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STRATEGIC PRICE DECISION INDUCING CONSUMER RATIONING: THEORY AND EVIDENCE

KWANG-SOOK HUH*

This paper assumes that consumers make their quality inference in part on the basis of past excess demand for the good. It indicates that excess demand in the previous period can influence subsequent potential buyers' purchasing behavior. It may then be rational for a firm introducing a new product to adjust its initial production and price to increase the likelihood of excess demand in an attempt to influence potential consumers' perception of quality and, thus, subsequent demand. This paper formally develops a model that demonstrates this result in the context of a market with demand and quality uncertainty. The model's predictions are tested using a data set of new cars in the US, and empirical results support the theory.

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I. INTRODUCTION

Economists typically are concerned with prices that equate supply and demand, but in many cases prices are below the market-clearing level and excess demand queued. Fine restaurants, well-known plays, sporting events, and other activities often involve non-price rationing of scarce seats. In the case of manufacturing industries, temporary and continuous

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* Senior Economist, POSCO Research Institute, 147 Samsung-dong, Gangnam-gu, Seoul 135-878, Korea. Tel: 822-3457-8115, Fax: 822-3457-8040, E-mail: kshuh@posri.re.kr. I would like to thank two anonymous referees for helpful comments and suggestions.

demand rationing is also commonly observed; examples include nonferrous metals, aluminum, game cartridges, video game player, personal computer, microprocessor chips, electric parts, childrens' toys, videos, and luxury/sports cars. In the case of the car market, excess demand is indicated by a low inventory that leads to long waits by buyers to take delivery, and in transaction prices above the manufacturers' suggested retail prices. It is particularly common to observe such low inventories and rationing for luxury/sports cars when they are introduced to the market.

It is an interesting economic puzzle that carmakers often accept excess demand during the initial periods after the introduction of new cars, rather than change price or output. According to standard microeconomic theory, when the firm is facing excess demand, it could increase profit by raising price or output. Of course, such instances could simply reflect a high demand realization given uncertain demand. However, uncertain demand alone can induce carmakers to specify relatively high, not low, inventory levels during the initial periods. Typical studies on inventory are based on the idea that the firm holds inventory to smooth production in the face of fluctuating sales. These studies emphasize that the firm has an inclination to hold relatively high inventory when the firm faces high uncertainty in the market.

This paper introduces a countervailing reason for initial low inventory levels that depends on a consumption externality among consumers. In particular, it is assumed that there are both informed and uninformed consumers in the market regarding the desirability or "quality" of a new good; it follows that uninformed consumers can infer quality in part on the basis of past excess demand for the good. If excess demand in the previous period influences subsequent potential buyers' purchasing behavior, then it may be rational for a firm introducing a new product to adjust its initial production and price to increase the likelihood of excess demand in an attempt to influence potential consumers' perception of desirability (quality) and thus subsequent demand.

This paper is organized as follows. Section II provides numerous observed examples from the real world that firms use rationing as a marketing strategy in an attempt to build up their reputations. A brief literature review is presented in Section III. Section IV introduces an analytical model that demonstrates firms' attempt to manipulate the uninformed consumers' beliefs regarding quality based on observed inventory. In Section V, using an extensive data set of inventories and sales for new brands of luxury/sports cars over the past 15 years in the US, we test the model's predictions. Conclusions are provided in Section VI.

II. EXAMPLES

We often observe carmakers using the rationing phenomenon to build up their reputations in the real world. For instance, BMW intended to "hold" its UK sales continuously at their current record in 1997 despite booming demand for new models since it emphasized the idea that, "Exclusivity is an extremely important feature of the BMW brand".[1] BMW was rationing its supplies for new models in an attempt to create cachet and keep it. Lexus' success story after it launched in 1989 included a strategy of "smart prices" to induce queuing that created exclusivity to lure affluent new buyers to its brand.[2] More overtly, when GM Saturn was facing continuously excess demand after its introduction in 1991, GM Saturn advertised in 1992 that it was a good thing that Saturn was so hard to find.[3] GM also attempted to raise the image of exclusivity and desirability for Saturn. Recently, when Ferrari, BMW, and Audi faced serious queuing for their new models in Australia, they emphasized that the scarcity of their cars is a significant signal of high quality, such as "Can't Buy Me, Love".[4]

The toy and video game industries are also industries in which individual producers often are rationing products to stir up demand. They have long sought to shake up the market for products that have seen better-selling days by stemming their supply. Marketing experts point out

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[1] Niki, P and E. Hamzic, "BMW rationings cars to keep it cachet", *Sunday Times*, Nov. 9, 1997, p.4.

