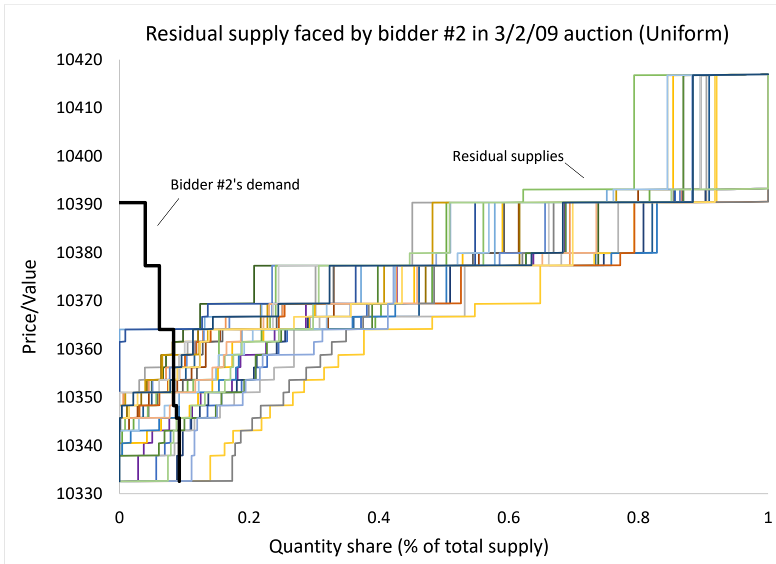
3. Construct a residual supply with the randomly drawn bid vectors and intersect it with the fixed bid vector of bidder i. Find the market-clearing price where the fixed bid vector and the residual supply meet.

4. By repeating steps 2 and 3 many times, construct the market-clearing price distribution given i's bid function.

5. Repeat steps 1-4 for each bidder in all auctions in the data set.

I randomly drew 5,000 sample sets to construct residual supplies and found 5,000 market-clearing prices per bid vector in an auction. The market-clearing prices are determined where the fixed bid vector and the residual supplies meet such as Figure 1.6. It is an example of a 30 sample sets case. I calculated the market-clearing price distributions of each bidder in each auction empirically by counting the number of market-clearing prices that were in specific ranges. I estimated the conditional expected market-clearing price by looking at the market prices in the corresponding range and their distribution under the condition where the prices were between the two bid steps (i.e., $\mathbb{E}_{S_{-i}|s_i}(p^c|p_k > p^c > p_{k+1})$). The expected market-clearing price's change by quantity perturbation (i.e., $\frac{\partial \mathbb{E}(p^c;p_k \geq p^c \geq p_{k+1})}{\partial q_k}$) also needed to be calculated to estimate the marginal benefit of shading. It could be calculated by the difference between the expected market-clearing price before and after the perturbation (i.e., $\mathbb{E}(p^c; p_k \geq p^c \geq p_{k+1}, q_k) - \mathbb{E}(p^c; p_k \geq p^c \geq p_{k+1}, q_k - \epsilon)$) divided by the perturbed quantity value (ϵ). The perturbed expected market-clearing prices could be estimated by perturbing

[11] In some papers, they draw random samples of bid vectors from all the auctions, not from the auction with the fixed bid vector. However, because I was concerned about unobserved heterogeneity across auctions and possible multi-equilibria, which might be caused by bidders' playing different equilibria in different auctions, I estimated marginal valuation auction by auction.



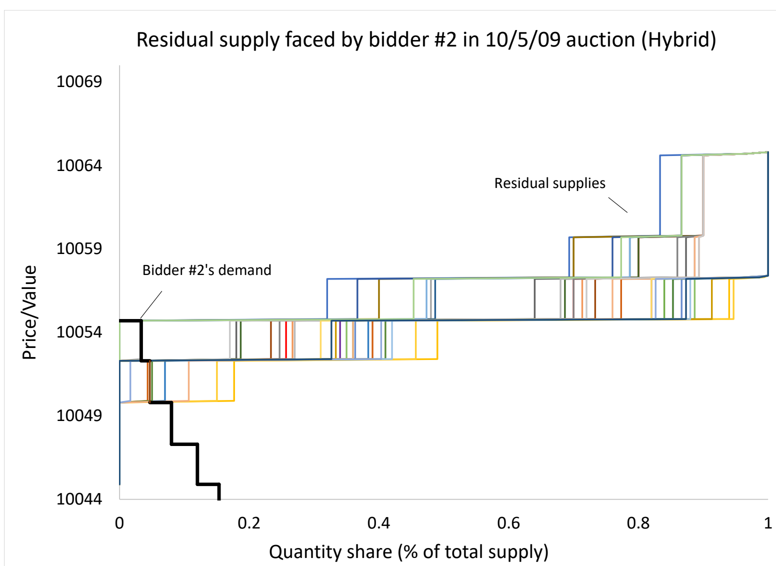


Figure 1.6: Example of the resampling residual supplies of a bid function

each step of the corresponding bid vector and repeating steps 1-5 above. If there were no residual supplies that crossed between the two bid steps, p_k and p_{k+1}, the marginal valuation at step k could not be calculated, because the conditional expected market-clearing price could not be figured out. For example, when the bidder's first or second step bids were very high compared to other bids, there might be no residual supply passing between the two steps. In this case, I made the marginal valuation equal to the bid price (p_k), since the bidder did not have any incentive for shading at the step.

1.5 Results

1.5.1 Marginal Valuation Estimation

Following the model and methodology presented above, I estimated the valuations of each bidder in each auction. Since the bidders are limited as to the maximum number of price-quantity bids in the real auction, the discrete step bid function model would do a better job of illustrating the reality. In practice, most bidders submit three to five bids per auction, and a non-negligible number of bidders occasionally submit a single bid. Therefore, the suggested results are based on the analysis considering 'discreteness.'

When the bidders' bid functions are step functions, the marginal valuations are often smaller than the bid prices at the observed marginal points of the steps (i.e., $v_k \leq p_k$). It is because bidders bid for a bundle, not for a point. Since marginal valuation weakly decreases in quantity, the marginal valuation of the inframarginal parts will be bigger than the marginal point in the same step. Even if a bid price is bigger than the estimated marginal valuation at a marginal point, the bidder's surplus is not negative. It is because the bidder pays the market-clearing price instead of her bid price. Once the marginal valuation is greater than the market-clearing price, the bidder's surplus is positive, and the surplus is bigger in the inframarginal parts than in the marginal points. In equations (1.10) and (1.12), the marginal valuation at step k is determined by the sum of the conditional expected market-clearing price between the two adjacent bid steps and the shading factor at step k. If a bidder is a price taker with no market power and the shading factor is zero, the marginal valuation at the marginal point of the step is the same as the conditional expected market-clearing price. On the other hand, if a bidder is influential in lowering a market-clearing price by shading, the marginal valuation is higher than the expected market-clearing price by her shading factor at the marginal step.

Counterfactual analysis requires estimating the marginal valuations for all quantities, not just observed bid points. To solve this practical problem, I use the upper bound of the marginal valuations, which is the maximum possible valuation schedule that can be derived from the observed points. The difference between the benchmark revenues calculated by using this conservative upper bound and the realized revenues shows the maximum amount that the government can obtain additionally by changing the issuance mechanism to the one which is the most profitable from the government's perspective. To construct the upper bound, we need to make some additional assumptions for the left side of the first step, where we do not have enough information. For the upper bound of the left part of the first step, I assign a higher value between the bid of the first step p_1 and the estimated marginal valuation of the first step v_1. Meanwhile, since the inframarginal units' true valuations are usually bigger than the bidders' bids at the marginal units, and markets are usually cleared at one of the interior steps of the most bidders, the assumptions for the left of the first step would rarely affect the market equilibrium analysis.

Figure 1.7 illustrates the examples of the marginal valuation estimation. It shows the estimated marginal valuations of bidder #4 and bidder #8 in a uniform-price auction and a hybrid auction each. Comparing each bidder's two graphs with one other, the differences between the estimated marginal value and the expected market-clearing price in the uniform-price auction tend to be greater than those of the hybrid auction. It is more pronounced when we compare the upper bounds and the original bid step functions of each mechanism.

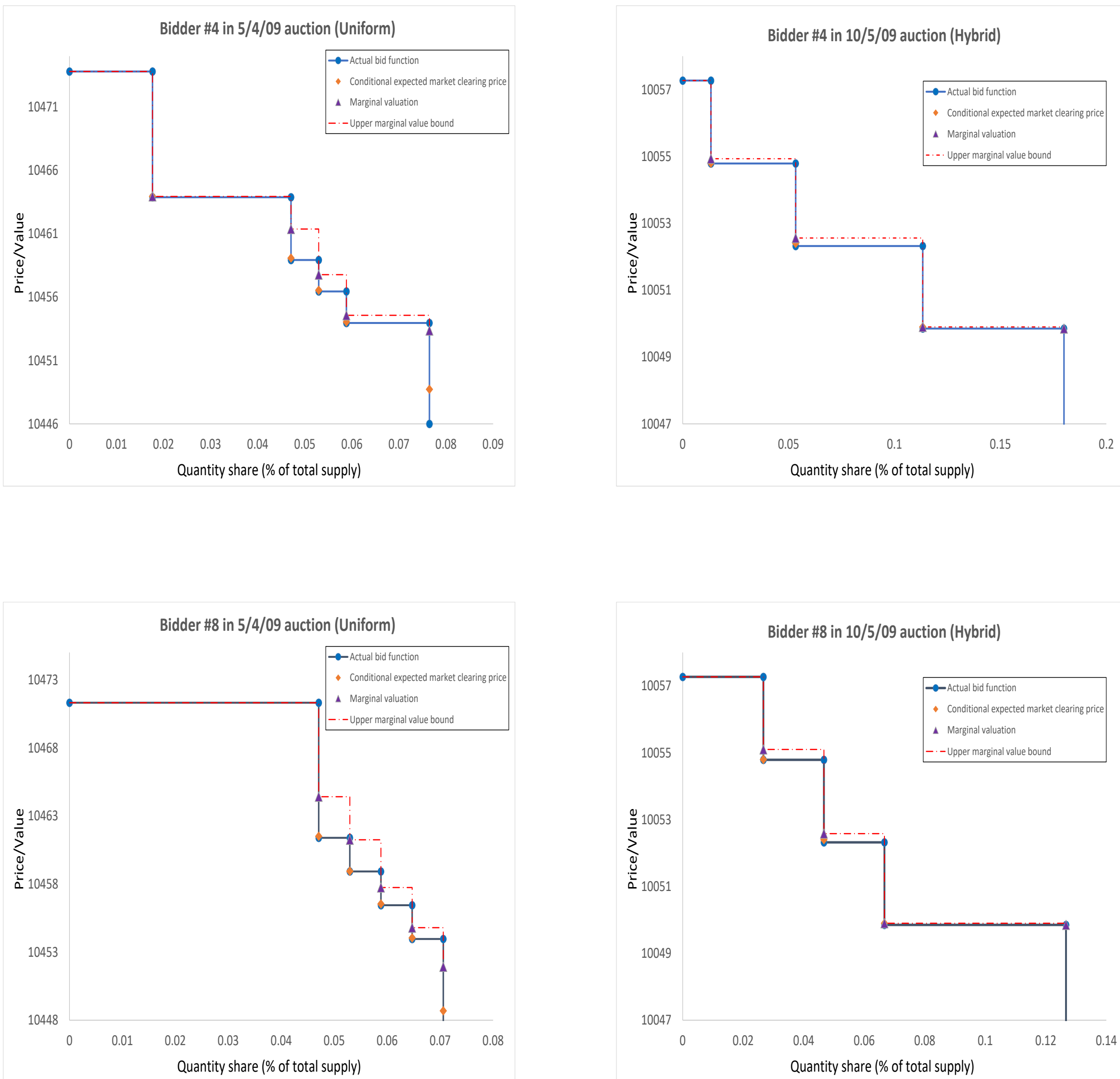


Figure 1.7: Bidders' marginal valuation estimation example

1.5.2 Government Revenue Comparison

I was able to construct the upper bounds of the estimated marginal valuations of every bid point by applying the above analysis to every bidder in every auction. As mentioned before, since the direct approach is not feasible, I compared the revenues of the two mechanisms —the uniform-price and the hybrid —indirectly by using a common benchmark, the total surplus in the Vickrey auction mechanism. Theoretically, the Vickrey auction mechanism is efficient, because it is designed for all bidders to bid according to their true valuations, but due to the complexity of the method, it is not actually easy to use. A bidder who wins k units in a Vickrey auction pays the sum of the highest bid to the k-th highest bid among the other bidder's losing bids, except for her own bids. Since the bidder's payment is independent of the bidder's bids, there is no incentive to shade the bids.

