Changing Market Structure and Evolving Ways to Compete: Evidence from Retail Gasoline*

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Abstract

This paper examines the pricing behavior of sellers in a market undergoing a significant restructuring using data from the ongoing introduction of self-service technology in the Korean gasoline market in the 2000s. I provide novel evidence that the full-service premium increased during the market transition. I show that a simple model of monopolistic competition is not enough to explain the increasing premium. I find that the pricing behavior of sellers differ by product position: self-service sellers compete for price-sensitive consumers, whereas full-service sellers differentiate their product by offering a variety of bundled products and services, such as coffee, carwash or even a nail salon, to compete for less-price-sensitive consumers. Taken together, the strategic choices of sellers evolve in different ways when market structure changes, each type of seller using its unique position, resulting in an increase in the full-service premium in this market.

JEL Codes: D22, L11, L81, O33

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1 Introduction

"There's a shift in people buying gas based on the quality of the sandwich as opposed to getting a sandwich based on the price of gas"

– Vice president for NACS in *Bloomberg* on August 18, 2017
(NACS: National Association of Convenience Stores)

Firms constantly innovate, and innovations force changes in the competitive landscape. Firm innovations have been remarkable particularly in the retail sector (Bronnenberg and Ellickson, 2015 and Hortaçsu and Syverson, 2015). One particular example is the introduction of automation, altering the optimal allocation of resources of buyers and sellers. There is a long-standing literature on effects of innovation on prices when the innovation entails falling marginal costs of firms, but relatively little empirical evidence on how the innovation changes prices of firms facing innovative competitors. In this paper, I examine the pricing behavior of new- and old-fashioned sellers jointly and product positioning, using a case-study approach: the introduction of self-service technology in retail gasoline in Seoul, Korea.

The retail gasoline industry is useful for examining the pricing behavior of sellers because the product is almost homogeneous and prices are clearly posted and observed by consumers. My setting is unique in that I have high-frequency, station-level data starting in 2010, when self-service sellers were very rare, and continuing through 2015, when they accounted for a quarter of the market. I analyze the pricing behavior of sellers by service level, and find that gas stations that continued to offer full service differentiated themselves by offering bundled products and services and *raised* their prices during this period.

Specifically, the price gap between full service and self service increased most dramatically in Seoul; the full-service premium was 2% in early 2010 and increased to 8% by 2015.[1] At the same time, the distribution of full-service prices became increasingly right-skewed and the variability of self-service prices was relatively stable. These stylized facts clearly

[1] A weaker but similar pattern also appeared at the country level.

suggest a different evolution of pricing strategies of sellers by service level during the market transition from full service to self service.

My findings are three-fold. First, I use the prediction of models of monopolistic competition – greater competition lowers price – to test whether exit of full-service stations can explain the increase in the full-service premium.[2] If the gasoline market is segmented by service level, the increase in the full-service premium could be explained by the falling number of full-service stations and the increased number of self-service stations. However, in a difference-in-difference specification, the changes in the service composition of gas stations barely explain the increasing full-service premium in this market, and the trend of full-service premium is very robust to measures of the competitive environment.

My second finding is a confirmation that self-service stations not only offer competitive prices but also drive down prices of nearby competitors. Difference-in-difference specifications show that, *ceteris paribus*, self-service stations charge 5% less per gallon on average during my study period. Regarding competitive effects, the price elasticity with respect to competition is much higher in absolute value when competitors are self service than when they are full service. Specifically, having one more self-service station within a 1-mile radius is associated with a 0.5% reduction in gas prices, whereas entry of full-service stations has no statistically significant effect on prices. This finding implies that self-service stations compete for price-sensitive customers who possibly want a low-priced gasoline component only rather than a bundle of gasoline and service.

The third finding is descriptive evidence of full-service stations' subtle differentiation on one or more non-price dimensions. For example, some gas stations combine with other types of businesses, including a dry cleaner, nail salon, or fast-food restaurant, and some stations offer extra products free of charge, such as coffee, carwash, or vacation packages, depending

[2] Barron, Taylor, and Umbeck (2004) show that the U.S. retail gasoline market resembles a setting of monopolistically competitive market, and Kim and Kim (2011) find similar evidence in the Korean market.

on the amount of gasoline purchased.[3] These unique features are generally provided by full-service stations whose gasoline prices are significantly higher than the average price for full service. I interpret such bundled products and services as new strategic choices of high-cost marginal sellers in response to the emergence of low-price competitors.

To supplement the descriptive evidence, I perform two analyses using price data. The first analysis is to compare stations that later bundle products to those that do not. Given information on stations' bundling choices in May 2017, I identify stations that later bundle products and those that do not in my price panel (from 2010 to 2015), and then trace the price difference between later-bundling stations and later-not-bundling stations. I find that the price difference increases in the later period of my sample, consistent with stations *increasingly* bundling their products and charging a premium during the market transition. The second analysis is to examine the relative price stability of stations. After controlling for station characteristics, I confirm that high-priced stations settle into fairly fixed prices much more low- or mid-priced stations. When applying insights from models of search, this result indicates that high-priced stations are perceived by consumers as heterogeneous.[4]

Differentiated sellers enjoy less intense competition on price, which allows them to charge high and stable prices. Consistent with this implication, my descriptive evidence and quantitative analyses together support the claim that the strategic choices of sellers evolve in different ways; higher-priced stations compete for less-price-sensitive consumers, while lower-priced stations that usually offer self-serve gasoline focus on price-sensitive consumers. Taken together, these features have led to an increase in the full-service premium during the market conversion from full service to self service.

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[3]This strategy is a sort of product bundling. There has been a well-established literature on product bundling and its profitability both theoretically and empirically. See Chen and Riordan (2013) for an overview of the literature on this topic. For example, Wang (2015) studies grocery-gasoline bundling and examines its effect on price in the Perth market of Western Australia; giving a discount on gasoline to supermarket customers is one typical case of bundling in retail gasoline.

[4]A relative price of sellers for one homogeneous good should not change systematically in general models of search (e.g., Varian, 1980 and Stahl, 1996). Consumers would otherwise know which seller charges the lowest price.

This paper contributes to a vast literature on product differentiation and its softening effect on competition. Mazzeo (2002) examines motel markets located along U.S. interstate highways, and finds that the effect of competition on price is little when motels are differentiated. Basker and Noel (2009) show that the effect of Wal-Mart's entry on competitors' prices is greatest at low-end chains that compete for price-elastic consumers, and smaller at supermarkets that differentiate themselves from Wal-Mart. Ellison and Ellison (2009) provide evidence that online retailers offer a variety of add-on products to frustrate consumers' price search, and show that this practice is designed to mitigate intense competition. Ching (2010) studies evidence that entry of generic drugs causes branded drug price to increase, and applies insights from theories of consumer learning and heterogeneity in price sensitivity to interpret the evidence.

My analysis also contributes to a broad literature on different aspects of retail gasoline pricing.[5] Shepard (1991) is the first study to document price discrimination by gas stations and estimate the premium charged for full-service gasoline. Png and Reitman (1994) focus on service-time competition as one aspect of station quality and estimate the premium for a service-time reduction at gas stations. Houde (2012) models retail-gasoline demand that allows for spatial differentiation of stations. More recently, Remer (2015) empirically examines asymmetric pricing of gasoline retailers along with consumer search.[6]

Within this literature, several other papers have studied the relationship between pricing and product differentiation. Borenstein (1991) examines why stations' markups differ for leaded vs. unleaded gasoline, and reviews some explanations for the difference, such as cost-based, purchase-size-based, and paying-method-based explanations. Hastings (2004) focuses on the brand dimension and examines price effects of brand-contract changes in retail gasoline market in Southern California. Similar to my setting, Soetevent and Bružikas (2018) exploit

[5] Noel (2016) provides a comprehensive overview of retail gasoline pricing.

[6] Asymmetric pricing is a well-known phenomenon in retail gasoline literature (Bacon, 1991 and Borenstein, Cameron, and Gilbert, 1997). Recently, many studies on this topic have explained the pattern in theories of consumer search. See, for example, Yang and Ye (2008), Tappata (2009), and Lewis (2011).

the transition of the Dutch retail gasoline market from self-service "staffed" stations to fully automated stations, and find no significant effects of automated stations on staffed stations' prices.

I describe the evolution of market segmentation in Section 2, and explain the data used in this paper in Section 3. I present my main results on the pricing behavior of sellers by product position in Section 4. Section 5 concludes.

2 The Evolution of Market Segmentation

2.1 Full Service vs. Self Service

The first introduction of self-service technologies in the Korean retail-gasoline market was in 1993, but self-service stations failed to attract customers and disappeared before long. A gas station with self-service pumps opened again in 2003, but the self-service format was still rare until the end of 2007, when it accounted for about 0.3% of the market. The market conversion from full service to self service accelerated in early 2008, possibly due to a sharp increase in global oil prices. One or two new self-service stations have opened every month on average since then. Self-service stations constituted 17% of all stations as of December 2015 at the country level. Most self-service stations are converted from full-service stations rather than being new entries.

The distinction between full service and self service is whether consumers must put their labor into the production function of stations.[7] Consumers who purchase self-serve gasoline fill their gas tank and pay at the pump themselves, whereas those buying full-serve gasoline wait for a service attendant in their car and request the amount of gasoline they want to buy. In the early 2000s, a few full-service stations in Korea used to provide "full services" such as

[7] Basker, Foster, and Klimek (2017) study the transformation of gasoline stations from full service to self service in the U.S. and examine the labor productivity of full- vs. self-service stations. Foster, Haltiwanger, and Krizan (2006) more generally examine productivity changes from a massive restructuring in the U.S. retail sector in the 1990s.

cleaning windshield and checking under the hood of a car, similar to the U.S. market in the 1960s. However, such services have disappeared.[8] Full-service consumers nowadays expect to receive only pumping and paying services, or at most, a windshield-cleaning service.

Gasoline stations in Korea are perfectly partitioned by service level at each point in time, with no mixed station offering both full- and self-service pumps, unlike in the U.S. market. I show the locations of gasoline stations in Seoul on May 2010 and December 2015 in Figure 1. Large dots are self service and small dots are full service. Self-service stations that entered later are often located near earlier self-service stations.

I plot the time series of price level and the number of stations by service level, also in Seoul.[9] Figure 2-(a) shows average log retail price by service level and wholesale price over time. The prices fell sharply in early 2015 due to an abrupt reduction in crude oil prices. In Figure 2-(b), the total number of stations falls by about 15% (from 658 to 559) over the period.[10]

2.2 The Evolving Full-Service Premium

My focus in this paper is on understanding the pricing behavior of stations by product position during a period in which (formerly) full-service stations have adopted self-service technologies. Using price information on all stations in South Korea, I plot the time series of the log price difference between the two services from May 2010 to December 2015 in Figure 3-(a). The full-service premium (or self-service discount) started to increase from mid-2011. Narrowing down the market to the city of Seoul, there exists the similar and

[8]There are two possible reasons for this. One reason is that modern cars require fewer services so demand for these services has fallen. Another reason is possibly related to a large increase in car ownership in Korea, with the result that gasoline is no longer a luxury good: the majority of customers has preferred low-priced stations to those offering these services. Korean Statistical Information System (KOSIS, 2018) reports that motor vehicles per 1000 people almost doubled from 1995 to 2010 (from 187.9 to 362.1).