[2] Rechtin, M., "Smart prices, more passion are vital to Lexus strategy", *Automotive News*, Sep. 15, 1997, p 27. McClellan, M., "Japanese Lexus cars lift the bar", *Ward's Auto World*, Sep. 1999, pp.40-41.

[3] Mitchell, J., "GM Saturn ads request buyers to be patient", *Wall Street Journal*, Sep. 25, 1992, B 1.

[4] Dowling, J., "Can't Buy Me, Love", *Sun Herald*, April, 30, 2000, p.4.

that toy and video game companies have manipulated supply into an overt strategy. The success of Beanie Babies, the bean-bag animals, is partly due to a lack of availability.[5] Many people also think that the marketing strategy of scarcity resulted in the success of Nintendo. The firm used excess demand as a conscious part of their marketing strategies to induce consumers' interest and to develop a reputation, when it introduced Nintendo games to the market.[6] Peter Main, vice president of marketing for Nintendo, mentioned about this marketing strategy, "Our marketing strategy is to take a product that is desirable and, through deft marketing, both stimulate demand and ration its availability, ensuring that Nintendo games are far more desirable than readily obtainable."[7] In the case of the Sony Playstation 2, it was facing substantial excess demand around the world as soon as it appeared on the market. Many marketing experts have speculated that the shortage is a marketing strategy that Sony adopted. Walt Disney also has excelled at maintaining high demand for its animated films by carefully controlling their availability on video. It regularly advertises that one or another of its beloved movies will be available on video only for a limited time.

III. LITERATURE REVIEW

This paper is related to the literature on rationing and optimal inventory determination under demand uncertainty. One approach for explaining a rationing phenomenon focuses on consumers' searching or switching costs. Slade (1991), Haddock and McChesney (1994), and Gilbert and Klemperer (2000) present prices that result in rationing as potentially more profitable than market-clearing prices if customers must pay searching or switching costs before they decide to purchase. In such cases, the firm may be unwilling to increase their prices in response to an increase of demand, because a price increase may upset the no-searching equilibrium and thereby devalue the firm's hard-won goodwill.

[5] Goldman, A., "Beanie Baby Statement Could Backfire On Ty Toys', *Los Angels Times*, Sep. 2, C-1.
[6] Wolpin, S., "How Nintendo Revived a dying Industry", *Marketing Communications*, May 1989, 36-40.
[7] Ramirez, A., "Nintendo's Main man; He's no Video wiz, but Master of Supply, Demand", *New York Times*, Jan., 1, 1990.

The second approach for explaining rationing is based on the assumption of precommitment of prices or outputs for durable goods (Van-Cayseele 1991 and DeGraha 1995). If the firm can precommit on either prices or capacity (outputs), this may result in rationing in the first period of a two-period model. For instance, Van-Cayseele assumes that the seller can commit to a given second-period output so that high-value consumers, if they wait for the second period, are not certain of obtaining the good. He demonstrates that the commitment on output may explain the rationing phenomenon of durable goods in the first period, and intertemporal price discrimination.

The third approach emphasizes a consumption externality among consumers (Becker 1991, Basu 1987, and Karni and Levin 1994). The motivation for this explanation for rationing is the recognition that restaurant dining, watching a game or play, attending a concert, or talking about books are all social activities during which people consume a product or service together and partly in public. Consumers' confidence in the quality of the food, writing, or performance is greater when a restaurant, book, or theater is more popular.

The explanation of rationing in this paper is similar to the idea presented by Becker. In doing so, we expand Becker's idea into a two-period dynamic model to emphasize that subsequent consumers infer unknown quality from the noisy observation of prior excess demand. In this setting, we develop an explicit characteristic of an uninformed monopolist's behavior to maximize its expected profits through strategic manipulation of uninformed consumers' beliefs. Although extreme, this assumption captures an important feature of practical experience. In many markets, past excess demand is observable and informative for subsequent consumers. For example, often consumers are aware of the difficulty of making reservations or of queues at well-known restaurants, long waiting lists to take delivery of some luxury/sports cars, and long lines to enter the best plays. In such cases, they infer high quality.

To summarize, in this paper, we accept the idea of a consumption externality, but emphasize the informational role of excess demand under the demand uncertainty in a dynamic setting. Focusing on informational asymmetry, we assume that subsequent consumers infer unknown quality from a noisy observation of excess demand. It is then rational for a firm introducing a new product to adjust its initial output or price to increase the likelihood of excess demand in an attempt to influence potential consumers' perception of quality and thus subsequent demand.