The total surplus in the Vickrey auction is the government's revenue, when the bidders bid with their truthful values and the government takes all the bidders' surplus. The more the government absorbs bidders' surplus, the greater the government's revenue will be. Since every issuance mechanism should guarantee the bidders a certain amount of surplus to encourage participation, this benchmark revenue may not be possible in reality. It is an extremely conservative upper limit on the revenue that the government can get from changes in the issuance mechanism, which has been introduced for relative comparison. With the true marginal valuations estimated by the method in the previous section, we can calculate the benchmark revenues, the total surplus of Vickrey auction that can hypothetically be obtained. By comparing this common benchmark revenue with the observed revenues under each mechanism, we can evaluate the issuance mechanism change effect on government revenues in Korea. If the revenue differences between the benchmark auction and the hybrid auction are smaller than the revenue differences between the benchmark and the uniform-price auction, we can say that the hybrid auction mechanism can bring in more revenue for the government.

Figure 1.8 shows examples of aggregate bids, estimated valuations and the market-

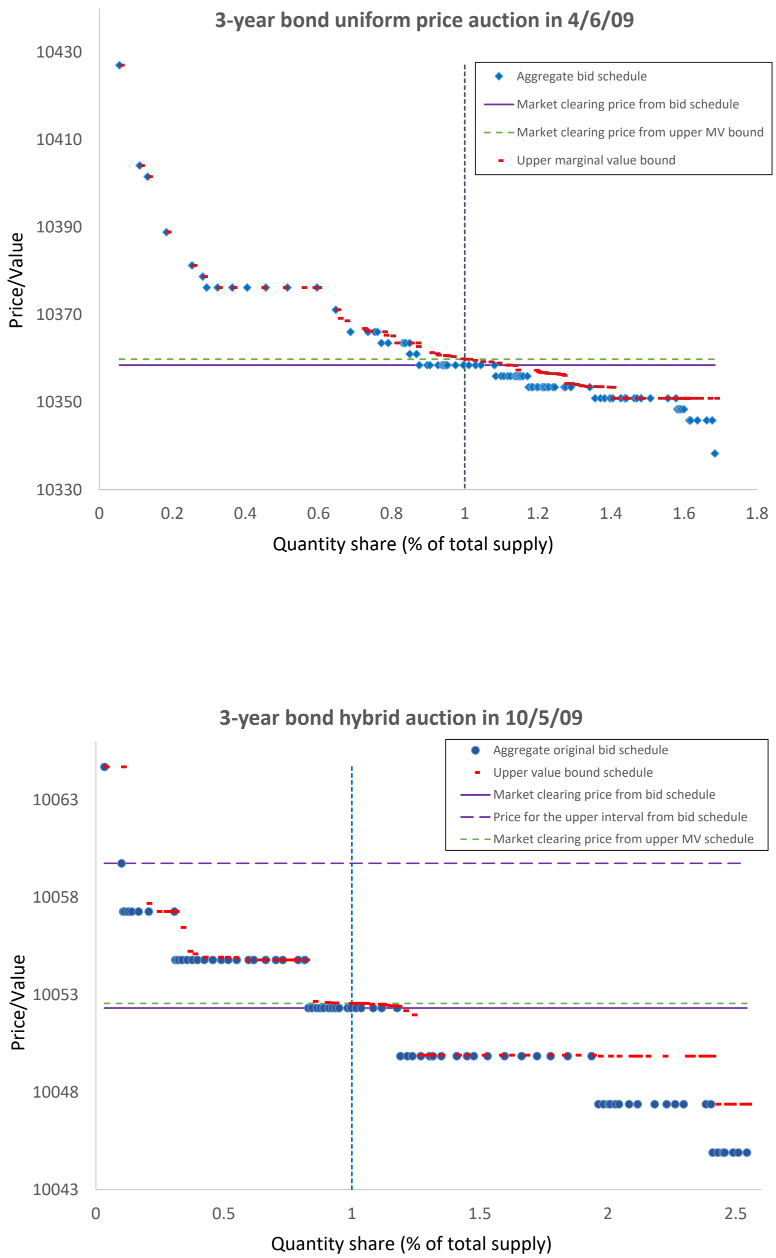


Figure 1.8: Aggregate bids and estimated valuations comparison

clearing prices under each auction and the Vickrey auction. The first graph is a 3-year bond uniform-price auction that was held on 4/6/2009. If we sort bids and estimated marginal valuations in the highest order each, we can construct the aggregate bid schedule and the upper marginal value bound of an auction. The bid price where the aggregate bid and the total quantity supplied meet (i.e., quantity share = 1) becomes the market-clearing price of the uniform-price auction actually conducted. The unit market-clearing price is 10,358.48 Korean Won (KW) per 10,000 KW face value, and it is illustrated with a solid horizontal line. Since all winners pay this unit price for the amount they earn, the government's revenue is the product of the market-clearing price divided by 10,000 and the quantity supplied. Meanwhile, from the upper bound of marginal valuations, we can find the market-clearing price under the Vickrey auction where bidders bid truthfully according to their valuations. The hypothetical market-clearing price illustrated with a dotted horizontal line, which is 10,359.82 KW, is above the actual market-clearing price. The benchmark revenue, the total surplus of the Vickrey auction, can be calculated as the sum of the bidders' surplus and the government revenue at the Vickrey auction. It is the area to the left of the vertical line, below the red dot. The revenue gap between the benchmark and the uniform-price auction is 0.17%.

The second graph in Figure 1.8 shows a 3-year bond hybrid auction that was held on 10/5/2009. With the original aggregate bid schedule, the market-clearing price is 10,052.32 KW, and the price applied to the upper interval is 10,059.75 KW.[12] The market-clearing price is indicated with a solid horizontal line, and the price for the upper interval is marked with a long dotted horizontal line. On the other hand, if the bidders bid with the truthful marginal value, the market-clearing price for the Vickrey auction is 10,052.56 KW; this is shown as a short dotted horizontal line right above the original market-clearing price. The revenue in the hybrid auction is the sum of the revenue from the bids in the upper interval

[12]The winning rate of the auction held in 4/6/2009 is 3.97%, but the winning rates of the auction held in 10/5/2009 were 4.34% and 4.31%. The lower the rate, the higher the bond price. That is why the bond price levels between the two auctions are different.

and the revenue from the bids in the lower interval. The revenue gap between the benchmark and the hybrid auction is 0.03%. This is smaller than in the case of uniform-price auctions.

Tables 1.3 and 1.4 show a comparison between the revenue under the actual mechanism and the benchmark that is the total surplus of the Vickrey mechanism in each auction. 'Actual revenue' columns show the government's revenues under the original mechanisms of uniform-price and hybrid auctions. The 'T.S in Vickrey' columns indicate the revenues that could have been obtained had the government used the Vickrey auction instead of the actual mechanisms and absorbed all the surplus of the bidders. The last columns show how much government revenues would increase if the government switched from a real implemented uniform-price or hybrid auction to a hypothetical scenario with a Vickrey auction.

As we can see from the table, the revenue differences with the benchmark in hybrid auctions are smaller than in uniform-price auctions for all maturities. The smaller difference in revenue means that the revenue under the mechanism is closer to the hypothetical maximum revenue cap. Therefore, there is a high possibility that the hybrid auction performs better than the uniform-price auction with respect to government revenue. For the 3-year bond auctions, the average revenue difference in uniform-price auctions is 0.15%, but in the hybrid auctions, it is 0.02%. For the 5-year bond auctions, the average differences are 0.25% and 0.04% for uniform-price and hybrid auctions, respectively. The differences are more pronounced for longer maturity bonds, such as 10-year and 20-year bonds. For the 10-year bond auction, the differences are 0.33% and 0.07%, respectively, and for the 20-year bond auction, 0.69% and 0.11%, respectively. Compared to the hybrid auction, the revenues from uniform-price auctions are about 5 to 7 times farther from the benchmark. In other words, there is 5 to 7 times more room for improvement in the uniform-price auctions than in the hybrid auctions.

The results can be explained as follows. First, in a hybrid auction, the government can absorb additional revenue from the bids that fall in the upper interval. In a uniform-price auction, bidders may bid aggressively, especially in small quantities, because bidders are less likely to pay their bid prices. This is a favorable side to increasing government revenue, but there is also a negative side to uniform-price auctions. That is, the government only absorbs a little bit of bidder surplus compared to hybrid auctions. Hybrid auctions are the opposite of uniform-price auctions. Bidders may bid less aggressively, but the government can absorb additional surplus from the bidders. If the effect of the additional surplus is bigger than the effect of the possible greater demand reduction, the government can derive more revenue from hybrid auctions.

Second, in a hybrid auction, the bidder may be more reluctant to shade their demand around the expected market-clearing price because of the risk that the bidder's bids may become included in other intervals, which are higher than the intervals before shading. Even if a bidder's shading in a marginal step can save the payout for all other winning bids, if there is a risk that the corresponding prices applying to some bids become higher by the corresponding interval level changes, the bidder's shading incentive could be lower. This is shown in the last term of equation (1.12). The closer a bidder's bids are to the ceiling of an interval below and the bigger the expected loss due to being included in the changed interval, the greater the role this factor plays in determining the bidder's shading decision.

Lastly, if a bidder finds it difficult to lower the market-clearing price through shading, the bidder would not shade her demand much. A bidder has an incentive to shade if the bidder can lower the market-clearing price at a marginal step to save the payout for all the winning quantities by the price difference. This incentive may depend on the data, but according to the data used in this paper, it seems to be difficult for a bidder to lower the market-clearing price in a hybrid auction. As seen in Figures 1.6 and 1.8, bids in the hybrid auctions are agglomerated in a small range, and large quantities are bid at the same price, so even if one bidder reduces her demand, it is difficult for the market-clearing price to be lowered. In other words, the residual supplies facing bidders in hybrid auctions are more elastic than in uniform-price auctions, and bidders are more likely to be price takers. The reason that the bid prices are formed thickly around the market-clearing price is that the more distant a bidder is from other bidders, the more penalties there will be, such as paying higher prices or failing to win. In hybrid auctions, bidders rarely tend to shade, because if a bidder shades her bid, the market-clearing price will barely change, but, rather, the bidder's benefit may be reduced due to the shaded demand.

Meanwhile, as the maturities of the bonds increase, the revenue differences with the benchmark (i.e., $T_v - R_a$) become larger in both auctions. In long-term bond auctions, a bidder has a high incentive to shade her true valuations, because the expected benefit of shading is bigger than for the short-term bond auctions.

Table 1.5 reflects the test for the revenue difference comparison. I constructed 500 bootstrapped resamples per auction by randomly drawing with replacement of the original bid vectors and estimated marginal valuations. Each resample consists of N_t (i.e., the number of bidders in auction t) randomly drawn pairs of bid vectors and the corresponding estimated marginal valuation vectors of the auction. With these resamples, we can calculate 500 pairs of revenues at each auction, revenues from the actual mechanisms, and the revenues from the benchmark. By summing up the revenue differences by maturity, we have the total revenue difference by maturity for both mechanisms. D_u is the difference between the benchmark and the uniform-price auction revenue (i.e., $D_u = (T_v - R_u)/R_u * 100$) and D_h is the difference between the benchmark and the hybrid auction revenue (i.e., $D_h = (T_v - R_h)/R_h * 100$). The null hypothesis that the difference in hybrid auctions is greater than the difference in uniform-price auctions (i.e., $H_0 : D_u < D_h$) is rejected for all maturities at a significance level of 0.05 (i.e., $\alpha = 0.05$). The t-test also supports the result that the revenues in hybrid auctions are closer to the benchmark than uniform-prices auctions.