[9]I explain the dataset used in this study in the next section.

[10]The decline in the number of stations is a well-known phenomenon in retail gasoline industry, which is called "station rationalization" and observed while retail gasoline markets have matured. Eckert and West (2005b) document a 63% decline in the number of stations in Canada over the period from 1972 to 2000 and a 47% fall in the U.S. over the same period.

strong pattern in Figure 3-(b): the full-service premium was 2% on the first Wednesday of May 2010 and increased to 8% over the next five years. Herein, I focus on Seoul, for which I have daily price information on all stations, and where the adoption rate of self-service pumps is much higher than that in the remainder of the country.

Figure 4-(a) shows price distributions for full- and self-service stations on the first Wednesday of May 2010 and December 2015, and Figure 4-(b) presents the time series of coefficient of variation, also by service level. The distributions shift to the left simply because of a difference in price levels between the two dates. The most important lesson from these figures is that the distribution of full-service prices has increasingly become *right-skewed* over time, while the variability of self-service prices has remained relatively stable. These features indicate the different evolution of pricing strategies of sellers by service level, and show that the increasing full-service premium is closely linked to gas stations that increasingly charge a premium for their *full-serve* gasoline. I discuss these stylized features more in the result section.

3 Data

My data are constructed from information available at the Oil Price Information Network (OPINET), a website operated by Korea National Oil Corporation. OPINET provides retail gasoline prices to the public at a daily frequency, and almost all prices are automatically collected based on transactions data.[11] OPINET also provides each station's non-financial information, such as address, brand, level of services, and name, also at a daily frequency. I utilize a station-level panel dataset of all stations in Seoul that covers the period from May 2010 to December 2015. Figure 5 is a screenshot of OPINET to help readers understand my data collection.

[11] If stations use manual updates, they must report their price within 24 hours of a change in price.

I make two compromises in constructing my dataset. First, I use data from the Wednesday of each week because using all daily observations is computationally burdensome to study the five-year period.[12] The loss of information is minimal: station prices change once every 11 days on average and Tuesday is the modal day for price changes in the full dataset. Second, since entry and exit information are not explicitly available, I infer the information from the enforcement implemented on May 1, 2009 – all stations must report price at least once a week even in case of no price change. To be conservative, I drop the first year after the implementation of this rule and assume that a station remains open even if it does not report for up to four weeks, as long as its observed characteristics (e.g., name or service level) do not change.[13] Additional information on the full dataset and these compromises are described in Appendix B.

Using the address information, I geocode every station in my dataset and measure each station's competitive condition based on two conventional metrics. I first count the number of full- and self-service competitors within a fixed-mile radius, denoted Num^{FS} and Num^{SS}, respectively. I also calculate the great-circle distance to the nearest stations of each service level, denoted Dist^{FS} and Dist^{SS}, respectively. In some regressions, I include the distance to the second-nearest stations, also by service level. Table 1 summarizes these variables. The average station has 2 full-service competitors and 0.4 self-service competitors within 0.5 miles; is located 0.3 miles from the nearest full-service competitors and 0.9 miles from the nearest self-service competitor.

I include three time-varying variables to help isolate competitive effects on price in my analyses. Table 2 summarizes the variables. First, I include indicators for station brands, which affects demand; brands are mostly time invariant but can change. There are five

[12] Using one day of each week is also useful to reduce measurement errors on sellers' entry and exit. See my second compromise in this paragraph.

[13] My compromise applies to 80 instances of a total of 175,940 observations. When stations drop out of the sample for longer than one week, changes in station characteristics such as service level are often observed. In this case, I assume that these stations temporally closed to make that change.

brands operating in this market. Second, I create the share of stations within 1.5 miles that have the same brand as each station in time, to control for the possibility that a dealer may operate multiple stations under the same brand in a local area.[14] Third, I also generate an indicator of whether a station sells regular gasoline only or premium gasoline together because the number of product lines affects optimal pricing.[15]

Lastly, I have cross-sectional information on each station's bundling and price, collected on May 17, 2017 (18 months after the end of my price panel). At no charge, stations can publicize their special promotions in OPINET and consumers can see it through the OPINET website or smartphone application. Of the 539 stations operating in Seoul in that date, 117 stations advertised a special promotion, including free coffee, tea, or carwash. There may exist stations offering such a promotion in reality but not posting it at the website, but I assume that stations with no advertisements offered no promotions. Unfortunately, OPINET does not provide past promotion information.

4 Results

4.1 Measure of Full-Service Premium

Using a regression framework, I quantify the full-service premium and the total increase of the premium over the sample period. A reduced-form regression finds a best-fitting straight line through data, so it is well-suited to the pattern of the full-service premium I observe in

[14] Station brand is not the same as joint ownership, but brand share is often used as a proxy for an ownership in retail gasoline. As in Lewis (2008) and Chandra and Tappata (2011) that study retail gasoline pricing, I also control for it in my estimation.

[15] For stations selling premium gasoline, there is another transaction price reported as in "premium gasoline" in the OPINET database. Following the construction of stations' entry and exit, I also assume that a station that does not report premium gasoline prices for four weeks has stopped selling premium gasoline.

this market (Figure 3-b). The specification is as follows:

$$lnP_{it} = \theta Full_{it} + \phi(Full_{it} * Trend_t) + \mu_t + \varepsilon_{it} \tag{1}$$

where P_{it} is the price of station i at time t, $Full_{it}$ is an indicator whether each station i offers full-serve gasoline in time t, and $Trend_t$ is an incremental number by 1/294 in each week, starting from 1/294 in the first period to 294/294 in the last period of my sample. My sample span is 294 weeks. μ_t is a time fixed effects that reflects changes in average prices, mostly driven by wholesale gasoline prices. The error term ε_{it} is clustered by station and is robust to interdependent pricing of stations.

The coefficient of interest is on $Full_{it} * Trend_t$ that picks up the total increase of the price difference between full-service and self-service stations over the sample period, which corresponds to the fitted slope of the full-service premium. In Column (1) of Table 3, the (log) full-service premium starts from 0.017 (i.e., when Trend≈0), and then it increases up to 0.072 for 294 weeks (i.e., when Trend=294/294). These estimates are consistent with plotted data in Figure 3-(b).

Equation (1) is parsimonious, which is good to understand the magnitude of the increase in the full-service premium, but it does not capture the possibility that the increase may be associated with systematic differences in seller characteristics across gas stations. To account for these possible differences, I augment Equation (1) by including station fixed effects δ_i and time-varying control variables X_{it} described in the data section (e.g., brands and presence of multi products), which is shown in Equation (2). Station fixed effects control for both observed and unobserved station characteristics that may be correlated with gas price and with service configuration, as long as these variables are time invariant.

$$lnP_{it} = \theta Full_{it} + \phi(Full_{it} * Trend_t) + \zeta X_{it} + \delta_i + \mu_t + \varepsilon_{it}. \tag{2}$$

In Column (2) of Table 3, there remains the very strong trend of the full-service premium although the coefficient on $Full_{it} * Trend_t$ is reduced by about 15%. This finding suggests that the pattern of the full-service premium is not a simple result of observed and unobserved time-invariant confounding factors, as well as the time-varying control variables.

Next, I test whether the increase in the full-service premium is correlated with firm entry and exit. If so, including appropriate variables of firm entry and exit in Equation (2) makes the coefficient ϕ to be reduced, which is due to the nature of regression. I discuss this "competition" hypothesis in greater detail in the following section.

4.2 Competitive Effects

4.2.1 Full-Service Premium

The theory of monopolistic competition is commonly used when explaining firm entry and exit. If one monopolistic incumbent earns a positive economic profit, other firms will be tempted to enter the market. Figure (6) describes the textbook model of it: the entry of competitors shifts the residual demand curve of a monopolistically competitive incumbent to the left (from D_0 to D_1), resulting in a decrease in the incumbent's optimal price (from P_0 to P_1). In my setting, full-service stations have been converted to self-service stations during the market transition, so that cross-type competition is less intense and that the reduction in the number of full-service competitors may, by the same theory, induce full-service stations to increase their prices.

Following the prediction of monopolistic competitive models, the increased number of self-service stations should decrease self-service prices and possibly also increase full-service prices, as long as the market is sufficiently segmented by service level. To test for this hypothesis, I utilize the number of gas stations within a fixed mile as a measure of seller competition, and specify Equation (3) which is the extension of Equation (2) as follows:

$$\ln P_{it} = \beta_1 Num_{it}^{SS0.5} + \beta_2(Num_{it}^{SS0.5} * Full_{it}) + \beta_3 Num_{it}^{FS0.5} + \beta_4(Num_{it}^{FS0.5} * Full_{it}) \\ + \theta Full_{it} + \phi(Full_{it} * Trend_t) + \zeta \boldsymbol{X}_{it} + \delta_i + \mu_t + \varepsilon_{it} \quad (3)$$

where $Num_{it}^{SS0.5}$ and $Num_{it}^{FS0.5}$ are the number of self- and full-service stations within a half-mile radius of station i in time t, respectively. This specification identifies the complete relative effects of stations within service and across services.

Column (3) of Table 3 shows the coefficient of the trend of full-service premium. Remarkably, the coefficient on $Full_{it} * Trend_t$ does not significantly differ from that I report in the earlier specifications; the estimate on the trend of the full-service premium is still around 0.05.[16] In Column (4), I use wider competition boundaries replacing half-mile radii with one mile radii as a robustness check; the coefficient on $Full_{it} * Trend_t$ is qualitatively and quantitatively very similar. Furthermore, the specification including half-mile and one-mile radii together also produces qualitatively similar results though I do not report the results in this paper.[17]

One concern about these specifications is the assumption that there is only a monotonic relationship between seller concentration and price, but the monotonicity assumption may not be justified in part because the market has been in a process of the diffusion of new technologies. For example, the initial entry of self-service stations may not be a threat to full-service stations if only few consumers know how to handle self-service pumps. To investigate this issue, I allow for a flexible relationship between price and competitive conditions of sellers by adding squared terms of the numbers of stations. In Column (5) of Table 3, I confirm that this does not meaningfully change the coefficient on the trend of the full-service

[16] I explain the price effects in the next section in detail.

[17] Here, I use the natural numbers of stations rather than taking logs because some gasoline stations do not have competitors within half a mile. I also estimate a log-log specification using a five-mile radius in which all stations have at least one competitor within five miles. Nevertheless, the results are qualitatively similar.

premium.