IV. AN ANALYSTICAL MODEL

In this section, we introduce an analytical model that demonstrates the firm's attempt to manipulate the uninformed consumers' beliefs regarding quality based on observed inventory. First, we derive the optimal price and quantity conditions for the basic single-period setting under the firm's myopic profit maximization strategy. These results provide benchmarks to compare to the outcome in a two-period setting in which monopoly manipulation can emerge. In many cases, there is uncertainty with respect to whether a good produced will meet the preferences of consumers. In the discussion to follow, a good that better matches the preferences of consumers will be termed a higher-quality (or desirability) good. It is important to realize that such quality is often not chosen by the producer, but instead arises from consumers' tastes that are difficult for the producer to discern *ex ante*. Nevertheless, these subjective and unobservable product attributes can be a significant factor determining the firm's competitiveness in the market.

Once a good is produced, some consumers become informed about the good's quality prior to purchase, while other "uninformed" consumers may infer unknown quality, in part, based on the actions of these informed consumers. Informed consumers choose their consumption under the conditions of a given price and known quality; uniformed consumers choose consumption of the good based on the given price and their expected quality.

We assume that a representative consumer varies in the value it places on quality, denoted by v, on the interval [0, 1] with a uniform distribution. A consumer in either group will purchase the good only if its expected value of the good exceeds the price p. The quality of the good, q, may be of either high (q^H) or low (q^L) with $q^H > q^L$. The prior probability (belief) that the good is high quality is denoted by ρ_0.

For the informed consumer, if quality is high $(q = q^H)$, it will purchase the good when $vq^H \geq p$. We assume that, for simplicity, the uninformed consumers are homogeneous and the number of informed consumers is denoted by N^I. The market demand by informed consumers is given by $N^I(1-(p/q^H))$ under the assumption about v. On the other hand, if quality were low $(q = q^L)$, the market demand by informed consumers is $N^I(1-(p/q^L))$. In the case of a representative uninformed consumer, its expected quality is denoted by $q^e = \rho_0 q^H + (1-\rho_0)q^L$. Since the uninformed consumer with $vq^e \geq p$ will purchase the good, the market demand by consumers who are uninformed is given by $N^{UI}(1-(p/q^e))$ under the assumption that the number of homogenous uninformed consumers is denoted by N^{UI}.

In addition to the informed and uninformed consumers, we introduce “irrational” consumers, whose purchasing decisions are made at random in the market without considering the quality differential and prices. The random number of irrational consumers (denoted by N^{IR}) is assumed to have an additive form; such as $\overline{N}^{IR} + \varepsilon$ where ε is characterized by an independent random variable normally distributed with mean zero, variance σ_ε^2, and density function $f(\varepsilon)$. With these random consumers, observed outcomes give only noisy information regarding quality to uninformed consumers.

From the view of the firm, demand for the good of quality q^i is

$$\begin{aligned} D(p,q^i,\varepsilon) = D^i &= N^I(1-(p/q^i)) + N^{UI}(1-(p/q^e)) + \overline{N}^{IR} + \varepsilon \\ &= d(p,q^i) + \varepsilon, \quad i = H, L, \end{aligned} \tag{1}$$

where $d(p,q^i) = N - (\frac{N^I}{q^i} + \frac{N^{UI}}{q^e})p$ and $N = N^I + N^{UI} + \overline{N}^{IR}$. We assume that the cost function the firm faces is linear in output y and that quality is independent of cost, since quality is considered a matter of consumers’ preference. Thus, total costs are given by cy where $c > 0$. If, after the firm chooses values for price p and output y, output exceeds demand, the firm has unsold inventory (excess supply) at the end of the period. For simplicity, we assume that any unsold inventory is perishable, and thus cannot be stored for sale in the next period.[8] If demand exceeds output, unsatisfied demand (excess demand) can not be backlogged, and it is lost forever.

Let m^i represent the maximum value of the random demand ε that does not lead to a stock-out in the period given realized quality i, where $i = L, H$. Namely, if $\varepsilon = m^i$, the firm's production exactly meets the market demand and there is no excess demand or excess supply. If $\varepsilon < m^i$, the firm has excess supply, and if $\varepsilon > m^i$, it has excess demand. Thus,

$$m^H = y - d(p, q^H) \ \ if \ \ q = q^H, \ \ m^L = y - d(p, q^L) \ \ if \ \ q = q^L. \tag{2}$$