In summary, the government is more likely to earn more revenue from hybrid auctions than from uniform-price auctions. That is, the hybrid auction's performance is closer to the benchmark. The result is consistent with the theory. Ausubel et al. (2014) suggest that the uniform-price auction does not generate as much expected revenue as the discriminatory auction. The discriminatory auction dominates the uniform-price auction, especially in settings with symmetric information with decreasing linear marginal utility. Since the hybrid auction in Korea has the characteristics of the discriminatory auction in addition to those of the uniform-price auction, the result showing that the hybrid auction performs better is consistent with the theory in this context.

1.5.3 Efficiency Comparison

Efficiency is an important factor in evaluating the performance of auction mechanisms. From the point of view of society, it is important to allocate the object of an auction to the bidder who values it most. To evaluate the efficiency of the two formats, the actual bidding under both formats needs to be observed. This is because both formats are inefficient compared to the Vickrey auction, and there is as yet no agreed-upon theoretical ranking of their efficiency. Most previous literature using only one format's data could not proceed to come up with an efficiency comparison. However, Kang and Puller (2008) suggested an efficiency comparison between the discriminatory and the uniform-price auction formats by observing the data from both formats in Korean treasury auctions.

Since I also obtained the bidding data from both uniform-price and hybrid auction mechanisms, it was possible for me to make an efficiency comparison. Following Kang and Puller (2008), the loss of efficiency was measured by the relative difference between the total surplus from the efficient allocation and the total surplus achieved from the allocation generated by the actual auction. The results are described in Tables 1.6 and 1.7. Efficiency losses in both uniform-price and hybrid auctions are very small. In most cases, the differences are close to zero. However, though they are arguably small, the losses in the hybrid auctions are smaller than in the uniform-price auctions for every maturity. In the 3-year bond auctions, the total efficiency loss in the uniform auctions is 0.0005%, but in the hybrid auction it is only 0.0001%. In the 5-year bond auctions, the total losses are 0.0004% and 0.0001%, respectively, and in the 10-year bond auctions, 0.0011% and 0.0002%, respectively. Lastly, in the 20-year bond auctions, the losses are 0.003% and 0.0005%, respectively. We can see that efficiency losses in the uniform-price auctions are about 4 to 6 times bigger than those of the hybrid auctions generally. Efficiency has been improved by introducing the hybrid auction format.

Efficiency is also related to the bidders' shading incentives. For example, if a bidder with a high valuation for some units has a strong incentive to shade her valuation and reduce the bid to lower the market-clearing price, then another bidder with a lower valuation can win the quantity instead of the bid shading bidder. That is why bid shading incentives can change the bid order differently than the valuation order. The greater the order change and the larger the shade scale, the greater the total surplus difference from the efficient Vickrey auction. The results show that even though there are bid shading incentives, they are not large enough to change the aggregated bid orders significantly. The absolute values of the efficiency losses are very small and both formats are close to the most efficient auction format, the Vickrey auction.

Nevertheless, since inefficiency arises due to differential bid shading by units rather than the shading itself, inefficiency tends to be bigger in the uniform-price auction. Even if bid shading is large, if it happens evenly across all units, there will be no change in demand order and no loss of efficiency. However, in the uniform-price auction, the deviation of bid shading in each unit is large. For smaller units, bidders do not have a large incentive to shade their actual demand, but for larger units that may affect market-clearing prices, the incentive becomes greater. The incentive is also greater for large bidders who have more market power than small bidders. As a result, the bidding order becomes different from the order of the actual values, and it leads to inefficiency. In hybrid auctions, the differential bid shading incentives are more limited than in uniform-price auctions. Even if there is the possibility of lowering the market-clearing price, bidders are reluctant to shade, because there is the risk that the intervals that apply to the bidder's bids may change, resulting in higher costs. Kang and Puller (2008) conclude that discriminatory auctions are more efficient than uniform-price auctions. According to their study, the average efficiency loss in the uniform-price auctions is over 20 times larger than the average efficiency loss in the discriminatory auctions. A hybrid auction is basically a uniform-price auction, but it possesses some of the discriminatory auction's characteristics. The results in this paper showing that the hybrid auction, with its discriminatory auction characteristics, is more efficient seem to be consistent with the results in the previous literature.

1.6 Conclusion

In this paper, I analyzed the effectiveness of uniform-price and hybrid auctions in terms of government revenue and efficiency using Korean treasury bond auction data. Due to the expected computational difficulties, I indirectly compared the two auction formats using a hypothetical common benchmark, the total surplus of Vickrey auction. By introducing the 'resampling approach,' which draws bid vectors randomly to construct a bidder's expected market-clearing price distribution, I estimated the true marginal valuations of all the bidders in every auction. Using the estimated valuations, I figured out the total surpluses in the Vickrey auctions and compared them with the revenues and total surpluses achieved in the actual auction mechanisms. The differences allow the two auctions to be compared in a parallel fashion by showing how far each auction's performance is from the benchmark auction. The results suggest that the hybrid auction mechanism performs better than the uniform-price auction mechanism. By switching to the hybrid auction mechanism, the Korean government was able to gain more revenue, and efficiency also improved. The Korean government's efforts, though not dramatic, seem to have succeeded as intended.

This Korean case suggests some policy implications. Most countries issue government securities employing two traditional auction formats, uniform-price or discriminatory. Many recent studies comparing the effects of the two methods suggest that discriminatory auctions perform better than uniform-price auctions, but it is not yet clear how much endogenous bidder participation decisions are affected by the mechanisms. Thus, despite the potential for increased government revenue, it is difficult for countries to fundamentally change their auction format to the discriminatory auction mechanism due to the fear of decreasing bidder participation. Therefore, as in Korea, some modification to the rules and a mixture of the characteristics of the two methods could be an alternative to find a balance between the desire to increase revenue and concern about a decrease in bidder participation. The results of this paper support this contention.

Table 1.3: Actual revenue vs. Total surplus in Vickrey auction (1)

(3-year bond auctions)

Mechanism	Date	Actual revenue (R_a, bil.KW)	T.S in Vickrey (T_v, bil.KW)	Difference (=[T_v-R_a/R_a*100], %)
Uniform	3/2/09	2,358.83	2,366.36	0.241
	4/6/09	2,817.51	2,822.69	0.171
	5/4/09	1,777.17	1,779.37	0.115
	6/1/09	2,450.83	2,455.15	0.156
	7/5/09	2,430.86	2,432.99	0.082
	8/3/09	2,505.55	2,508.13	0.100
	Total	14,340.75	14,364.68	0.146
Hybrid	10/5/09	1,507.96	1,508.40	0.034
	11/2/09	1,037.33	1,037.46	0.013
	12/7/09	1,199.49	1,199.76	0.022
	1/6/10	2,011.75	2,012.33	0.029
	2/1/10	2,062.93	2,063.16	0.011
	3/2/10	1,825.32	1,825.72	0.020
	4/5/10	1,209.15	1,209.35	0.017
	5/3/10	1,341.12	1,341.54	0.030
	6/7/10	1,083.68	1,083.84	0.014
	7/5/10	1,200.84	1,201.10	0.020
	Total	14,479.57	14,482.68	0.021

(5-year bond auctions)

Mechanism	Date	Actual revenue (R_a, bil.KW)	T.S in Vickrey (T_v, bil.KW)	Difference (=[T_v-R_a/R_a*100], %)
Uniform	3/9/09	2,577.88	2,590.25	0.383
	4/13/09	2,870.06	2,874.59	0.155
	5/11/09	2,397.56	2,401.41	0.123
	6/8/09	2,659.91	2,673.14	0.456
	7/13/09	2,242.63	2,246.48	0.172
	8/10/09	2,674.86	2,679.68	0.170
	Total	15,422.89	15,465.54	0.245
Hybrid	9/14/09	2,470.21	2,471.87	0.063
	10/12/09	1,832.43	1,833.14	0.039
	11/9/09	2,250.70	2,251.55	0.035
	12/14/09	1,242.23	1,242.76	0.042
	1/11/10	3,125.49	3,126.83	0.041
	2/8/10	2,777.85	2,778.49	0.023
	3/8/10	2,499.84	2,500.42	0.023
	4/12/10	2,646.37	2,647.68	0.048
	5/10/10	1,946.11	1,947.07	0.048
	6/14/10	2,137.49	2,138.36	0.039
	Total	22,928.71	22,938.17	0.040

Table 1.4: Actual revenue vs. Total surplus in Vickrey auction (2)

(10-year bond auctions)

Mechanism	Date	Actual revenue (R_a, bil.KW)	T.S in Vickrey (T_v, bil.KW)	Difference (=[T_v-R_a/R_a*100], %)
Uniform	2/16/09	623.21	627.96	0.762
	3/16/09	848.15	857.73	0.842
	4/20/09	1,075.95	1,079.46	0.268
	5/18/09	1,387.88	1,391.16	0.165
	6/15/09	1,400.29	1,403.95	0.262
	7/20/09	1,536.30	1,541.20	0.306
	8/17/09	1,444.40	1,446.93	0.154
	Total	8,316.18	8,348.40	0.333
Hybrid	9/21/09	1,911.63	1,912.75	0.059
	10/19/09	1,736.80	1,738.07	0.070
	11/16/09	1,484.27	1,485.87	0.108
	12/21/09	1,364.67	1,366.06	0.116
	1/18/10	2,075.58	2,076.91	0.065
	2/16/10	1,651.48	1,652.06	0.035
	3/15/10	2,203.30	2,204.33	0.048
	4/19/10	1,997.56	1,999.32	0.083
	5/17/10	1,799.10	1,800.42	0.070
	6/21/10	1,704.09	1,704.49	0.024
	Total	17,928.47	17,940.28	0.066

(20-year bond auctions)

Mechanism	Date	Actual revenue (R_a, bil.KW)	T.S in Vickrey (T_v, bil.KW)	Difference (=[T_v-R_a/R_a*100], %)
Uniform	2/23/09	309.86	312.45	0.554
	3/23/09	418.19	426.93	2.089
	4/27/09	534.14	537.46	0.534
	5/25/09	720.64	725.29	0.511
	6/22/09	745.28	750.34	0.612
	7/27/09	764.13	768.00	0.483
	8/17/09	783.51	788.03	0.535
	Total	4,275.75	4,308.50	0.688
Hybrid	9/28/09	813.50	814.59	0.194
	10/26/09	814.23	815.47	0.152
	11/23/09	849.37	850.66	0.153
	12/28/09	692.36	693.12	0.103
	1/25/10	1,065.90	1,066.91	0.090
	2/22/10	1,158.14	1,158.55	0.035
	3/22/10	900.23	901.31	0.120
	4/26/10	869.44	870.42	0.112
	5/14/10	993.85	994.92	0.108
	6/28/10	933.46	934.50	0.095
	Total	9,090.47	9,100.45	0.112

Table 1.5: Test for Revenue Differences Comparison (Diff=$D_u - D_h$)

Maturity	Rev. Diff. with T_v	Mean (Std. Err.)	95% C.I.	Test Result (H_0: Diff<0)
3-year	D_u	0.1679 (0.0008)	[0.1663, 0.1696]	
	D_h	0.0270 (0.0001)	[0.0267, 0.0272]	
	Diff	0.1409 (0.0008)	[0.1394, 0.1425]	Reject
5-year	D_u	0.2705 (0.0029)	[0.2648, 0.2761]	
	D_h	0.0564 (0.0002)	[0.0560, 0.0568]	
	Diff	0.2141 (0.0029)	[0.2084, 0.2197]	Reject
10-year	D_u	0.4097 (0.0029)	[0.4040, 0.4155]	
	D_h	0.0860 (0.0003)	[0.0854, 0.0866]	
	Diff	0.3237 (0.0029)	[0.3181, 0.3294]	Reject
20-year	D_u	0.7204 (0.0043)	[0.7119, 0.7290]	
	D_h	0.1158 (0.0008)	[0.1143, 0.1173]	
	Diff	0.6046 (0.0046)	[0.5956, 0.6136]	Reject

Note (1): $D_u = (T_v - R_u)/R_u * 100$, $D_h = (T_v - R_h)/R_h * 100$, Diff $= D_u - D_h$
Note (2): The significance level used for the t-tests is 0.05 ($\alpha = 0.05$)
Note (3): The t-tests are based on 500 bootstrapped resamples.