I perform robustness checks on the earlier measurement of local competitive environments: substituting the number of stations within a fixed mile for the distance to the nearest station as in Equation (4):

$$\begin{aligned}\ln P_{it} &= \beta_1 \ln Dist_{it}^{SS} + \beta_2(\ln Dist_{it}^{SS} * Full_{it}) + \beta_3 \ln Dist_{it}^{FS} + \beta_4(\ln Dist_{it}^{FS} * Full_{it}) \\ &\quad + \theta Full_{it} + \phi(Full_{it} * Trend_t) + \zeta \boldsymbol{X}_{it} + \delta_i + \mu_t + \varepsilon_{it} \end{aligned} \tag{4}$$

where $Dist_{it}^{SS}$ and $Dist_{it}^{FS}$ are the great-circle distance to the nearest self- and full-service competitors of station i in time t, respectively. Similar to the earlier specifications, I also try including the distances to the 2nd-nearest stations or squared terms of the distances. These results are shown in Column (6)-(8) of Table 3. Across all specifications, the coefficients on $Full_{it} * Trend_t$ remain economically and statistically significant.

To summarize, the evolution of the full-service premium and the changes in the service composition of gas stations appear very correlated (Figures 2 and 3). However, using a difference-in-difference specification, I show that the increase in the full-service premium is not explained by the conventional model of monopolistic competition. It means that a bit more sophisticated model needs to understand the increasing full-service premium, which I come back to it in the later section of this paper.

4.2.2 Price Effects

In the meantime, it is worth checking whether competitive effects of sellers on price are consistent with the prediction of monopolistically competitive market. The emergence of self-service stations can affect market price through two channels: self-service stations can charge a low price due to their lower labor costs (direct effect) and drive down competitors' price if the market is imperfectly competitive (indirect effect).

The mid-panel of Table 4 presents the competitive effects of stations on price. The RHS variables of Columns (1)-(3) are the number of nearby stations, and those of Columns (4)-(6) are the distance to nearby stations. Starting with Column (1), the coefficients on the numbers are not statistically different from zero. This would be because of two reasons: big standard errors clustered by station and little variation in the number of gas stations within a half-mile radius. In Column (2), *ceteris paribus*, having one more self-service station within one mile decreases gas price by 0.5% regardless of station's service level. The interactions of the numbers and a full-service indicator pick up differential sensitivity to the degree of competition when a station offers full-serve gasoline, and they are statistically insignificant in this specification.

In Column (3), the trend of the full-service premium is dropped, in which the variation in the numbers significantly grows in this case. The magnitude of competitive effects of self-service stations on prices generally doubles, and the competition effect between full-service stations becomes significant at the 1% level and is much smaller than that between self-service stations. From this analysis, I find that the trend of the price difference between two services absorbs a large portion of the variation in the log price across gas stations.

The patterns I observe in the specifications including the numbers mirror those for the specifications along with the distances (Columns 4-6).[18] For example, in Column (4), when a distance to the nearest self-service station doubles, it allows self-service stations to charge a 0.3% high price and full-service stations to charge a 0.6% high price (i.e., 0.0027+0.0035), but these are statistically insignificant. In Column (5)-(6), the distances to the nearest stations are replaced by those to the second-nearest station. The coefficients on Dist^{SS} become significant at the 1% level in both specifications even after controlling for the trend of full-service premium, and the estimates are qualitatively similar to those in the specifications along with the numbers.

[18]Note that the increased number is corresponding to the falling distance to the nearby competitor. Thus, the signs are in opposite.

Overall, stations' prices are more elastic with respect to competition when their local competitors are self service than when they are full service. One possible explanation for this is that self-service customers who purchase only gasoline are more sensitive to price than full-service customers buying a bundle of both gasoline and service, and actually I find descriptive evidence on this possibility which is shown in later section of this paper.

The coefficients in Table 4 should be interpreted with caution as service level and location would be endogenous. For example, self-service stations may prefer to locate in markets with many full-service stations to attract more consumers through a relatively cheap price. In this case, the coefficient on Dist^{SS} would be biased downward in absolute value. It is also possible that full-service stations may prefer to locate in high-income areas, where they can charge a high premium to less-price-sensitive consumers, causing the coefficient on Dist^{FS} to be biased downward in absolute value. Although station fixed effects do not eliminate these concerns, they greatly mitigate them since seller characteristics are generally fixed for long periods in the retail gasoline industry.

Lastly, the coefficients on control variables are shown in the bottom of Table 4; the estimates are consistent across all specifications. The coefficient on brand share is positive, implying less intense competition within brands. Other things equal, stations that sell both premium and regular gasoline charge 2% more for their regular gasoline than those selling only regular gasoline. Lee, Kim, and Park (2015) also observe an increasing price gap between "premium" and "regular" stations.[19] Although it is beyond the scope of my paper to identify a link between a full-service premium and a product-grade premium, the similarity in results suggests that the different pricing strategies of full- vs. self-service stations might have a common basis with those of premium vs. regular stations.[20]

To summarize, I find that self-service stations affect the average price of gasoline both

[19]They define "regular" stations as ones selling only regular gas and "premium" stations as ones selling both premium and regular gas.

[20]I estimate the relationship between the level of services and the type of stations using a logistic regression where other covariates are controlled. The estimate is insignificant in my setting.

directly and indirectly, whereas full-service stations charge higher prices and have little indirect impact on price. I also find that signs of price effects are consistent with the prediction of monopolistically competitive market. Yet, it is still not clear how full-service stations have retained their premium for gasoline while they do not seem to be competing on price. The following section attempts to shed light on this question by introducing a further complication of price-competition models.

4.3 Product Differentiation

Recall, from Figure 4, that the distribution of full-service prices displays an increasing right-tail over time, meaning a growing share of stations charge a very high premium. The striking increase in the variability of full-serivce prices is a key factor to understand the increase in the full-service premium. A broad literature has developed on the relationship between price and competition along with product differentiation, and many of the literature have demonstrated that competition is less intense if products are differentiated among sellers.[21] Consistent with existing studies, I find that full-service stations that charge an extra premium tend to differentiate their product on one or more non-price dimensions.[22]

4.3.1 Descriptive Evidence

I start by providing some descriptive evidence that product differentiation increases largely in full-service stations. Moreover, product differentiation takes far more subtle and varied forms than simply location and brand often considered in most retail-gas-pricing studies.

[21] Particularly in the context of retail gasoline, Netz and Taylor (2002), Lewis (2008), and Noel and Qiang (forthcoming) examine pricing along with market segmentation – e.g., Netz and Taylor on a spatial dimension, Lewis for a brand dimension, and Noel and Qiang for a product-grade dimension. Economic theory defines two types of product differentiation (i.e., horizontal and vertical), but empirically it is not trivial to separate the types because consumer preference is not known *ex-ante*.

[22] Matsa (2011) examines the relationship between competition and product quality in the U.S. supermarket industry, and finds that competition increases sellers' incentive to provide quality and the largest improvement of quality arises in lower income areas of the markets affected by Wal-Mart's entry.

Specifically, some gas stations have added another type of business, such as a fast-food restaurant, dry cleaner, or nail salon to their station. A few gas stations were completely rebuilt as a complex-mall structure with multiple floors, rented to other businesses.[23] I display four typical examples of these stations in Figure 7. Station (a), located in Yeoeuido where many businesses and government agencies have offices, operates a dry cleaner within the station. Station (b) includes a coffee shop along with the gasoline pumps. Station (c) advertises itself as "a female-friendly station" equipped with a powder room and nail-care shop and decorated in purple. Station (d) has a multiplex structure; the entrance to the gas station is the right wing of the building, on which the SK logo is shown.

The average price at these four stations is 12% higher than the market average for full-service gasoline on the last day of my sample. Except for Station (b) whose price is 4% lower than its nearby stations, the remainder of the stations charges 2%, 17%, and 25% higher than their neighborhood within one mile, respectively in alphabetical order. This evidence supports the finding of earlier studies that firms enjoy less competitive pressure when their product is differentiated. To the best of my knowledge, these business formats did not exist in the Seoul gasoline market before the self-service model took off in 2008.[24]

I observe further evidence of product differentiation from advertisements of each station, collected on May 17, 2017, approximately 17 months after the end of my panel dataset. Some gas stations provide additional products along with gasoline, such as coffee, tissue, or even vacation packages. Some of these stations dispense "free" bundled products, as long as consumers purchase gasoline (50,000 KRW or more).[25] Table 5 presents the number of unique

[23]Only selected types of businesses are allowed to operate within gas stations, according to the enforcement rule under Safety Control of Dangerous Substances Act (Chapter 37 of Title 3: Gas-Station Location, Structure, and Facility).

[24]The four stations reopened on (a) 12/2012; (b) 11/2011; (c) 11/2008; (d) 12/2012. There is no official statistic on the number of stations that have adopted these unique types of business formats, but a news article (Taek, 2016) reports that SK Energy and GS Caltex have 65 and 50 gas stations that take such business formats in 2015, respectively.

[25]This is the amount that average consumers pay at one time fuel in Korea. See the survey from Korean Transportation Database (KTDB, 2013). 50,000 KRW, or approximately 50 USD, is equivalent to the cost of eight gallons of a gas.

stations and their average price by service level, and the detailed description on bundled ("free") products and their locations are shown in Table A-1 and Figure A-1 in Appendix A. The total number of stations operating on May 2017 was 539, and 55 full-service stations and 11 self-service stations provide "free" bundled products, respectively.

I draw two conclusions from Table 5. First, full-service stations are more than twice as likely to provide bundled offers as self-service stations, suggesting that full-service stations are more likely to differentiate their product on this subtle dimension. Second, prices at stations that offer extra products are higher than prices elsewhere; this pattern is much stronger for full-service stations than for self-service stations.[26] Taken together, these results support the prediction of product-differentiation models that offering a variety of bundled products and services enables stations to charge a extra premium, mostly to less-price-sensitive customers by engaging in less-intense competition on gas price.[27]

4.3.2 Evidence from Price Data

In this section, I use data in my price panel to supplement the descriptive evidence for subtle differentiation and the description on bundled "free" products, both of which are observed after the end of my price panel. Using the price panel, I identify which stations offer bundled products in May 2017 and which stations do not. After that, I compare prices of stations that later bundle products and those that do not bundle.[28] The intuition of this exercise is that if gas stations were differentiated in 2010 or 2015 as much as they were in May 2017, they would have charged a higher price than others.

[26]I find a qualitatively similar pattern when I estimate a cross-sectional regression of station prices on a dummy of whether stations have bundled offers, controlling for observed station characteristics and district fixed effects.

[27]Selling bundled products is not necessarily a strategy to increase stations' markups in this case. For example, the extra premium at bundling stations may reflect the cost of the additional services. Nevertheless, this is still true that observed prices of stations that differentiate themselves on additional dimensions are generally higher than those of stations that only sell a gasoline component.

[28]This is because I cannot identify when each station starts publicizing its special promotions. Gas stations may retrieve their strategic plan to offer bundled products depending on time, but I find supporting evidence that it is less likely. I show the evidence later in this section.