Table 1.6: Efficiency losses under each auction format (1)

(3-year bond auctions)

Mechanism	Date	Total Surplus: Actual allocation (S_a, bil.KW)	Total Surplus: Allocation in the best-case Vickrey (S_v, bil.KW)	Efficiency Loss(%) (=[S_v-S_a/S_a*100])
Uniform	3/2/09	2,366.343	2,366.357	0.0006
	4/6/09	2,822.641	2,822.691	0.0018
	5/4/09	1,779.363	1,779.366	0.0002
	6/1/09	2,455.135	2,455.146	0.0004
	7/5/09	2,432.989	2,432.989	0.0000
	8/3/09	2,508.134	2,508.134	0.0000
	Total	14,364.605	14,364.683	0.0005
Hybrid	10/5/09	1,508.400	1,508.403	0.0001
	11/2/09	1,037.460	1,037.460	0.0000
	12/7/09	1,199.763	1,199.764	0.0001
	1/6/10	2,012.333	2,012.333	0.0000
	2/1/10	2,063.162	2,063.162	0.0000
	3/2/10	1,825.720	1,825.724	0.0002
	4/5/10	1,209.353	1,209.354	0.0001
	5/3/10	1,341.537	1,341.538	0.0001
	6/7/10	1,083.839	1,083.839	0.0000
	7/5/10	1,201.096	1,201.099	0.0002
	Total	14,482.663	14,482.676	0.0001

(5-year bond auctions)

Mechanism	Date	Total Surplus: Actual allocation (S_a, bil.KW)	Total Surplus: Allocation in the best-case Vickrey (S_v, bil.KW)	Efficiency Loss(%) (=[S_v-S_a/S_a*100])
Uniform	3/9/09	2,590.211	2,590.245	0.0013
	4/13/09	2,874.582	2,874.587	0.0002
	5/11/09	2,401.398	2,401.414	0.0007
	6/8/09	2,673.126	2,673.140	0.0005
	7/13/09	2,246.474	2,246.475	0.0000
	8/10/09	2,679.678	2,679.678	0.0000
	Total	15,465.469	15,465.539	0.0004
Hybrid	9/14/09	2,471.865	2,471.873	0.0003
	10/12/09	1,833.140	1,833.140	0.0000
	11/9/09	2,251.542	2,251.550	0.0003
	12/14/09	1,242.762	1,242.763	0.0001
	1/11/10	3,126.833	3,126.833	0.0000
	2/8/10	2,778.487	2,778.487	0.0000
	3/8/10	2,500.419	2,500.419	0.0000
	4/12/10	2,647.677	2,647.677	0.0000
	5/10/10	1,947.069	1,947.069	0.0000
	6/14/10	2,138.355	2,138.358	0.0001
	Total	22,938.149	22,938.169	0.0001

Table 1.7: Efficiency losses under each auction format (2)

(10-year bond auctions)

Mechanism	Date	Total Surplus: Actual allocation (S_a, bil.KW)	Total Surplus: Allocation in the best-case Vickrey (S_v, bil.KW)	Efficiency Loss(%) (=[S_v-S_a/S_a*100])
Uniform	2/16/09	627.964	627.964	0.0000
	3/16/09	857.691	857.728	0.0043
	4/20/09	1,079.440	1,079.462	0.0020
	5/18/09	1,391.163	1,391.163	0.0001
	6/15/09	1,403.943	1,403.952	0.0007
	7/20/09	1,541.188	1,541.200	0.0007
	8/17/09	1,446.916	1,446.928	0.0008
	Total	8,348.305	8,348.397	0.0011
Hybrid	9/21/09	1,912.754	1,912.754	0.0000
	10/19/09	1,738.047	1,738.066	0.0010
	11/16/09	1,485.873	1,485.873	0.0000
	12/21/09	1,366.045	1,366.057	0.0008
	1/18/10	2,076.907	2,076.907	0.0000
	2/16/10	1,652.064	1,652.064	0.0000
	3/15/10	2,204.326	2,204.326	0.0000
	4/19/10	1,999.315	1,999.315	0.0000
	5/17/10	1,800.417	1,800.424	0.0004
	6/21/10	1,704.489	1,704.493	0.0002
	Total	17,940.237	17,940.279	0.0002

(20-year bond auctions)

Mechanism	Date	Total Surplus: Actual allocation (S_a, bil.KW)	Total Surplus: Allocation in the best-case Vickrey (S_v, bil.KW)	Efficiency Loss(%) (=[S_v-S_a/S_a*100])
Uniform	2/23/09	312.433	312.448	0.0049
	3/23/09	426.929	426.929	0.0000
	4/27/09	537.400	537.459	0.0110
	5/25/09	725.266	725.290	0.0033
	6/22/09	750.322	750.344	0.0030
	7/27/09	767.994	767.998	0.0005
	8/17/09	788.024	788.029	0.0006
	Total	4,308.366	4,308.495	0.0030
Hybrid	9/28/09	814.594	814.594	0.0000
	10/26/09	815.466	815.466	0.0000
	11/23/09	850.665	850.665	0.0000
	12/28/09	693.116	693.125	0.0013
	1/25/10	1,066.898	1,066.910	0.0011
	2/22/10	1,158.552	1,158.552	0.0000
	3/22/10	901.308	901.309	0.0002
	4/26/10	870.421	870.421	0.0000
	5/14/10	994.919	994.919	0.0000
	6/28/10	934.473	934.495	0.0024
	Total	9,100.409	9,100.454	0.0005

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Chapter 2

FRANCHISE FIRMS' STORE LOCATION SELECTION STRATEGIES BY OWNERSHIP AND CONTRACT

2.1 Introduction

Many franchise chains such as burger chains operate different types of ownership stores, company-owned, and franchised. Company-owned stores are owned and operated by the franchiser company directly, and both revenues and costs are attributed to the company. On the other hand, franchised stores are owned and operated by a person or a group of people who purchases the right to use the franchiser's trademarks and other proprietary knowledge. In this case, not only revenues but costs as well are shared between the franchiser and the franchisee. As such, since the profit-sharing of a company depends on the ownership of its brand store, ownership can greatly influence the company's behavior, affecting such things as entry, exit, or store location choices.

However, there has not been much research into the effect of franchise store ownership and subsequent contracts on multi-store companies' market entry decisions and store location choices. In the franchise industry, it is important to study which store will enter which market, i.e., the mechanism that determines stores' locations. This is because store location is crucial for the success of a franchise, as shown in studies in which poor location is the top reason that a franchise store will fail. However, store locations are largely determined by franchisers, which are usually big companies, so information about their strategies is hard to access. Moreover, it is not easy to directly observe the ownership effect on firms' store locations, because every chain's restaurants use the same trademark and provide almost the same goods and services. A lack of information due to these reasons makes it difficult to know how franchise store locations are determined. It is therefore meaningful to model and assess franchise firms' strategies to reduce the information gap in the franchise industry.

This paper empirically analyzes how the ownership structure and the revenue-cost sharing contract between the franchisers and the franchisees affect firms' store location choice strategies. It also analyzes how the cannibalization effect (with stores of the same brand) and competition effect (with other brands' stores) affect store locations, because the presence of other stores also affects location choices. The influence of market characteristics such as population, housing prices on locations is also discussed. For this analysis, I use the burger chain industry data from Burger King Korea, McDonald's Korea, and other burger chains. I set the model of franchise headquarters' profit function, which is determined by market characteristics and the presence of other stores, taking into account ownership and contracts. I then find the parameters that best describe the present status by using Maximum Likelihood Estimation (MLE).

One of the main findings of this paper is that the characteristics of the markets in which company-owned stores are located may differ from the markets in which franchised stores are located. Also, when the franchise headquarters takes more revenues and pays more fixed costs, the franchised store locations become similar to the company-owned store locations. In other words, the greater the extent to which the headquarters gets involved in its franchisees' businesses —similar to a joint investor —the more it tends to allocate its franchised stores like its company-owned ones. When it comes to the effect of other stores' presence on location choices, the cannibalization effect from the same brand stores is bigger than the competition effect from other brands' stores. That is, firms are reluctant to have the same brand stores in the same market. Market characteristics such as population and housing prices are also important factors that influence the burger chains' store location preferences.

To the best of my knowledge, this is the first paper that deals with firms' location choices, store ownership, and profit-sharing contracts together. Among existing studies, Mazzeo

(2002) is the most closely related to this paper in terms of its methodology. He proposes an empirical model for analyzing product differentiation and oligopoly market structure by endogenizing firms' product-type decisions. I follow the basic concept of Mazzeo's (2002) methodology but develop it by introducing firms' profit functions reflecting two types of store ownership and profit-sharing contracts in this paper. Prior to Mazzeo (2002), Bresnahan and Reiss (1991) suggested the seminal methodology for estimating the equilibrium in the static entry model. They used the entry decisions of firms as indicators of underlying profitability. Berry (1992) extended the Bresnahan and Reiss (1991) model by allowing for heterogeneity among companies entering the market, including differences in fixed entry costs. Seim (2006) further developed it by introducing private information into the model, allowing idiosyncratic sources of profitability which are not observable by rivals.

This paper is also related to the literature which studies the entry and competition of the franchising industry. Toivanen and Waterson (2005) use data from McDonald's and Burger King in the UK to show that the presence of a rival increases expectations for market size and increases the likelihood of a company entering the market. Yang (2012) analyzed the spillover effects that a firm's decision to open a store is affected by its competitor. Kalnins (2004) analyzed encroachment within franchised and company-owned branded chains by using Texas lodging industry data. His findings that company-owned brand chains are more careful in deciding on additional store openings so as not to cannibalize existing stores than franchise companies are similar to my findings that companies behave differently depending on the type of governance form. Pancras et al. (2012) studied the cannibalization effect of the impact of a new store opening nearby using fast food restaurant chains data in a large U.S. metropolitan area. Nishda and Yang (2019) demonstrated that strategic considerations regarding market entry and expansion play a role in organizational-form decisions using convenience-store chains' data in Japan. My paper also contributes to the literature on these topics, as it also analyzes the cannibalization and competitive effects in firms' store location choices.

The remainder of this paper is organized as follows. Section 2.2 explains the institutional features of the burger chain market in Korea and provides descriptive statistics of the data used in this paper. Section 2.3 suggests a model and methodology for the estimation. Section 2.4 shows the estimation results, and Section 2.5 offers a conclusion.

2.2 Industry and data

2.2.1 Burger chain market in Korea

The primary reason I chose the burger chain industry for my analysis is that this is a market in which two kinds of ownership coexist, company ownership and franchise ownership, and even in some companies, two kinds of ownership coexist within the same entity. Though the share varies by brands, each type of ownership divides the market into a significant proportion. The other reasons are similar to those of Igami and Yang (2016). They mentioned that burger chain firms are one of the simplest multi-store firm forms in oligopolistic competition. Also, burger restaurants compete in relatively small geographical areas, which makes it possible to provide sufficient cross-sectional variation for econometric analysis. Entry and exit are the most important strategic decisions for burger chains, and we can analyze more complicated firm strategies, such as location choices, by observing the opening, not-opening or closing of stores.

In Korea, there are five big burger chains: Kentucky Fried Chicken (KFC), Burger King, McDonald's, Lotteria and Mom's Touch. The total number of restaurants of these five chains was about 3,163 at the end of 2016. Among them, Lotteria and Mom's Touch are local Korean brand chains, and their headquarters run the business based on the franchise system. More than 90% of Lotteria and 100% of Mom's Touch restaurants are franchises. On the other hand, McDonald's and Burger King make use of franchised and company-owned stores in tandem. At the end of 2016, about 29% of McDonald's and 27% of Burger King restaurants were franchises, and company-owned restaurants account for the rest. KFC's restaurants are 100% company-owned and are operated by KFC Korea[1].

Table 2.1: Big burger chains in Korea (At the end of 2016)

	KFC	Burger King	McDonald's	Lotteria	Mom's Touch	Total
Stores	236	266	435	1,332	894	3,163
Franchise ratio (%)	0	27.1	29.2	89.9	100	-

For the market unit, I use 'Dong,' which is one of the administrative districts in Korea. There are 3,503 'Dong' in Korea, and the average number of residents was about 14,780 as of 2017. For example, Seoul Metropolitan City, the capital of Korea, has 424 'Dong' with 9.78 million residents. Out of 3,503, I analyze 1,497 'Dong' that have one or more of those five big burger chain restaurants.

Table 2.2: Number of markets with each number of burger chains

	1	2	3	4	5	6	7	8	9	10	11	12	Total
markets	647	462	188	95	46	32	11	6	3	3	3	1	1,497

2.2.2 Market characteristics by each chain's distribution

The markets in which each chain's stores are located show significant differences. To determine the market characteristics of each chain, I calculated the average of the observable factors in the markets which can affect firms' profit. For the purchasing power from the population, I consider both the number of residents and the working people of the markets.

[1] The headquarters of KFCs in Korea is KFC Restaurants Asia Pte. Ltd. in Singapore. All KFC restaurants in Korea are franchises from that point of view. However, every KFC store in Korea is run by KFC Korea, and no individuals are allowed to operate KFC with a franchise contract. Therefore, I took into account that all of the KFC restaurants are company-owned and are owned and operated by KFC Korea.

Many studies do not take into account the working population, but ignoring it can distort the results of the studies. For example, we cannot measure the purchasing power correctly for the downtown areas, which have a small number of residents but a large number of employees who work in many of the businesses. I also considered population density calculated by dividing the total population[2] by the size of the market area. I assume that the greater the population density, the more attractive the market is, because burger restaurants compete in relatively small areas.

To reflect purchasing power by income, I use average housing price as a proxy, which is obtained from the apartment trading price per $1m^2$ of the market, since income data at the 'Dong' level are not available. More than 60% of households in Korea live in apartments, and apartments are prevalent throughout the country. Since every apartment transaction price is released almost in real-time, and the correlation between apartment price and the income tax per taxpayer is about 0.8, it can be a good proxy for income. In the meantime, to consider the impact of competition, I use the average number of own-brand stores and the average number of other brand stores in the market.

I obtained demographic data from diverse sources. The number of residents was obtained from 'resident registration statistics' of the Ministry of the Interior and Safety, Korea. The market areas for population density and the number of working people were from the 'census on establishments' of the National Statistical Office, Korea. Apartment transaction prices were obtained from the Ministry of Land, Infrastructure, and Transport, Korea. The number of burger chains was obtained from the 'local administration data' of the Ministry of the Interior and Safety, Korea.

As shown in Table 2.3, franchise ratios of firms and their market characteristics are closely related. When the franchise ratio of a chain —i.e., the ratio of franchised stores out of the total number of stores of the chain —is high, its markets tend to show the following

[2]For the total population, I add the number of residents and the number of working people. There may be some overlap, but it is not possible to distinguish between them.

characteristics. The average population, especially the number of working people, in the chain's markets is small, and the average population density and housing prices are low. In addition, the average number of other chains' stores in the market is small. To summarize, the burger chains which mainly operate franchised stores tend to be dispersed in diverse areas, including small cities and the outskirts of big cities, while the chains which mainly operate company-owned stores tend to be concentrated in busy commercial areas of big cities.

Table 2.3: Summary statistics of markets with each chain (2016)

	KFC	Burger King	McDonald's	Lotteria	Mom's Touch
No. of stores	236	266	435	1,332	894
Franchise ratio (%)	0	27.1	29.2	89.9	100
No. of markets with each chain	209	237	401	1,041	774
Average Population	45,379.3	44,974.95	40,680.4	35,100	33,109.5
(Resident)	26,475.4	26,855.8	26,688.9	24,238.2	23,796.5
(Working people)	18,903.9	18,119.2	13,991.4	10,861.8	9,313
Population density	24,649.3	22,870.6	20,224.1	14,780.2	12,291.4
Apt.trading price per $1m^2$ (10,000 Korean Won[3])	472.8	467.5	414.9	336.6	294.0
Avg. no. of stores per market					
(Own chains)	1.13	1.12	1.09	1.28	1.16
(Other chains)	2.68	2.38	2.02	1.17	1.41

The differences are more distinct when looking at the burger chain store location map in Figure 2.1. For example, KFC, with 100% company-owned stores, is located in the markets with a large population, high population density, high housing prices, and many competitors. On the other hand, Mom's Touch, with 100% franchised stores, is located in markets with less demand and a smaller number of competitors. This suggests that store ownership may be closely related to store location choices. The headquarters of the burger chains that operate

[3] Average exchange rate in 2016: 1 dollar = 1,161.1 Korean won

their stores with different ownership systems may have different strategies in determining store locations.

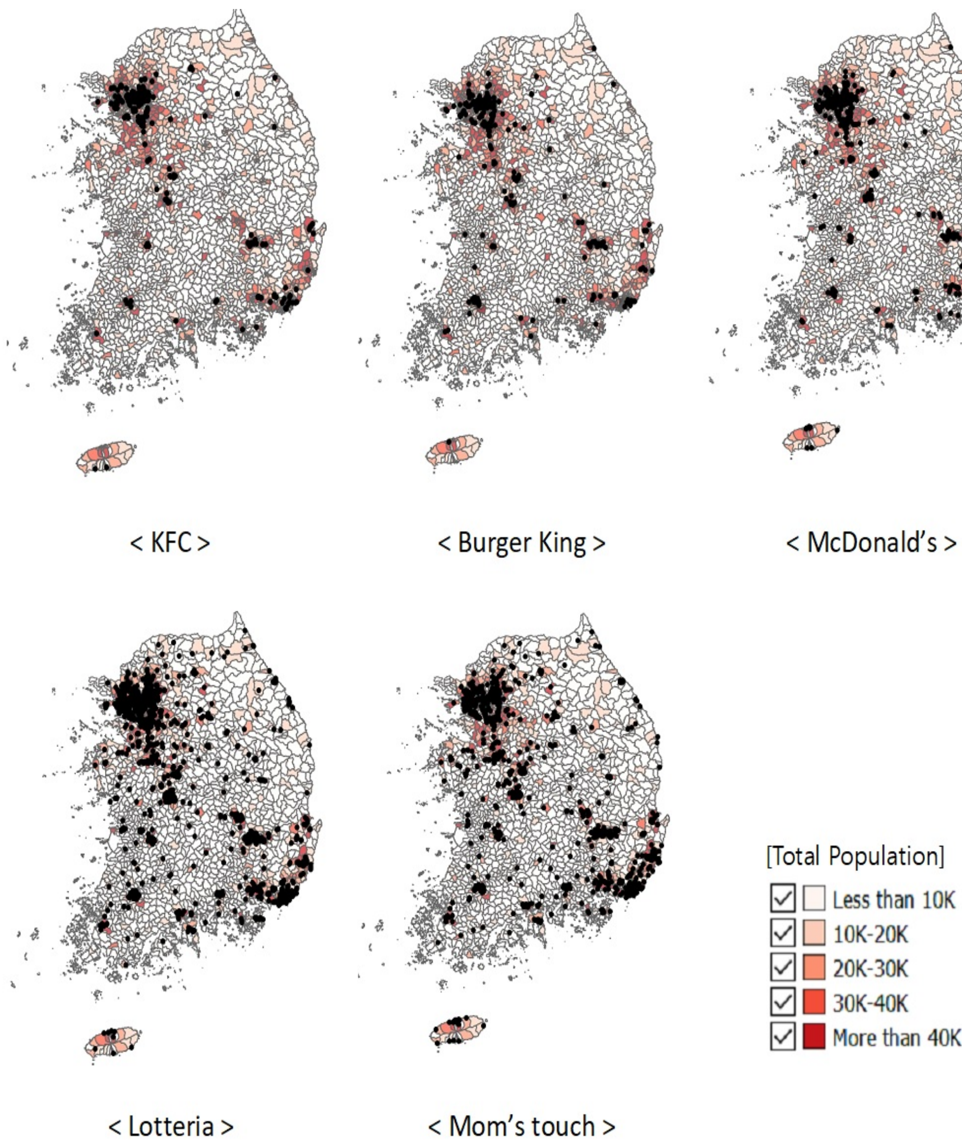

Figure 2.1: Burger restaurants distribution (2016)

2.2.3 Store location choices by ownership and contract

Store locations of Burger King and McDonald's

To determine the precise effect of ownership on store location choices, it is necessary to examine the decision within a firm. If we simply compare the different chains that operate using different types of ownership, it is hard to control for other factors that can affect the firms' choices. Therefore, it is necessary to analyze firms which have both types of ownership, such as Burger King and McDonald's. The advantage of this method is that we can control for the players' heterogeneity, because the entry decision is made by a single headquarters. Meanwhile, since the list of stores by ownership is considered to be the company's proprietary information, it is typically hard to use this approach, however, fortunately, I was able to obtain unique data from Burger King Korea and McDonald's Korea. It consisted of a complete listing of company-owned and franchised restaurants, including their addresses, as of the end of 2016. I combined it with other demographic data.

Both McDonald's Korea and Burger King Korea had run their restaurants based on company-owned ownership prior to 2010, but since early 2010 they have expanded their franchise businesses rapidly. As of the end of 2016, the ratio of franchised stores became 29% and 27% each. Their markets can be divided into three types: 1) markets with only company-owned stores, 2) markets with only franchised stores, 3) markets with both ownership stores. Table 2.4 and Table 2.5 show each chain's market summary statistics.

To ascertain which type of market each chain prefers by market characteristics, I found the regression coefficients of the multinominal logistic regressions in equation (2.1). The coefficients of the variables explain the log-odds of each chain's preference for markets with only franchised stores or for markets with both ownership types, compared to markets with only company-owned stores that have the base outcome.

Table 2.4: Summary statistics of markets of Burger King (2016)

	Company- only	Franchised- only	Both
No. of markets with each type	165	69	3
Average Population	44,375.1	43,332.42	115,747.3
(Resident)	24,991.3	31,231.3	28,761.0
(Working people)	19,383.7	12,101.1	86,986.3
Population density	27,215.9	11,477.0	45,932.4
(Population/Area)			
Apt.trading price per $1m^2$	531.2	289.2	1,068.4
(10,000 Korean Won)			
Avg. no. of stores per market			
(Own chains)	1.13	1	3.33
(Other chains)	2.27	2.61	3.67

Table 2.5: Summary statistics of markets of McDonald's (2016)

	Company- only	Franchised- only	Both
No. of markets with each type	277	112	12
Average Population	41,297.4	36,255.3	67,738.9
(Resident)	27,211.6	25,912.0	21,876.2
(Working people)	14,085.8	10,343.2	45,862.8
Population density	19,785.8	19,264.6	39,297.6
(Population/Area)			
Apt.trading price per $1m^2$	417.4	407.1	430.5
(10,000 Korean Won[4])			
Avg. no. of stores per market			
(Own chains)	1.06	1.03	2.33
(Other chains)	2.03	1.78	3.92

$$\begin{aligned} ln\left(\frac{Pr(\text{Market=Only F})}{Pr(\text{Market=Only C})}\right) &= \vec{\beta_{i1}}\vec{\text{X}} \\ ln\left(\frac{Pr(\text{Market=Both C and F})}{Pr(\text{Market=Only C})}\right) &= \vec{\beta_{i2}}\vec{\text{X}} \end{aligned} \tag{2.1}$$

- i: Firm, Burger King or McDonald's.

- $\vec{\beta}$: Vector of regression coefficients

- $\vec{X}$: Vector of variables such as the number of residents, working people, etc.

The preference difference between the markets with different ownership stores is more pronounced for Burger King than for McDonald's. The relative log-odds which prefer the markets with only franchised stores decrease as population density and apartment trading price increase, under 5% and 1% significance level each for Burger King. On the other hand, for McDonald's, the relative log-odds which prefer the markets with only franchised stores decrease as the number of working people increases, under 10% significance level, but other coefficients are not significant.

The difference between the two chains can also be seen visually in the store distribution map for each chain in Figure 2.2. The store locations between company-owned stores and franchised stores for Burger King are distinguishable, but not for McDonald's. Burger King's company-owned stores are concentrated in big cities such as Seoul, the capital of Korea, or Busan, the second largest city in Korea. On the other hand, Burger King's franchised stores are dispersed among small cities or located on the outskirts of big cities. Meanwhile, McDonald's does not show a distinct difference between the two ownership types.