Specifically, among 539 stations in Seoul on May 17, 2017, I confirm that 536 stations are matched with my price panel (i.e., only three stations entered in a new location after my study period), and restrict the matched stations by removing 22 stations that had changed service level as of May 2017. For each station, I take prices on the first and the last days of my price panel, and then compare the price of stations that later bundle products and those that do not bundle. The comparison results are shown in Table 6

At the top panel of Table 6, I show the log prices on the first day of my sample (May 5, 2010), for stations that later offered bundled products and those that did not. Focusing on full-service stations, the price gap between stations that later bundled products and those that did not was 1.5%, which is much smaller than the difference on May 17, 2017 (8.5%). In addition, there was essentially no difference in self-service prices between stations that later bundled than those that did not. The results support the notion that the stations were much less differentiated on this dimension in May 2010 than in May 2017, and this result is strongest for full-service stations.

At the bottom panel, I show the result of the same exercise above, using the last day of my sample (December 16, 2015). The premium at the bundling (or bundling-anticipated) stations was 8.1%, which is quite similar to the actual premium on May 17, 2017 (8.5%). This similarity becomes clear when looking at Figure 8 – the price distributions of all full-service stations (panel a) and the full-service stations that later bundle (panel b) at three points in time. The price distributions on May 17, 2017 closely resembles those on December 16, 2015.[29] From these exercises, I infer that some full-service stations that charge high premiums for their gasoline retain their market share by offering bundled products, and that this strategy is closely related to the increasing variability of full-service prices in this market.

[29] These prices are adjusted for inflation to real values for December 16, 2015.

4.4 Price Search and Relative Price's Change

Many papers have shown the existence of price dispersion in retail gasoline market where gasoline itself is almost identical across sellers.[30] More interestingly in this market, the variability of full-service prices has remarkably increased during the market conversion from full service to self service. In this section, I continue to claim the reliable relationship between the increasing full-service premium and product re-positioning of mainly full-service stations, this time using a statistical approach based on insights from models of search, which once again supplements the descriptive evidence for subtle differentiation.

The theory of search explains why prices of homogeneous firms do not necessarily converge to a single price equal to their marginal cost, which demonstrates that the Bertrand Nash equilibrium is empirically not valid. The standard models of search assume a certain fraction of consumers who are unaware of which sellers charge high or low prices, and this assumption is a key driver generating price dispersion in a market for one homogeneous product and variation in prices of sellers from one period to the next.[31]

Given the predictions of the models, I hypothesize a testable implication that if a product is homogeneous across gas stations, their relative prices should not move systematically; otherwise, consumers will be informed about dispersion of stations' prices. To test for this hypothesis, for each week, I create price rankings of stations and group them by octile, and then calculate transition probabilities ($\mathbf{P}$) of price rankings to determine relative price

[30] See, for example, Marvel (1976), Lewis (2008), Tappata (2009), Lewis (2011), and Kim (2018)

[31] Baye, Morgan, and Scholten (2016) provide a detailed overview of both theoretical and empirical research on search and price dispersion.

stability.[32]

$$\mathbf{P} = \begin{bmatrix} p_{1,1} & p_{1,2} & p_{1,3} & \cdots & p_{1,8} \\ p_{2,1} & p_{2,2} & p_{2,3} & \cdots & p_{2,8} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ p_{8,1} & p_{8,2} & p_{8,3} & \cdots & p_{8,8} \end{bmatrix}$$

where the states (i) are 1, ... , 8. Note that the one-step transition probability $p_{ik} \geq 0$, and for all i,

$$\begin{aligned} \sum_{k=1}^{8} p_{ik} &= \sum_{k=1}^{8} P(X_{t+1} = k | X_t = i) \\ &= 1. \end{aligned} \tag{5}$$

Table 7 shows results of the transition probabilities using all stations in my sample.[33] Each row represents an initial octile and each column is a final octile. The probabilities along the diagonal line show that with the exception of the first octile, the stability of price rankings is higher for higher-end stations than for lower-end stations. To be specific, the probability that the eighth-octile stations stay in the same octile in the next week is 95%, whereas the average probability over all octiles is 75%. This result suggests that higher-end stations keep price positions much more stable than other stations.[34] Following the prediction of the search models, this finding supports my earlier notion that a product of gas stations that charge very high premiums for their gasoline ought to be differentiated from a product of average stations.

If customers of higher-priced stations never know prices of other nearby sellers, the high

[32]Focusing on price uniformity, Eckert and West (2005a) examine price competition in the Vancouver retail-gasoline market and find the tacitly collusive pricing behavior of sellers in the market.

[33]My results are qualitatively similar when I group rankings by quartile (1/4) or hexadecile (1/16).

[34]When controlling for station characteristics, I find these pricing patterns of sellers very strong in this market. I show the result later in this section.

stability of higher-priced stations may occur even without offering differentiated products. In my setting, however, there are many examples this would appear unlikely. First, Seoul is a dense city and gas stations are located almost everywhere. Second, as one typical example, there were seven stations in the Gangnam downtown, all within a 1-mile area, where the highest-priced station charged 20% more than the lowest-priced station. The large price gap remained for multiple years despite their similar (observed) amenities, so it is not reasonable to believe that higher-end stations' consumers are not entirely informed of large price differences across stations in this market.

To strengthen my inference further, I attempt to generalize the results of the transition probabilities using a regression framework that allows me to control for precision of time invariant station characteristics (e.g., rent and traffic). I specify a linear probability model of stability, including a full-service indicator, all control variables described in the data section, and station and time fixed effects:

$$Stable_{it} = \beta Octile_{it-1} + \theta Full_{it} + \gamma \boldsymbol{X}_{it} + \delta_i + \mu_t + \varepsilon_{it} \tag{6}$$

$$\text{where} \quad Stable_{it} = \begin{cases} 1 & \text{if } Octile_{it-1} = Octile_{it}; \\ 0 & \text{if } Octile_{it-1} \neq Octile_{it}. \end{cases}$$

where $Stable_{it}$ is a dichotomous variable that equals 1 if station's octile at week t-1 is the same as in week t, and 0 if it is not.[35] $Octile_{it-1}$ is a categorical variable based on station i's price ranking from 1 to 8 (the lowest 12.5% to the highest 12.5%) in t-1. The coefficient β picks up how stability of relative price depends on a stations' initial position.

Table 8 shows estimation results of Equation (6).[36] Column (1) shows results controlling for station and time fixed effects. I find that a one-octile increase is associated with a three

[35]Stability is undefined in the first week a station appears in the data and after a temporary exit.

[36]The results of a linear probability model are qualitatively similar to those of a logit regression. Here, I show the results a linear probability model for ease of interpretation, and present logit results in Table A-2 in Appendix A.

percentage point increase in the probability that the station's price remains in the same octile one week to the next. This is a confirmation of the earlier finding that the price rankings of higher-priced stations are more stable than those of lower-priced stations. As discussed earlier, if the product were homogeneous across stations, this finding would show a breakdown of search models as the high-priced stations settle into fairly fixed prices relative to the lower-priced stations. Rather than that, this finding supports my continuous claim that consumers are likely to perceive a package of gasoline at high-priced stations as different products at lower-priced stations.

The result is robust to adding more covariates. In Column (2), I add controls for a full-service indicator and the numbers of competitors within one mile by service level. The estimated coefficient on Octile remains approximately 0.03. Full-service stations are four-percentage points more likely to have prices in the same octile from one period to the next. Also, the positive coefficient on Num^{FS1} means that greater competition with full-service stations increases the stability of a station's pricing position, consistent with the earlier result that price competition is relatively less intense in local markets with many full-service stations. In Column (3), I include an interaction of octile and a full-service dummy. I find that the pattern – the higher priced stations display more stable relative price rankings – is much stronger for full-service stations than for self-service stations, as long as the price octile is greater than one.[37]

Together with the finding in Section 4.2 that self-service stations compete primarily for price-sensitive consumers, my results show that the strategic choices of stations evolve in different ways when the market is undergoing a significant restructuring, each type of station using its unique position to its advantage.

[37] When Octile is greater than 1, stability is greater for full-service stations than for self-service stations.

5 Concluding Remarks

This paper contributes to a literature on revisiting competitive outcomes in a market undergoing a massive change in the retail sector. The literature on this topic is growing thanks to increased accessibility to rich, micro-level data. Using a case study of the retail gasoline market in Korea, I provide insight into the price behavior of sellers during the diffusion of self service, and document a new stylized fact: the price gap between a full-service format and a self-service format has gradually increased during the transformation of gas stations from full service to self service. The descriptive and statistical evidence together solve the initially-puzzling question why a simple model of firm entry and exit alone is not enough to explain the increase in the full-service premium. This finding highlights the importance of descriptive evidence which is often overlooked by the empirical econometrician.

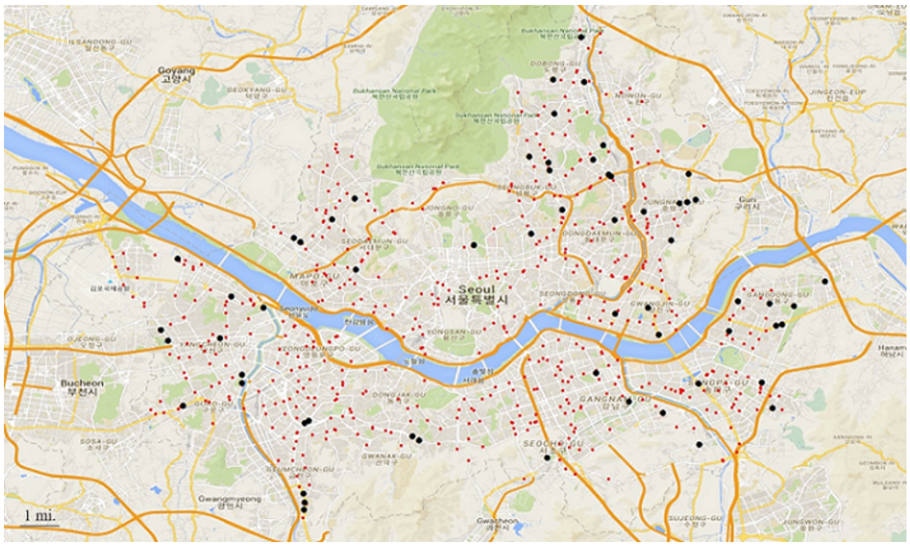
My paper has two important implications. First, I find that the strategic choices for incumbents differ by service type. Some gas stations close and others adopt the self-service model.[38] As an alternative choice of existing firms, some stations differentiate their product on one or more dimensions, allowing them to maintain their business by engaging in less-intense competition on price. These results suggest that seller characteristics are important to understanding price competition among differentiated sellers in real-world markets.