Tests for equality between the two groups (e.g., markets with only company-owned stores vs. markets with only franchised stores) in Table 2.8 also show the difference between the two chains. By using MANOVA (i.e., multivariate analysis of variance and covariance), I tested the equality of two group means with market characteristics variables. The null

Table 2.6: Multinomial Regression by Burger King's market types

Category	Independent Variable	Coefficient (Std.Err)
Only C market	(base outcome)	
Only F market	Resident	0.0000237* (0.0000123)
	Working people	-9.49e-06 (0.00002)
	Population density	−0.0000365** (0.0000166)
	Apt.trading price	−0.0079455*** (0.0018521)
	No.of other chains	0.0127962 (0.1034463)
	Constant	2.111486 (0.6410758)
Both C and F market	Resident	0.000099 (0.0001143)
	Working people	0.000058 (0.0000392)
	Population density	0.000027 (0.0000491)
	Apt.trading price	0.0058646** (0.0029405)
	No.of other chains	-0.7647947 (1.026923)
	Constant	-13.59423 (6.284302)

Note: Standard errors are given in parentheses. The symbols *, ** and *** indicate the significance level of 10%, 5% and 1%, respectively.

Table 2.7: Multinomial Regression by McDonald's market types

Category	Independent Variable	Coefficient (Std.Err)
Only C market	(base outcome)	
Only F market	Resident	-1.82e-06 (8.65e-06)
	Working people	−0.0000268* (0.0000138)
	Population density	1.41e-07 (9.50e-06)
	Apt.trading price	0.0003716 (0.0006766)
	No.of other chains	-0.0077998 (0.0793654)
	Constant	-0.6810738 (0.3370247)
Both C and F market	Resident	-0.0000281 (0.0000262)
	Working people	0.0000185 (0.000013)
	Population density	0.0000258 (0.000018)
	Apt.trading price	-0.0031636 (0.0019245)
	No.of other chains	0.2670517 (0.1624512)
	Constant	-2.968361 (0.9972107)

Standard errors are given in parentheses. The symbols *, ** and *** indicate the significance level of 10%, 5% and 1%, respectively.

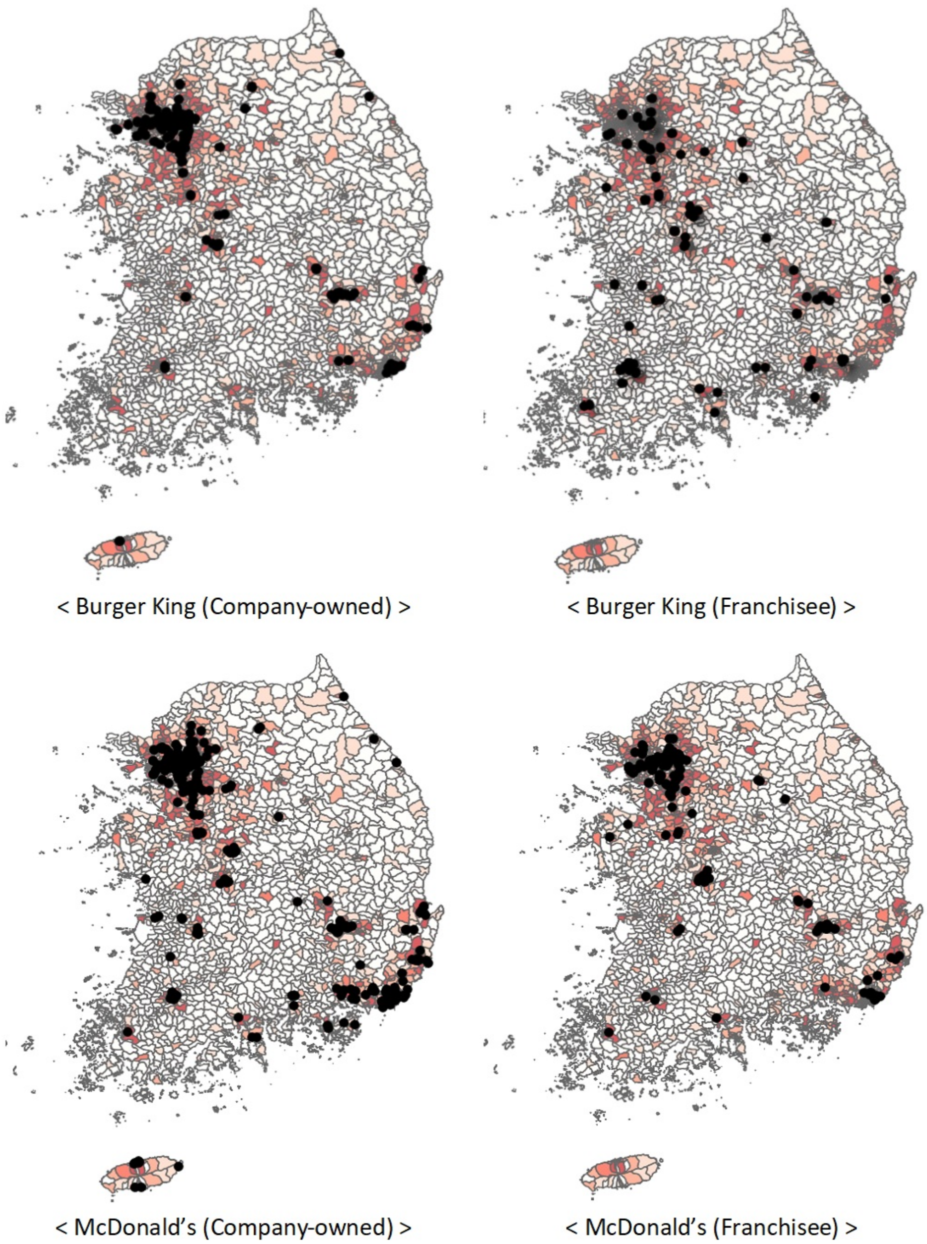

Figure 2.2: Burger King and McDonald's store distribution

hypothesis that the two group means are equal is rejected for Burger King but not rejected for McDonald's, at a significance level of 1%.

Table 2.8: Test for equality of two group means (Assuming homogeneity)

	Burger King			McDonald's		
	Statistics	F	Prob.>F	Statistics	F	Prob.>F
Wilks' lambda	0.7700	13.08	0.0000***	0.9861	1.03	0.3987
Pillai's trace	0.2300	13.08	0.0000***	0.0139	1.03	0.3987
Lawley-Hotelling trace	0.2987	13.08	0.0000***	0.0141	1.03	0.3987
Roy's largest root	0.2987	13.08	0.0000***	0.0141	1.03	0.3987

Note: The symbol *** indicate the significance level of 1%.

The difference is graphed in Figure 2.3 for easy comparison. I categorized each firm's markets into three by ranking such market characteristics as population, housing prices, etc. For example, Burger King is situated in 237 markets, and I divided the markets into three so that each category had the same number of markets, i.e., 79. I also divided McDonald's 401 markets into three so that each category contained 136 or 137 markets. Market 1 consists of markets with low population and low housing prices; on the other hand, market 3 consists of markets with a large population and high housing prices. I then looked at the percentage of each type in each market. Burger King shows a big difference between each type of ownership. For example, Burger King's company-owned stores have the largest proportion in market 3, while its franchised stores have the largest proportion in market 1. On the other hand, there is not much difference between McDonald's stores.

Franchise contract of Burger King and McDonald's

Both chains have stores using different types of ownership, and the franchise ratios are also similar, but their franchise store allocation behaviors are quite different. To figure out the reasons for such differences, I examined the franchise contracts of each chain between the

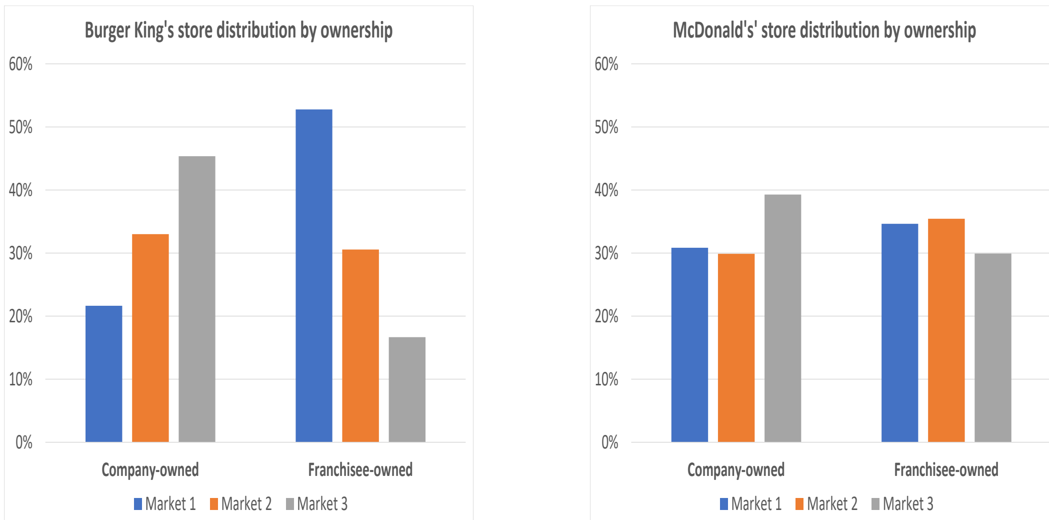

Figure 2.3: Each chain's market distribution by ownership

headquarters and its franchisees. The biggest difference between the two firms' contracts that can be found in the information disclosure statements is the rental policy.

Burger King's headquarters does not invest in the real estate properties for the franchisees. Paying rent to the landlord is up to the franchisees, and the headquarters is not involved with issues of rent. From its franchisees, the headquarters takes 6% royalties, 5% advertisement fees of the total sales and gets some distribution margins by distributing food supplies and other materials to their franchisees, which would be proportionate to the total sales. However, the headquarters does not charge its franchisees any rent.

On the other hand, McDonald's headquarters buys or rents the real estate properties in advance for prospective franchise restaurants' locations. Paying rent to the original landlord is up to the headquarters instead of the franchisees. After the headquarters sells a business right to a franchisee and the franchisee starts a business, the headquarters charges a fixed percentage of the franchisee's total sales as rent in addition to royalties, advertisement fees, and distribution margins. McDonald's Korea does not reveal the exact range of the rent percentage, and it is known that it varies by each restaurant's development costs.[5]

Table 2.9: Fees from franchisee (per month)

Type of fees	Burger King	McDonald's
Service fee (royalty)	6% of net sales	5% of gross sales
Rent	-	varies by restaurants
Advertisement	5% of net sales	more than 5% of gross sales
Distribution margin	Unknown	Unknown
Promotion	varies by promotions	Unknown
Education	varies by education	Unknown
Others (Facilities maintenance, etc.)	varies	varies

The two firms' different rental policies are closely related to the revenue-cost sharing contracts with their franchisees. McDonald's business behaviors with their franchisees are close to that of a joint investment. In other words, McDonald's shares more costs and revenues with franchisees than Burger King. On the other hand, Burger King's headquarters gets less partial revenue from franchisees as profit together with paying less of the costs than McDonald's. These observations provide us qualitative evidence to believe that revenue-cost sharing in the franchise contracts can influence the headquarters' store location choices. In the following section, a more detailed analysis will be conducted to validate this proposition.

2.3 Equilibrium model of firms' location choices

2.3.1 Payoff functions

The decisions to open a franchise store and the store's location are mainly up to each brand's headquarters.[6] Therefore, I focus on suggesting the profit functions of headquarters that can

[5]U.S. McDonald's has revealed that it charges 8.5%-15% of its franchise store's gross sales as rent.

[6]The location of a new franchised store is usually determined in the following order: 1) Assignment of headquarters personnel, 2) Identification of the desired area by the potential franchise owner, 3) Optimal

be obtained from each type of store's ownership.

Basically, I assume that the profits of the same chain stores in the same market are the same for the following reasons. First, regardless of the store's ownership, the same chain restaurants offer the same products at the same prices and provide uniform services to customers. Second, since the ownership information of the stores is not disclosed publicly, demand would not be affected by ownership. Third, most burger chains rely on minimum wage workers and use similar materials and facilities. Therefore, the cost will be also similar regardless of the ownership of the store.

However, even though we assume that same chain stores in the same market make the same profits, the profits of the franchise headquarters differ by stores' ownership. From company-owned stores, the headquarters gets all the revenues and bears all the costs. On the other hand, from franchised stores, the headquarters gets partial revenues and bears partial costs. The distribution rates of revenues and costs depend on the franchise contract between the headquarters and the franchise store. Considering this, we can construct a profit function of a firm's headquarters.

The profit function's basic setting follows Bresnahan and Reiss (1991), Berry (1992) and Mazzeo (2002). A firm's profit depends on market demand denoted as X and the number of competitors. I transformed it into a headquarters' profit function reflecting its stores' ownership. Therefore, in the model of this paper, a firm's headquarters' profit in a market is determined not only by market demand and the number of competitors but also by the number of its stores per each ownership and the revenue-cost distribution ratio between the headquarters and the franchisees.

The notations of this model are as follows:

- Π^C_{im}: Firm i's headquarters' profit from a company-owned store in market m

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location selection through analyzing the markets and considering the distances from existing stores, 4) Confirmation after obtaining consent from the potential franchise owner.

  - i: Firm (Burger King or McDonald's)
  - m: Market (Where one or more than one of the 5 big chains restaurants are present)

- Π_{im}^F: Firm i's headquarters' profit from a franchised store in market m

- X_m: Market demand characteristics in market m that can affect firms' payoffs; X consists of 1) The number of residents, 2) The number of working people, 3) Population density, 4) Average apartment trading price per $1m^2$

- β_{iX}: Parameters of market demand characteristics of firm i

  - β_{iR}: Demand effect from the number of residents
  - β_{iW}: Demand effect from the number of working people
  - β_{iD}: Demand effect from the population density
  - β_{iH}: Demand effect from the housing trading prices

- N_{im}^C: Number of company-owned stores of firm i in market m

- N_{im}^F: Number of franchised stores of firm i in market m

- $g(\theta_{ic}; \vec{N})$: The portion of the payoff function captures the effects of competitors; the competitors consist of other stores of the same brand and other stores of different brands (e.g. $g(\theta_{ic}; \vec{N}) = \theta_{i1}N_{im1} + \theta_{i2}N_{im2}$)

  - θ_{ic}: Competition effect parameter vector
    * θ_{i1}: The effect from other stores of the same brand
    * θ_{i2}: The effect from other stores of different brands
  - $\vec{\text{N}}$: Number of competing stores that each store faces

- * N_{im1}: Number of other stores of its own brand in market m.
  (e.g. $N_{im1} = N_{im}^C + N_{im}^F - 1$)
- * N_{im2}: Number of other stores of different brands in market m

- C_i: Constant revenue of firm i
- F: Fixed cost of a store; Assuming that both chains have the same fixed cost
- α_i: Revenue ratio that firm i's headquarters gets from a store
- γ_i: Fixed cost ratio covered by firm i's franchisee
- ϵ_{im}^C: The unobserved part of payoffs from a company-owned store
- ϵ_{im}^F: The unobserved part of payoffs from a franchised store

Π_{im}^C, the profit which firm i's headquarters gets from its company-owned store in market m is as equation (2.2). From a company-owned store, it gets all the revenues from the store, which is determined by market characteristics $X_m\beta_i$, the presence of competitors $g(\theta_{ic}; \vec{N})$ and constant revenue C_i. At the same time, it bears all the costs F. The error term ϵ_{im}^C represents firm i headquarters' unobserved payoffs when operating a company-owned store in market m.[7]

$$\Pi_{im}^C = X_m\beta_i + g(\theta_{ic}; \vec{N}) + C_i - F - \epsilon_{im}^C \tag{2.2}$$

Π_{im}^F, the profit which firm i's headquarters gets from its franchised store in market m, is seen as equation (2.3). From a franchised store, it gets partial revenues and pays partial

[7] Assumptions about error terms: 1) The error terms of stores with different ownership are different (e.g., ϵ_{im}^C vs. ϵ_{im}^F), 2) Under the same ownership type, the error terms of the same chain stores in the same market are identical. 3) The error terms are independent of observable parts such as market characteristics and the number of competitors. 4) They are additively separable.

costs. The portion of a store's revenue that firm i's headquarters takes from its franchisee is α_i, and the portion of a store's fixed cost that is covered by its franchisee is γ_i. In other words, the headquarters' fixed cost burden becomes (1-γ_i)F. The unobserved payoffs from a franchised store is ϵ_{im}^F.

$$\Pi_{im}^F = \alpha_i\{X_m\beta_i + g(\theta_{ic};\vec{N}) + C_i\} - (1-\gamma_i)F - \epsilon_{im}^F \tag{2.3}$$

If there are N_{im}^C company-owned stores and N_{im}^F franchised stores of firm i in market m, firm i's total profit in market m which is Π_{im} becomes,

$$\Pi_{im} = N_{im}^C\Pi_{im}^C + N_{im}^F\Pi_{im}^F \tag{2.4}$$

2.3.2 Equilibrium conditions

I assume that the status of 2016 is in equilibrium. As we can see in Figure 2.4, the franchise ratio of each chain, Burger King and McDonald's, stagnated in 2016. Situations may change after 2016, but with the data currently available, that would be a reasonable assumption for static entry analysis. In the equilibrium status, the following conditions need to be satisfied.

First, regardless of a store's ownership, firm i's profit from each existing store in market m should be positive. If any store had shown a negative profit, the store would have been closed.

$$\begin{aligned} &\Pi_{im}^C(N_{im}^C, N_{im}^F, X_m) > 0 \\ &\Pi_{im}^F(N_{im}^C, N_{im}^F, X_m) > 0 \end{aligned} \tag{2.5}$$

Second, if firm i opens an additional store, either company-owned or franchised, its total profit would decrease. When a headquarters makes an entry decision, it considers its total

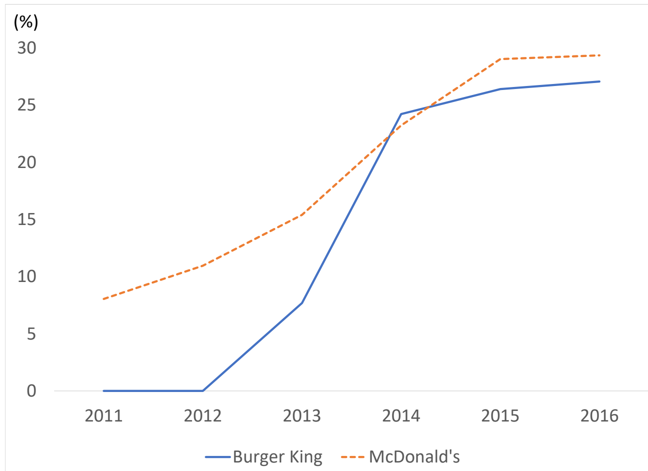


Figure 2.4: Franchise ratio trend of each chain

profit. Even if each store brings a positive profit to the headquarters, if the additional store lowers the present total profit by cannibalization, the headquarters would not allow the additional store's entry. That is why in equilibrium status at the present time, the firm has N_{im}^C and N_{im}^F stores in market m instead of $N_{im}^C + 1$ or $N_{im}^F + 1$.

$$\Pi_{im}(N_{im}^C, N_{im}^F, X_m) > \Pi_{im}(N_{im}^C + 1, N_{im}^F, X_m)$$
$$\Pi_{im}(N_{im}^C, N_{im}^F, X_m) > \Pi_{im}(N_{im}^C, N_{im}^F + 1, X_m) \quad (2.6)$$

Third, if firm i does not currently have a store in a market, entering the market will yield a negative profit either from a company-owned store or a franchisee. For such a market, a zero margin without entry is better for the firm than a negative profit when entering.

$$\Pi^C_{im}(1,0,X_m) < 0$$
$$\Pi^F_{im}(0,1,X_m) < 0 \tag{2.7}$$

By solving these equilibrium conditions simultaneously, it is possible to obtain a closed-form expression for the error terms (ϵ^C_{im}, ϵ^F_{im}), the unobserved payoffs in the profit functions. From the ranges, we can find a quadrangle region in the space of the error terms that generates a particular value of the equilibrium pair (N^C_{im},N^F_{im}).

When there is one or more than one store in a market, the range of ϵ^C_{im} is

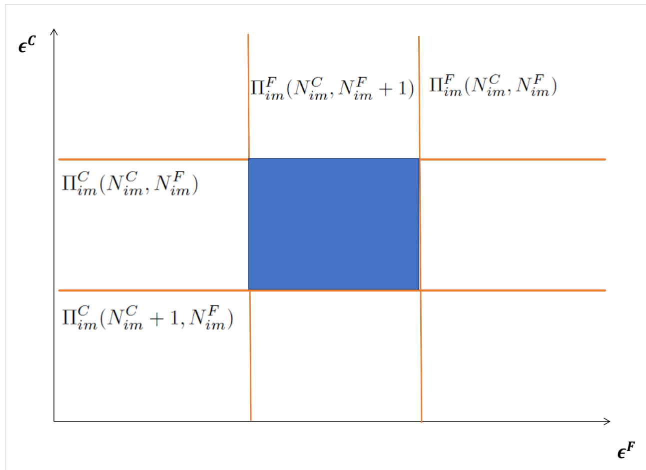
$$\begin{aligned} X_m\beta_{iX} + \theta_{i1}N_{im1} + \theta_{i2}N_{im2} + C_i - F + (N^C_{im} + 1 + \alpha_i N^F_{im})\theta_{i1} \\ < \epsilon^C_{im} < X_m\beta_{iX} + \theta_{i1}N_{im1} + \theta_{i2}N_{im2} + C_i - F \end{aligned} \tag{2.8}$$

and the range of ϵ^F_{im} is

$$\begin{aligned} \alpha(X_m\beta_{iX} + \theta_{i1}N_{im1} + \theta_{i2}N_{im2} + C_i) - (1-\gamma_i)F + (N^C_{im} + \alpha_i(N^F_{im} + 1))\theta_{i1} \\ < \epsilon^F_{im} < \alpha(X_m\beta_{iX} + \theta_{i1}N_{im1} + \theta_{i2}N_{im2} + C_i) - (1-\gamma_i)F \end{aligned} \tag{2.9}$$

When there is no store, the range of ϵ^C_{im} and ϵ^F_{im} are

$$\epsilon^C_{im} > X_m\beta_{iX} + \theta_{i1}N_{im1} + \theta_{i2}N_{im2} + C_i - F \tag{2.10}$$
$$\epsilon^F_{im} > \alpha(X_m\beta_{iX} + \theta_{i1}N_{im1} + \theta_{i2}N_{im2} + C_i) - (1-\gamma_i)F \tag{2.11}$$



Note: Profits(Π) in this graph are the values which exclude the error terms

Figure 2.5: Partitioning for equilibrium outcomes

2.3.3 Estimation method

As illustrated in Figure 2.5, the probability that generates firm i's status combination of (N^C_{im},N^F_{im}) can be calculated by integrating the probability distribution function of the error terms (ϵ^C_{im}, ϵ^F_{im}) over the area of this quadrangle region. For purposes of estimation, I use the Maximum Likelihood Estimation (MLE) method. It selects the parameters of the profit functions that maximize the probability of the observed market status in the data.

In the meantime, there are 27 market configurations that show the observed market status. They are the number of stores according to the type of ownership of each firm in 1,497 markets. The order of each configuration is $\{N^C_{Bm}, N^F_{Bm}, N^C_{Mm}, N^F_{Mm}\}$[8], and it ranges from $\{0, 0, 0, 0\}$ to $\{4, 1, 3, 0\}$ as Table 2.10. Each configuration contributes to the

[8]Each number of {Burger King company-owned stores, Burger King franchised stores, McDonald's' company-owned stores, McDonald's' franchised stores}

likelihood function by its probability and frequency. For example, The contribution of $\{N^C_{Bm}, N^F_{Bm}, N^C_{Mm}, N^F_{Mm}\}$= (1,0,1,0) to the total likelihood function is $[Prob(1,0,1,0)]^{37}$.