Grabowski and Vernon (1992) focus on the third strategic choice of sellers in the pharmaceutical industry. They examine competitive effects of generic drugs on price and find that the entry of generic drugs causes the price of major branded drugs to *increase*. We have a very different setting with regard to market structure, but understand the pricing pattern of existing sellers similarly through insights from models of price competition with differentiated products. In my paper, full-service stations are unlikely to compete with self-service

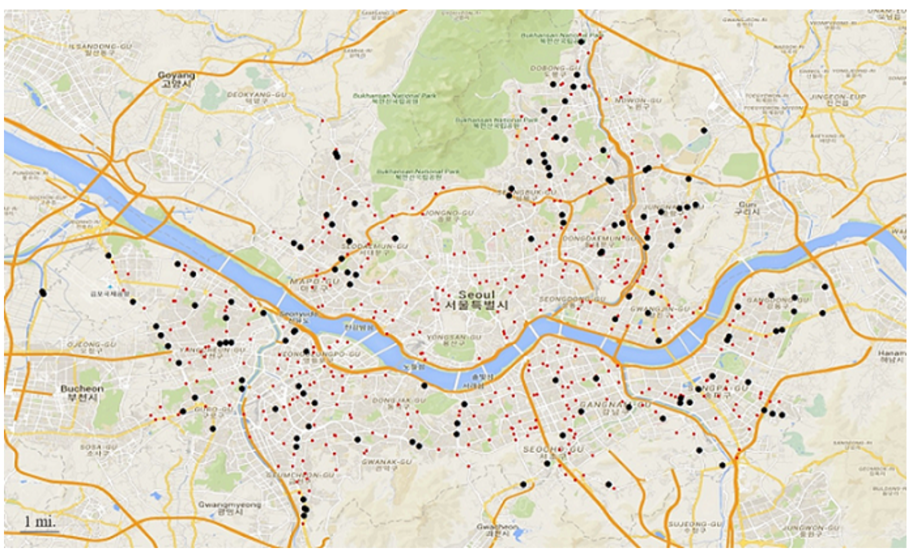
[38] As an auxiliary analysis, I also check how full-service stations' decisions are correlated with intensity of competition they face. I find that stations that compete with more self-service competitors nearby are more likely to close than to remain full service, and there exists the presence of strategic complementarities in service in this market. Details of this estimation are in Appendix C.

stations on price because their marginal costs are higher than those of self-service stations. As a result, full-service stations probably need to compete through product differentiation to focus on a market where additional services are valued by customers and charge a premium.

Second, I investigate a recent phenomenon that industry boundaries become blurred in various industries including retail, mainly due to new technologies and innovative ideas for business. For example, not limited to the business expansion of Korean gas stations beyond gasoline, some U.S. gas stations have "gone gourmet": food service at Wawa gas-stations has received national attention from customers and news media (Murray, 2014 and Johnson and Taylor, 2018). Moreover, some major oil companies have contracted with chain stores to bring stores into their gas stations, and some giant supermarkets have added gas stations (Ponczek and Blewitt, 2017). Last but not least, Amazon Go is very novel; it is a chain of fully-automated retail stores with hundreds of cameras and no checkout/cashiers. Fast-growing advanced technologies like artificial intelligence have enabled various markets to be linked. In this regard, quantifying the across-industries effects of the new competitive landscape is an interesting area for future research.

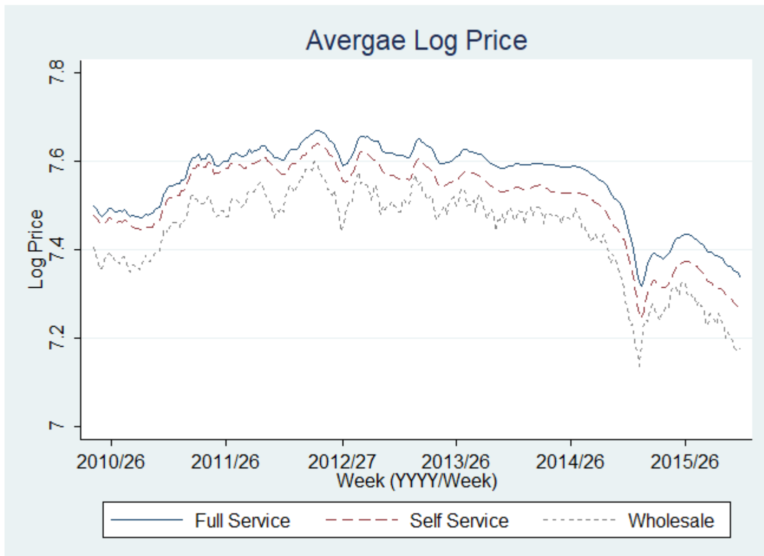


(a) May, 2010

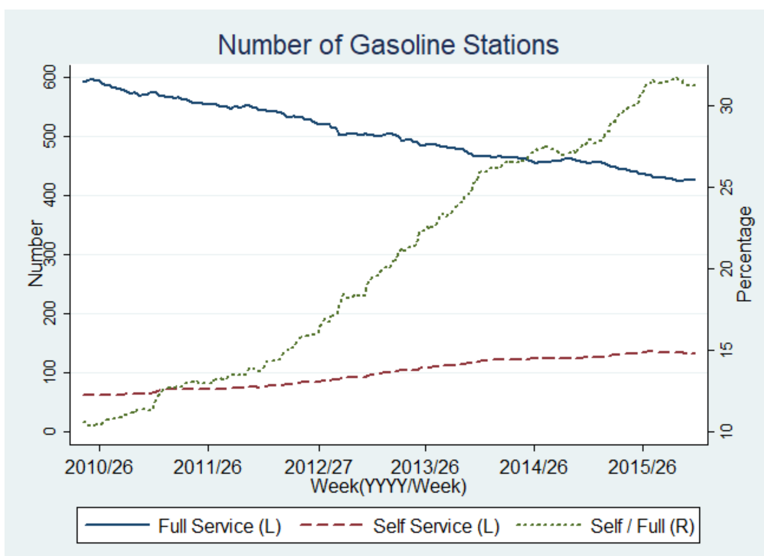


(b) December, 2015

Figure 1. Locations of gasoline stations by service level in Seoul
Note: Large dots are self service and small dots are full service

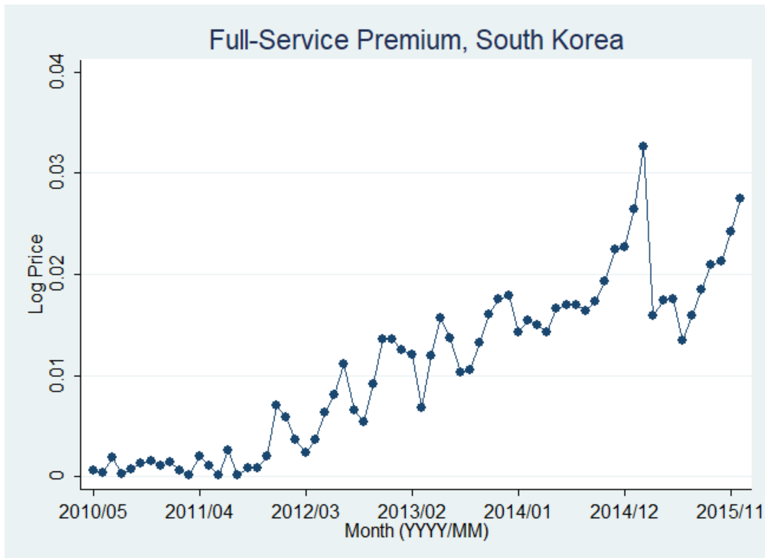


(a) Time series of market prices

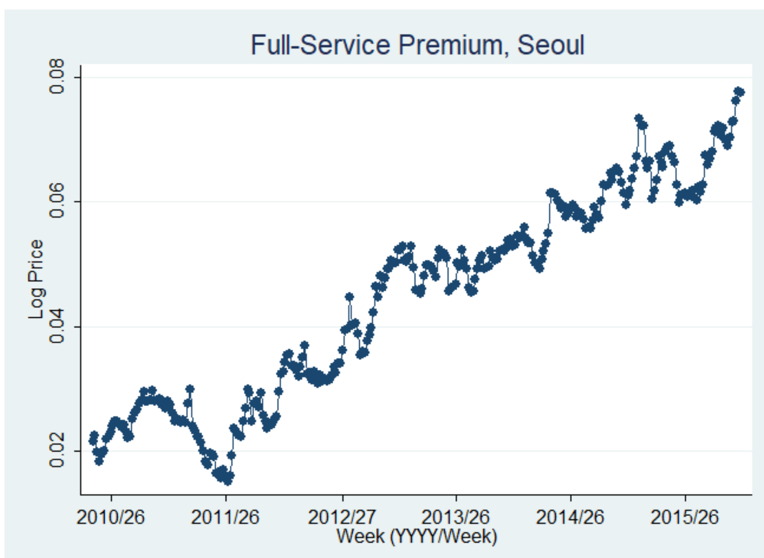


(b) Time series of the number of gasoline stations

Figure 2. The overview of market prices and market conversion, 2010-2015

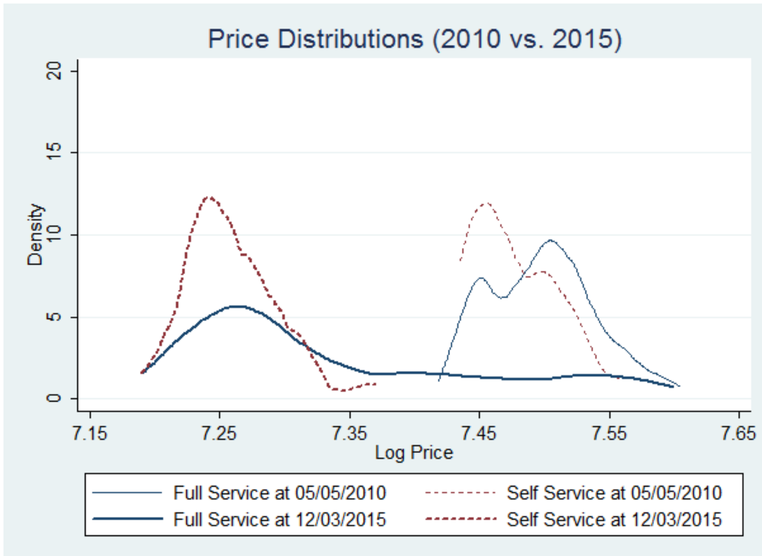


(a) Korea, Monthly

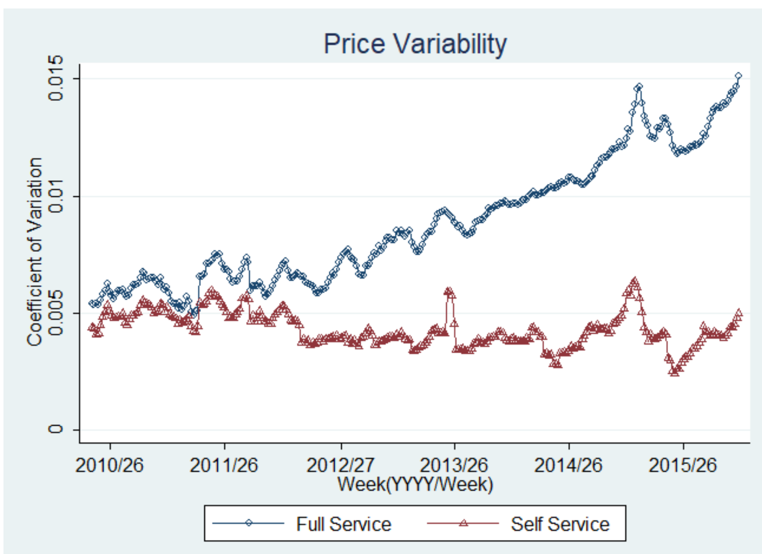


(b) Seoul, Wednesday

Figure 3. The evolving full-service premium, 2010-2015



(a) Price distributions: 05/05/2010 vs. 12/03/2015



(b) Time series of price variability, by service level

Figure 4. The different patterns of price variability by service level, 2010-2015

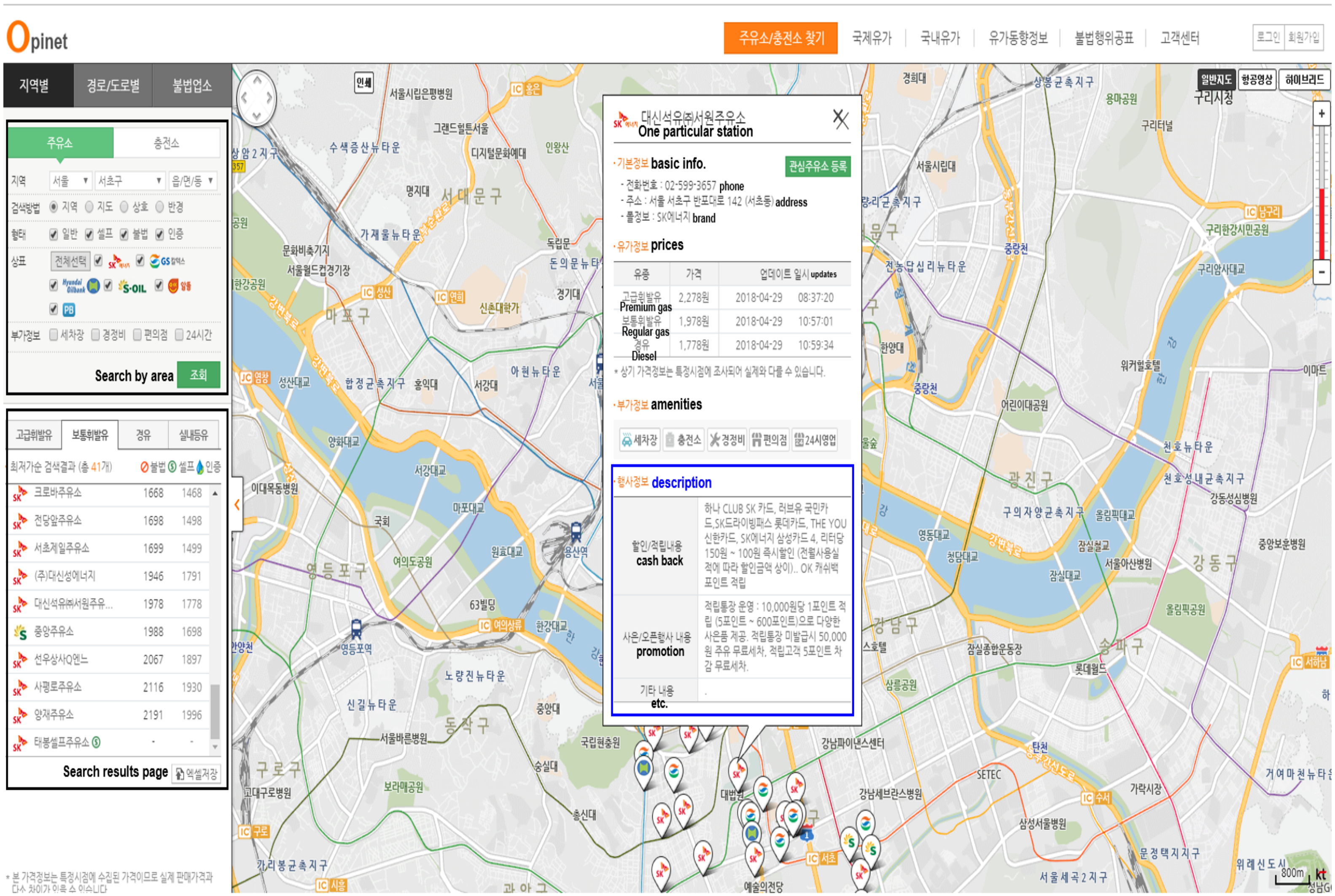


Figure 5. Web page of OPINET on April 29, 2018

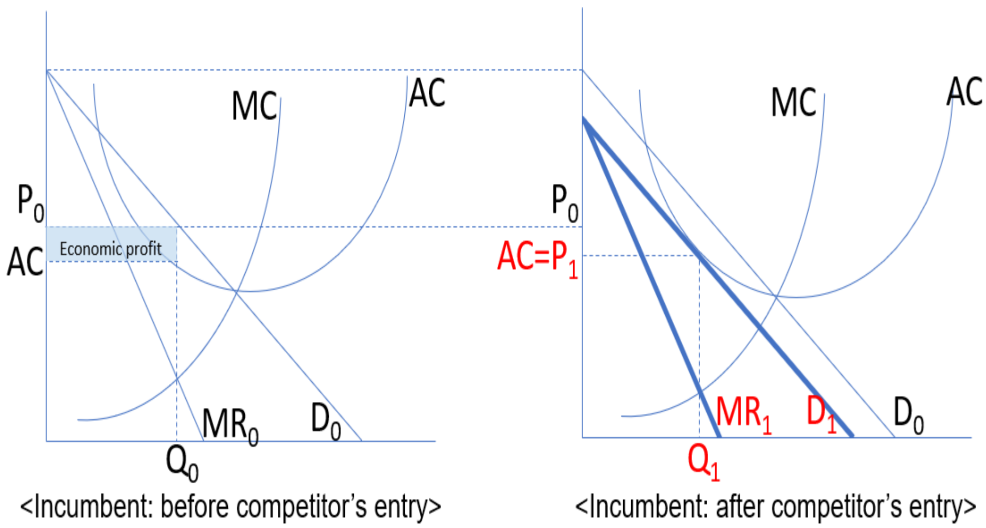


Figure 6. the prediction of monopolistically competitive market in the short run

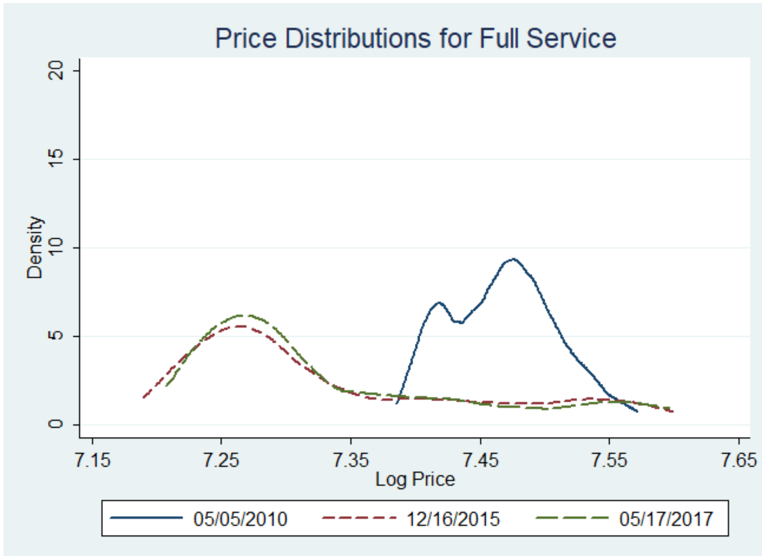
(a) Dry cleaner

(b) Coffee shop

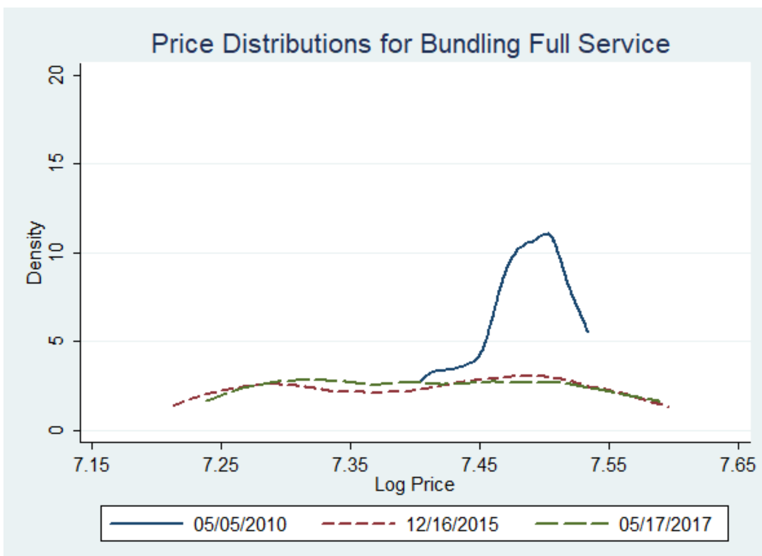
(c) Powder room & nail care

(d) Complex mall station

Figure 7. Examples of differentiated gas stations in Seoul
Source: (a) http://www.korea-news.com/news/articleView.html?idxno=46986; (b) http://cafe.daum.net/oilproject; (c) and (d) https://skenergy.tistory.com.



(a) All full-service stations



(b) Later bundling full-service stations

Figure 8. The Price distributions of full-service stations on the selected days
Note: bundling information is as of on May 17, 2017

Table 1. Summary statistics: numbers and distances of nearby competitors [175,940 Obs.]

	Mean	SD	Min	Max	Mean	SD	Min	Max
Number of	**FS competitors (Num^{FS})**				**SS competitors (Num^{SS})**			
Within 0.5 mile (#)	1.98	1.54	0.00	10.0	0.41	0.67	0.00	4.0
Within 1.0 mile (#)	7.15	3.44	0.00	21.0	1.33	1.32	0.00	7.0
Distance to	**FS competitors ($Dist^{FS}$)**				**SS competitors ($Dist^{SS}$)**			
1st nearest (mi)	0.32	0.22	0.01	2.70	0.89	0.63	0.02	3.50
2nd nearest (mi)	0.50	0.24	0.03	2.71	1.31	0.70	0.12	4.12

Note: Average across all stations in all time periods.

Table 2. Summary statistics: control variables [175,940 Obs.]