The likelihood function is

$$\begin{aligned} L = \prod_i \prod_m Pr[N^C_{im}, N^F_{im} | X_m, N_{im2}] &= \prod_i \prod_m Prob[(N^C_{im}, N^F_{im})^O_{im}] \\ &= \prod_i \prod_m \int 1\{(\epsilon^C_{im}, \epsilon^F_{im} \in R_\epsilon(\epsilon^C_{im}, \epsilon^F_{im}; X_m, N_{im2})\} dF(\epsilon^C, \epsilon^F) \end{aligned} \tag{2.12}$$

The subscript i means firm, Burger King or McDonald's and m means market. The superscript O means market configuration outcome. $R_\epsilon(N^c_{im}, N^F_{im}; X_m, N_{im2})$ is the quadrangle region in R^2 associated with the configuration (N^c_{im}, N^F_{im}) given exogenous variables, market characteristics, X_m, and the number of other stores of different brands in the market, N_{im2}. $F(\epsilon^C_{im}, \epsilon^F_{im})$ is the cumulative distribution function of the unobservable variables.[9]

X variables are the factors that affect profit functions by demand. They are 1) the number of residents, 2) the number of working people, 3) population density, 4) average housing trading price in the markets. For tractability, following Mazzeo (2002), I introduced the transformation to facilitate the estimation of the model according to equation (2.13). The optimization process is known to perform better when using scaled variables in scope that are narrower and similar to the model. Table 2.11 provides summary statistics.

$$X^*_m = \ln \left[\frac{X_m}{\frac{1}{1497} \sum_{m=1}^{1497} X_m} \right] \tag{2.13}$$

[9]I assume that the distribution of $(\epsilon^C_{im}, \epsilon^F_{im})$ is bivariate normal, with a correlation coefficient of zero. I also assume that the error terms are also independent between firms.

Table 2.10: Observed Market configurations for the two firms

Market Configuration	Number of Markets	Percent of Total (%)
(0, 0, 0, 0)	954	63.73
(0, 0, 0, 1)	84	5.61
(0, 0, 0, 2)	2	0.13
(0, 0, 1, 0)	206	13.76
(0, 0, 1, 1)	6	0.40
(0, 0, 2, 0)	8	0.53
(0, 1, 0, 0)	45	3.01
(0, 1, 0, 1)	10	0.67
(0, 1, 1, 0)	14	0.94
(1, 0, 0, 0)	88	5.88
(1, 0, 0, 1)	14	0.94
(1, 0, 1, 0)	37	2.47
(1, 0, 1, 1)	2	0.13
(1, 0, 2, 0)	5	0.33
(1 ,0, 2, 1)	1	0.07
(1, 0, 2, 2)	1	0.07
(1, 1, 1, 0)	1	0.07
(2, 0, 0, 0)	7	0.47
(2, 0, 1, 0)	2	0.13
(2, 0, 1, 1)	1	0.07
(2, 0, 2, 0)	1	0.07
(2, 0, 2, 1)	1	0.07
(2, 1, 0, 1)	1	0.07
(3, 0, 0, 0)	2	0.13
(3, 0, 0, 1)	1	0.07
(3, 0, 1, 0)	2	0.13
(4, 1, 3, 0)	1	0.07
Total	1,497	100

Note: Market configuration order (Company-owned stores of Burger King, franchised stores of Burger King, Company-owned stores of McDonald's, franchised stores of McDonald's)

Table 2.11: Summary Statistics of X variables

Variable	Description	Mean	Standard Deviation	Minimum	Maximum
Resident	Number of registered residents	22,526.7	13,119.7	1,028	98,599
	who live in the market	(-0.185)	(0.658)	(-3.087)	(1.476)
Working People	Number of hired people	9,961.0	12,293.7	415	153,339
	who work in the market	(-0.358)	(0.786)	(-3.178)	(2.734)
Population Density	Total population	15,555.7	15,190.2	12,949	119,265.5
	/Size of the market area	(-0.818)	(1.653)	(-7.091)	(2.037)
Avg. housing price	Average Apt. trading price	346.86	199.48	53.34	1,525.74
	per $1m^2$ in the market	(-0.138)	(0.519)	(-1.872)	(1.481)

Note 1: The values in parentheses (X^*) are values converted by equation (2.13)
Note 2: Apartment trading price unit : 10,000 Korean Won
(Average exchange rate in 2016: 1 dollar = 1,161.1 Korean Won)

2.4 Estimation results

2.4.1 Revenue and cost distribution

Table 2.12 displays the estimated parameters of both firms' payoff functions. The parameters of X variables that show the effect of market characteristics on stores' revenues are similar for both chains. β_R is the effect of the number of residents, β_W is the effect of the number of working people, β_D is the effect of the population density and β_H is the effect the housing trading price per unit area. Except for the number of residents, other characteristics have positive effects on the firms' profits. The result does a good job of reflecting reality. Burger King and McDonald's stores tend to be concentrated in downtown or busy commercial areas of big cities. In these areas, there are a lot of working people in many corporate buildings, and the population density is also high. Housing prices are also high, because land prices in these areas are high. On the other hand, the number of residents is relatively small. That would be the reason for the negative sign of β_R. Assuming that both chains' fixed cost sizes are the same, McDonald's constant profit is bigger than that of Burger King. This can be seen from the value of constant profit C.

The parameters that show the relationship between a franchiser and franchisees are α and γ. α stands for the revenue distribution ratio between a headquarters and its franchised stores, which becomes 1 for company-owned stores. γ is the fixed cost portion paid by franchised stores, and it is 0 for the company-owned stores. The larger α means the more that the headquarters gets of the franchisees' revenues. And the larger γ means the less that the headquarters bears the fixed costs. We can find distinct features of α and γ in each firm's profit function parameters from the model. Burger King has smaller α, but larger γ compared to McDonald's. In other words, Burger King's headquarters derives less revenue from its franchised stores and pays less in fixed costs for them than McDonald's. McDonald's is the opposite. McDonald's headquarters derives more revenue from its franchised stores and pays more fixed costs for them. For each parameter's comparison test, I implemented a t-test. First, the null hypothesis that Burger King's α is greater than or equal to McDonald's α (e.g., H_0: $\alpha_B \geq \alpha_M$), which is Burger King's headquarters takes more portion of its franchisee's revenue than McDonald's, is rejected at the significance level of 0.05. Second, the null hypothesis that Burger King's γ is less than or equal to McDonald's (e.g., H_0: $\gamma_B \leq \gamma_M$), which is Burger King's franchisees bear a smaller portion of fixed costs than McDonald's, is also rejected at the significance level of 0.05. Significantly, McDonald's has a bigger α and smaller γ, and Burger King has a smaller α and bigger γ.

These results —the revenue-cost sharing parameters obtained from the model —are consistent with the expectations from the observation. McDonald's, whose headquarters invests in real estate for a franchise in advance and later receives a certain portion of the franchisee's revenues as rent, was expected to have high α and low γ levels. On the other hand, Burger King, whose headquarters does not invest in real estate for a franchise in advance and does not charge rent later, was expected to have low α and high γ relatively. In getting more revenues and paying more fixed costs, a headquarters' profit function from a franchised store

Table 2.12: Estimated parameters of Burger King and McDonald's

Parameter		Constrained Optimization		Optimization	
		Burger King	McDonald's	Burger King	McDonald's
Resident	β_R	-0.071	-0.031	-0.078	-0.031
		(0.065)	(0.060)	(0.064)	(0.058)
Working pop.	β_W	0.138	0.062	0.134	0.058
		(0.063)	(0.056)	(0.063)	(0.053)
Pop.Density	β_D	0.027	0.033	0.026	0.034
		(0.035)	(0.031)	(0.035)	(0.030)
Apt.Price	β_H	0.569	0.418	0.569	0.393
		(0.103)	(0.078)	(0.100)	(0.076)
Same brand	θ_1	-1.053	-1.119	-1.067	-1.079
		(0.226)	(0.089)	(0.243)	(0.078)
Other brands	θ_2	-0.022	-0.001	-0.018	0.000
		(0.038)	(0.032)	(0.037)	(0.031)
Revenue dist. ratio	α	0.522	0.783	0.516	0.906
		(0.081)	(0.067)	(0.069)	(0.112)
Fixed cost dist. ratio	γ	0.178	0.020	-0.020	-0.185
		(0.063)	(0.053)	(0.126)	(0.100)
Constant profit	C	2.147	2.502	0.924	1.284
		(0.329)	(0.323)	(0.390)	(0.399)
Fixed cost	F	3.221	3.221	2.007	2.007
		(0.316)	(0.316)	(0.391)	(0.391)
Log-likelihood		-1,818.43		-1,818.27	

Note 1: For the 'constrained optimization' analysis, I imposed the constraint of $\gamma > 0$.
Note 2: Standard Errors obtained from 1,000 bootstrap estimations are in parentheses.

becomes closer to that of a company-owned store. This can explain why McDonald's store location choices for its franchisees are more similar to those of its company-owned stores than Burger King's choices.

2.4.2 Competition effect

The parameters that show the effects of competition are θ_1 and θ_2. θ_1 is the parameter that represents the cannibalization effect from other stores of the same brand and θ_2 is the parameter that represents the competition effect from other brands' stores. Opening an additional same brand store in the same market can harm the profitability of existing stores. From θ_1, we can see that there are significant cannibalization effects to both chains' headquarters. Compared to θ_2, the effect from other brand stores, an additional same brand store encroaches on existing stores' revenues a lot more. This explains why there are not many same brand stores in the same market. Due to concerns about the cannibalization effect, in more than 90% of cases, each chain has only one store in a given market. Out of Burger King's 237 markets, only 20 markets (8.4%) have two or more Burger King stores. Likewise, out of 401 McDonald's markets, only 29 markets (7.2%) have two or more McDonald's stores. The cannibalization effect of McDonald's is slightly bigger than that of Burger King. Since McDonald's headquarters takes a greater portion of revenues, if there is a revenue reduction from encroachment, the effect would be bigger than that for Burger King's headquarters. According to the t-test, the null hypothesis that there is no cannibalization effect from the same brand stores (e.g., H_0: θ_1=0) is rejected at the significance level of 5% for both chains.

Both chains' θ_2 are negative, but the sizes are close to 0. The impact of additional stores of other brands on existing stores are smaller than the impact of stores of the same brand. It is also insignificant. The null hypothesis that there is no competition effect from other brand's stores (e.g., H_0: θ_2=0) cannot be rejected at the significance level of 5% for both chains. The small θ_2 can be explained by product differentiation. If consumers tend to prefer a specific brand each, the impact of additional stores of different brands on existing stores will be smaller than the impact of stores of the same brand. The result that the cannibalization effect from the same brand stores is bigger than the competition effect from other brand stores is similar to other research conducted, such as Toivanen and Waterson (2005), Yang (2012) and Igami and Yang (2016).

2.5 Conclusion

This paper has examined store location choice strategies of franchise firms by ownership and contract. The strategies vary by store ownership and also vary by franchise revenue-cost sharing contracts between the headquarters and the franchisees. I analyzed the relationship empirically by using unique data from McDonald's Korea, Burger King Korea, other burger chains and demographic data from many sources.

Specifically, I focused on the strategies of burger chains operating both types of ownership stores, Burger King and McDonald's. The store location choices for each ownership type of the two firms are different. While Burger King shows a big difference between the two types, McDonald's does not show a distinct difference. For the purpose of analysis, I set up a model of headquarters' profit functions reflecting stores ownership and estimated the parameters of the profit functions which best described the current market status. The profit functions consisted of demand variables, revenue-cost sharing ratios between the headquarters and franchisees, cannibalization effects with the same brand stores, and competition effects with the different brand stores.

The estimation indicates the following results. First, the higher the headquarters' acquisition ratio from its franchisee's revenue and the lower the fixed cost burden ratio of the franchisees, the headquarters' location choice for franchised stores more closely approximates that of its company-owned stores. This explains why firms behave differently when allocating their franchise stores, as shown in the case of McDonald's and Burger King. Second, the cannibalization effect from same brand stores is significant, but the competition effect from different brand stores is negligible. This shows why the same brand stores tend not to be located in close proximity in the same market. Third, market characteristics such as housing prices, working population, and population density influence the burger chains' preferred store locations. This explains why burger chains tend to locate their stores in downtown or busy commercial areas rather than in residential areas.

My research was based on a static entry model. If more data were available, I could further develop my study in the future by introducing dynamic analysis.

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