Variable	Description	Mean	SD	Min	Max
P	Price of gasoline (unit: KRW/liter)	1904.7	206.7	1317	2490
lnP	Log price of gasoline	7.54	0.11	7.18	7.82
Full	Station offering full-serve gasoline	0.83	0.37	0	1
SK	Station brand: SK Energy	0.36	0.48	0	1
GS	Station brand: GS Caltex	0.25	0.43	0	1
SO	Station brand: S-Oil	0.11	0.31	0	1
HD	Station brand: Hyundai Oilbank	0.12	0.33	0	1
AD	Station brand: Alddle	0.02	0.13	0	1
Unbranded	Station brand: Unbranded	0.03	0.17	0	1
Brand Share	Share of same-brand stations within 1.5 miles	0.27	0.16	0	1
Multi Product	Station selling regular and premium gasoline	0.33	0.47	0	1
Stations	Number of gasoline stations in Seoul	602.8	25.4	558	658

Note: Average across all stations in all time periods.

Table 3. Estimation results, full-service premium trend

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OLS	FE	Nums	Nums	Squared Nums	Dists	Dists	Squared Dists
			0.5-mi	1.0-mi	1.0-mi	1st-nearest	2nd-nearest	2nd-nearest
Full*Trend	0.0550***	0.0477***	0.0486***	0.0488***	0.0492***	0.0495***	0.0491***	0.0491***
	(0.0066)	(0.0057)	(0.0063)	(0.0075)	(0.0063)	(0.0062)	(0.0065)	(0.0062)
Full	0.0169***	0.0196***	0.0231**	0.0327**	0.0222**	0.0168*	0.0175**	0.0151
	(0.0044)	(0.0058)	(0.0100)	(0.0135)	(0.0100)	(0.0104)	(0.0089)	(0.0105)
Control variables	N	Y	Y	Y	Y	Y	Y	Y
Station FE	N	Y	Y	Y	Y	Y	Y	Y
Obs	175940	175940	175940	175940	175940	175940	175940	175940
Adj R	0.687	0.898	0.900	0.901	0.900	0.900	0.901	0.900

Specifications (3)-(8) also include the measure of local competitive conditions.
All specifications also include time fixed effects.
Robust standard errors in parentheses, clustered by station.
* p<10%; ** p<5%; *** p<1%.

Table 4. Estimation results, competitive effects on prices

	(1) Nums 0.5-mi	(2) Nums 1-mi	(3) Nums 1-mi	(4) Dists 1st-nearest	(5) Dists 2nd-nearest	(6) Dists 2nd-nearest
Full*Trend	0.0486***	0.0488***		0.0495***	0.0491***	
	(0.0063)	(0.0075)		(0.0062)	(0.0065)	
Full	0.0231**	0.0327**	0.0761**	0.0168*	0.0175**	0.0584***
	(0.0100)	(0.0135)	(0.0127)	(0.0104)	(0.0089)	(0.0082)
Num^{SS}	-0.0041	-0.0048**	-0.0089***			
	(0.0033)	(0.0021)	(0.0021)			
Num^{SS}*Full	-0.0064	-0.0037	0.0013			
	(0.0042)	(0.0025)	(0.0023)			
Num^{FS}	0.0002	0.0003	0.0020			
	(0.0026)	(0.0012)	(0.0012)			
Num^{FS}*Full	-0.0006	-0.0010	-0.0038***			
	(0.0026)	(0.0012)	(0.0011)			
$Dist^{SS}$				0.0027	0.0130***	0.0261***
				(0.0032)	(0.0048)	(0.0050)
$Dist^{SS}$*Full				0.0035	0.0032	-0.0129**
				(0.0042)	(0.0060)	(0.0057)
$Dist^{FS}$				0.0008	0.0026	-0.0073
				(0.0041)	(0.0059)	(0.0060)
$Dist^{FS}$*Full				-0.0025	-0.0004	0.0116*
				(0.0040)	(0.0063)	(0.0063)
SK	0.0322***	0.0326***	0.0313***	0.0332***	0.0324***	0.0312***
	(0.0087)	(0.0088)	(0.0085)	(0.0088)	(0.0086)	(0.0084)
GS	0.0246***	0.0240***	0.212***	0.0246***	0.0238***	0.0220***
	(0.0079)	(0.0078)	(0.0077)	(0.0080)	(0.0078)	(0.0076)
SO	0.0109	0.0116	0.0115	0.0117	0.0108	0.0105
	(0.0118)	(0.0119)	(0.0117)	(0.0121)	(0.0115)	(0.0113)
HD	0.0141	0.0126	0.0097	0.0133	0.0126	0.0107
	(0.0112)	(0.0116)	(0.0110)	(0.0114)	(0.0115)	(0.0112)
AD	-0.0225*	-0.0230*	-0.0250	-0.0211	-0.0214	-0.0186
	(0.0135)	(0.0138)	(0.0124)	(0.0137)	(0.0139)	(0.0140)
Brand Share	0.0289**	0.0270*	0.0308**	0.0286**	0.0287**	0.0344**
	(0.0148)	(0.0148)	(0.0149)	(0.0150)	(0.0149)	(0.0147)
Multi Product	0.0204***	0.0208***	0.0208***	0.0207**	0.0205***	0.0213***
	(0.0067)	(0.0066)	(0.0065)	(0.0067)	(0.0067)	(0.0066)
FS Trend	Yes	Yes	No	Yes	Yes	No
Obs	175940	175940	175940	175940	175940	175940
Adj R^2	0.900	0.901	0.899	0.900	0.898	0.899

All specifications also include station and time fixed effects.

LHS variable is station log price.

RHS variables are the numbers of nearby stations in Columns (1)-(3); log distances to nearby stations in Columns (4)-(6).

Unbranded is omitted.

Robust standard errors in parentheses, clustered by station.

* p<10%; ** p<5%; *** p<1%.

Table 5. Price comparisons of stations by bundling status

	Full Service		**Self Service**	
May 17, 2017	# Stations	Avg. Log Price	# Stations	Avg. Log Price
Bundled[a]	55	7.444	11	7.321
Not Bundled[b]	337	7.360	136	7.298
Difference		0.085		0.023
P-value		(0.000)		(0.073)
All	392	7.372	147	7.300
Difference		0.072		
P-value		(0.000)		

[a] Stations that dispense "free" bundled products when the purchase amount of gasoline is 50,000 KRW or more.

[b] Stations that do not dispense "free" bundled products.

Table 6. Price comparisons of stations by bundling-anticipated status

	Full Service		Self Service	
May 05, 2010	# Stations	Avg. Log Price	# Stations	Avg. Log Price
Bundled in 2017[a]	48	7.514	2	7.503
Not bundled in 2017[b]	290	7.499	50	7.475
Difference		0.015		0.028
P-value		(0.011)		(0.268)
All	338	7.501	52	7.476
Difference		0.025		
P-value		(0.000)		

	Full Service		Self Service	
Dec 16, 2015	# Stations	Avg. Log Price	# Stations	Avg. Log Price
Bundled in 2017[a]	55	7.407	7	7.282
Not bundled in 2017[b]	332	7.326	115	7.258
Difference		0.081		0.023
P-value		(0.000)		(0.156)
All	387	7.338	122	7.259
Difference		0.078		
P-value		(0.000)		

[a] Stations that provide bundled their products in May 2017

[b] Stations that do not provide bundled products in May 2017

Table 7. Transition matrix of price rankings (unit: %) [174,648 Obs.]

		t+1								
		1	2	3	4	5	6	7	8	Total
Lowest 12.5%	1	77.35	20.03	2.14	0.35	0.09	0.04	0.00	0.00	100.0
	2	18.32	59.12	20.58	1.69	0.21	0.07	0.00	0.02	100.0
	3	2.73	18.19	59.71	18.25	0.97	0.11	0.02	0.01	100.0
	4	0.67	2.38	15.30	66.23	14.92	0.45	0.04	0.01	100.0
t	5	0.28	0.43	1.74	12.83	73.93	10.56	0.20	0.03	100.0
	6	0.15	0.13	0.20	0.68	9.37	81.04	8.37	0.07	100.0
	7	0.04	0.06	0.08	0.17	0.37	7.43	86.53	5.32	100.0
Highest 12.5%	8	0.06	0.05	0.05	0.05	0.07	0.28	4.87	94.58	100.0
Total		12.37	12.56	12.48	12.56	12.46	12.45	12.52	12.60	100.0

Rows show an initial octile and columns are a final octile. This matrix represents one-week transition probabilities of price rankings of stations.

Table 8. Estimation results, relative stability of price rankings

	(1) Baseline	(2) Controls	(3) By Service
Octile	0.0303***	0.0296***	0.0092*
	(0.0023)	(0.0022)	(0.0053)
Octile*Full			0.0251***
			(0.0055)
Full		0.0433***	-0.0390***
		(0.0164)	(0.0237)
Num^{SS1}		-0.0000	0.0003
		(0.0038)	(0.0037)
Num^{FS1}		0.0095***	0.0104***
		(0.0023)	(0.0023)
Control variables	N	Y	Y
Station and Time FE	Y	Y	Y
Obs	174648	174648	174648
Adj R^2	0.092	0.092	0.093
% predicted outside [0, 1]	1%	2%	3%

LHS variable is a dummy of whether station's octile at week *t*-1 is the same as in week *t*.

In Column (3), the coefficient on Full is positive whenever Octile >=2.

Robust standard errors in parentheses, clustered by station.

* p<10%; ** p<5%; *** p<1%.

A Appendix A: Supplementary Results

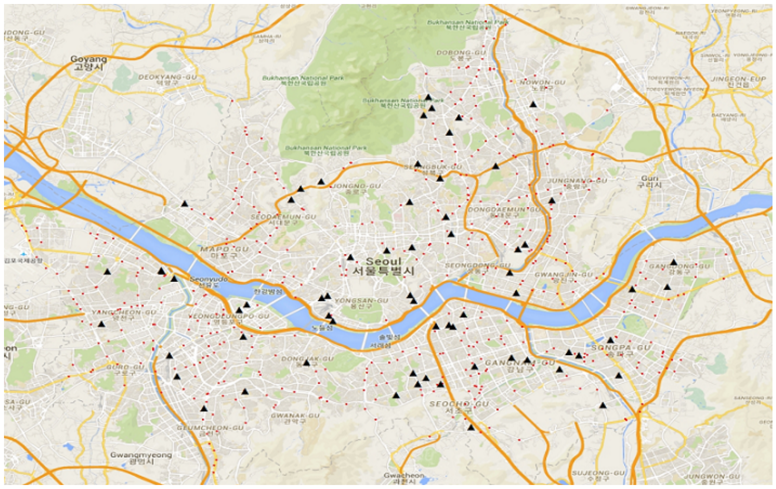


Figure A-1. Locations of stations with “free” offers on May 17, 2017 (triangle)

Table A-1. Description of bundled products and the number of stations on May 17, 2017

	# Full Service	# Self Service	Total #
Reward points[a]	29	4	33
Carwash	9	3	12
Carwash, if buying premium gas	1	0	1
Carwash & Coffee	1	0	1
Carwash & Coffee & Washer fluid	1	0	1
Coffee or Tea	3	1	4
Coffee & Washer fluid	1	0	1
Coffee & Facial tissue	2	0	2
Water	3	0	3
Facial tissue	1	1	2
Water or Facial Tissue	1	1	3
Car Inspection	2	0	2
Service for Diplomatic vehicles	1	0	1
Coffee, Soda, Noodle, Copy/Fax, TV, Lounge[b]	0	1	1
Total #: 539 (Full Service 392; Self Service 147)	55/392 (14%)	11/147(7%)	66/539(11%)

[a] These are station-specific reward points, not brand-membership points. Reward points can be redeemed as gasoline or station’s own bundled products: the bundled products are various ranging from wiper blades to vacation packages.

[b] This station seems to serve largely tractor-trailer drivers.

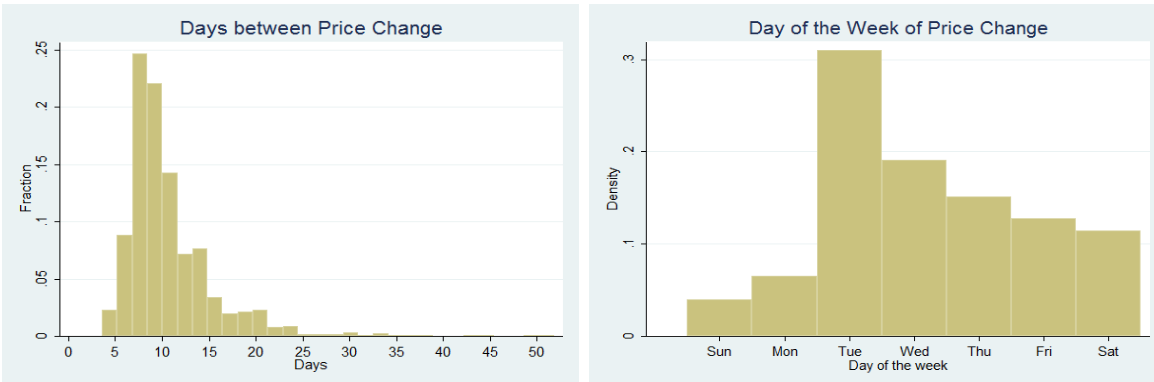
Table A-2. Logistic regression results, stability of price rankings

	(1) Baseline	(2) Controls	(3) By Service
Octile	0.170***	0.164***	0.039***
	(0.005)	(0.005)	(0.011)
Octile*Full			0.157***
			(0.012)
Full		0.267***	-0.242***
		(0.015)	(0.057)
Num^{SS1}		-0.015	-0.012
		(0.012)	(0.012)
Num^{FS1}		0.051***	0.058***
		(0.008)	(0.008)
Control variables	N	Y	Y
Station and Time FE	Y	Y	Y
Obs	174648	174648	174648

Standard errors in parentheses.

* p<10%; ** p<5%; *** p<1%.

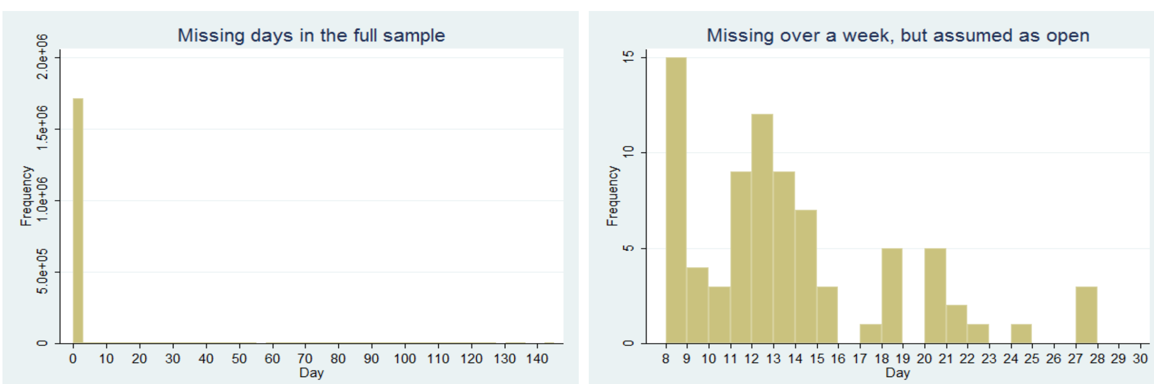
B Appendix B: Price Information



(a) Timing (b) Frequency

Figure B-1. Price changes: timing and frequency

More information on Figure B-1: The left-hand figure presents that stations change price once average 11 days on average (median=11; sd=5.22; min=3.50; max=45.1). The right-hand figure shows that stations' price changes are more common on Tuesdays and least common on Sudays.



(a) Missing Days (b) Compromise

Figure B-2. Missing days and compromise

More information on Figure B-2: The left-hand figure shows the frequency of missing observations in the full dataset. The right-hand figure shows my compromise for instances which do not report price for up to four weeks, but report no changes of observed station characteristics. This compromise applies to 80 instances of a total of 175,940 observations.

C Auxiliary Analysis: Full-Service Stations' Choices

Table C-1. Full-service stations' choices during the sample period.

	Permanent exit	Conversion to SS	FS continuation
# of stations in the market[a]		from 593 to 426	
# of instances	122	65	406
Avg. Num^{SS1} on the first day	0.93	1.02	0.72
Avg. Num^{FS1} on the first day	9.20	8.77	8.63

[a] The total number is from one on the first day to one on the last day of the sample. 593−122−65<426; the difference is the number of full-service stations newly entered during the period.

When self-service technology is introduced in the gasoline market, full-service stations decide to either close, convert to self service, or continue to sell full-service gasoline. This auxiliary section is intended to examine full-service stations' decisions in response to their local competitive environments.[39] Based on entry and exit information, I identify "permanent exit" for full-service stations when they stopped reporting prices and did not return by the end of the sample period; "conversion to SS" as those that stopped reporting full-service prices but later reported self-service prices in the same location; and "FS continuation" when they neither closed nor converted during my study period.[40] The top panel of Table C-1 shows the number of stations corresponding to each situation during my study period.

I specify a multinomial logistic model of full-service station i's decision j to be correlated with the number of local competitors and some other covariates. The multinomial logistic model allows me to simultaneously consider three options: continuing as full service, switching to self service, and station exit. The coefficients of interest are β and γ in Equation (7):

$$log(\frac{\pi_{ij}}{\pi_{iJ}}) = \alpha_j + \beta_j Num_i^{SS1} + \gamma_j Num_i^{FS1} + \zeta_j \boldsymbol{Z}_i + \varepsilon_{ij} \tag{7}$$

where $j = \{$"permanent exit" or "conversion to SS"$\}$ and $J =$ "FS continuation"

[39] Globerman (1978) and Basker, Foster, and Klimek (2017) study the relationship between rates of adoption of self service and station characteristics, using Canada data from 1973 to 1974 and US data from 1977 to 1992, respectively.

[40] Full-service stations take time to convert to self service. The average number of weeks during which a station is closed for conversion is 12; the median is 4; the minimum is zero; the maximum is 88.

Table C-2. Explaining the relative probability to FS continuation

	(1) May 05, 2010	(2) May 04, 2011
Outcome: permanent exit		
Num^{SS1}	1.293**	1.286***
	(0.145)	(0.125)
Num^{FS1}	1.047**	1.073***
	(0.023)	(0.026)
Outcome: conversion to SS		
Num^{SS1}	1.413*	1.345**
	(0.267)	(0.178)
Num^{FS1}	1.021	1.048
	(0.032)	(0.033)
Control variables	Y	Y
Obs	591	546

The coefficients are the relative probability of one outcome to the base outcome, FS continuation.
The coefficients on control variables are generally insignificant.
Robust standard errors in parentheses, clustered by district.
* p<10%; ** p<5%; *** p<1%.

where $\frac{\pi_{ij}}{\pi_{iJ}}$ is the odds that full-service station i falls in category j as opposed to the baseline outcome (J="FS continuation"). Num_i^{SS1} and Num_i^{FS1} are the number of self- and full-service competitors within a one-mile radius of full-service station i, respectively. $\boldsymbol{Z}_i$ is a vector of all covariates described in the data section. Note that I also control for monthly household income and the registration number of vehicles at the district level, both of which come from Seoul Statistics, a database operated by the Seoul government. The monthly household income is based on survey data and the number of vehicles registered is from administrative data. These variables are observed in May of 2010 and 2011, in which this auxiliary analysis particularly focuses on those two periods. Lastly, I allow the standard errors to be correlated within district in that the decisions of stations are possibly correlated with their nearby competitors.

It should be noted that Equation (7) is a cross-sectional specification that uses the first day of the sample. A panel regression or hazard model of self-service adoption that utilizes information on the timing of switching would potentially use the available information more efficiently. In my particular setting, however, the endogeneity of the number of local competitors and their service levels worsens if I add the time domain in the specification; today's exit and switch decisions of stations are interdependent of their local competitive conditions in the past. That is, the error structure of a panel regression or hazard model becomes hard to specify in later time periods. Because of that concern, I select a cross-sectional regression as my main specification. Nevertheless, a panel regression shows qualitatively similar results of these estimates though I do not show them here.

Table C-2 presents relative-probability ratios for each outcome relative to "FS continuation", with two different days. I start by showing results with the first day of my sample (May 5, 2010) in Column (1). For each additional self-service competitor nearby, the relative probability of exiting is 29% higher and relative probability of converting is 41% higher, respectively, than the probability of remaining full service. Consistent with Figure 1, this finding implies the presence of strategic complementarities in service in this market. Two possible explanations for this phenomenon are learning by consumers, and learning by sellers. In the first case, in the early period of the market transformation, consumers need to learn how to use self-service pumps. In the second case, stations may choose to learn about demand by observing their competitors' success or failure before making the transition. Switching carries a huge financial burden to sellers, so a rash decision to switch leads to serious damages to their future business.

The coefficient on Num^{FS1} shows how competition among full-service stations is correlated with their decisions. Having one more full-service station nearby increases the probability of closing by 5% compared to the probability of remaining full service at a significance level of 0.05, but does not statistically predict their decision to switch to self service.

In Column (2), I estimate Equation (7) again, this time using data from May 4, 2011 (one year after the first day of my sample). The results generally mirror those for the first day of the sample and the statistical significance of estimates becomes stronger. It is worth noting that the magnitude of estimates or even their signs can differ by degree of market transformation because the progress of the transition is not constant. For example, when the number of self-service stations is in equilibrium, entry of self-service stations should no longer predict conversion from full service to self service.

Overall, my results support basic competitive models that entry of low-price competitors drives high-cost marginal stations out of a market. That is, in my setting, more intense competition on price driven by entry of self-service stations is positively correlated with either full-service stations' exit or conversion.

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