The firm's profit maximization problem facing uncertain demand in the single period setting is

$$\begin{aligned}\pi(p, y \mid \rho_0, c) = \underset{p,y}{Max}\, \rho_0 [p\int_{-\infty}^{m^H} D^H f(\varepsilon) d\varepsilon + py\int_{m^H}^{\infty} f(\varepsilon) d\varepsilon] + \\ (1-\rho_0)[p\int_{-\infty}^{m^L} D^L f(\varepsilon) d\varepsilon + py\int_{m^L}^{\infty} f(\varepsilon) d\varepsilon] - cy \\ = \rho_0 p[d^H F^H + (1-F^H) y] + \rho_0\, p\int_{-\infty}^{m^H} \varepsilon\, f(\varepsilon) d\varepsilon + \\ (1-\rho_0) p[d^L F^L + (1-F^L) y] + \\ (1-\rho_0) p\int_{-\infty}^{m^L} \varepsilon\, f(\varepsilon) d\varepsilon - cy,\end{aligned} \tag{3}$$

where $F^i = F(m^i)$ is the cumulative distribution function of m^i. The first order condition of price to maximize its expected profit is

$$\begin{aligned}\frac{\partial \pi}{\partial p} &= \rho_0 [d^H F^H + (1-F^H) y] + \rho p (d^{H'} F^H + d^H f^H \frac{\partial m^H}{\partial p} - y f^H \frac{\partial m^H}{\partial p}) \\ &+ \rho \int_{-\infty}^{m^H} \varepsilon f(\varepsilon) d\varepsilon + \rho p m^H f^H \frac{\partial m^H}{\partial p} + (1-\rho_0)[d^L F^L + (1-F^L) y] \\ &+ (1-\rho_0) p (d^{L'} F^L + d^L f^L \frac{\partial m^L}{\partial p} - y f^L \frac{\partial m^L}{\partial p}) \\ &+ (1-\rho_0) \int_{-\infty}^{m^L} \varepsilon f(\varepsilon) d\varepsilon + (1-\rho_0) p m^L f^L \frac{\partial m^L}{\partial p} \ = \ 0,\end{aligned} \tag{4}$$

[8] We will discuss the case of storable goods at the end of this section.

where $f^i = f(m^i)$ is the probability density function of m^i and $d^{i'} = \frac{\partial d^i}{\partial p}$. Since $m^i = y - d^i$, (4) can be simplified as,

$$\begin{aligned}\frac{\partial \pi}{\partial p} &= \rho_0(d^H + pd^{H'})F^H + \rho_0 y(1-F^H) + \rho_0 k^H + (1-\rho_0)(d^L + pd^{L'})F^L \\ &\quad + (1-\rho_0)(1-F^L)y + (1-\rho_0)k^L \\ &= y + (N - y - \frac{2N^{UI}p}{q^e})[\rho_0 F^H + (1-\rho_0)F^L] \\ &\quad - 2N^I[\frac{\rho_0 F^H}{q^H} + \frac{(1-\rho_0)F^L}{q^L}]p + [\rho_0 k^H + (1-\rho_0)k^L] = 0,\end{aligned} \tag{5}$$

where $k^H = \int_{-\infty}^{m^H} \varepsilon f(\varepsilon) d\varepsilon$ *and* $k^L = \int_{-\infty}^{m^L} \varepsilon f(\varepsilon) d\varepsilon$.

Similarly, the first order condition of output to maximize the firm's expected profit is

$$\begin{aligned}\frac{\partial \pi}{\partial y} &= \rho_0 p[d^H f^H \frac{\partial m^H}{\partial y} + (1-F^H) - yf^H \frac{\partial m^H}{\partial y}] + \rho_0 pm^H f^H \frac{\partial m^H}{\partial y} \\ &\quad + (1-\rho_0)p[d^L f^L \frac{\partial m^L}{\partial y} + (1-F^L) - yf^L \frac{\partial m^L}{\partial y}] \\ &\quad + (1-\rho_0)pm^L f^L \frac{\partial m^L}{\partial y} - c = 0.\end{aligned} \tag{6}$$

Again, from $m^i = y - d^i$, (6) can be simplified as follows:

$$\begin{aligned}&\frac{\partial \pi}{\partial y} = \rho_0(1-F^H)p + (1-\rho_0)(1-F^L)p - c = 0 \\ &\Rightarrow \rho_0 F^H + (1-\rho_0)F^L = \frac{p-c}{p}.\end{aligned} \tag{7}$$

From (5) and (7), the optimal price (p^*) and output (y^*) can be derived as a function of cost (c) and prior belief for the good (ρ_0)[9]. Specifically, if we consider the extreme case that production cost is

[9] We calibrated the optimal price and output through simulation at the end of this section.

assumed to be zero (i.e., c =0), the firm chooses only the optimal price to maximize its expected profit, because it can produce the good without cost constraint. Then, the optimal price can be derived in a straightforward way as follows:

$$p^*(\rho_0) = \frac{1}{2}\frac{N}{[\frac{\rho_0}{q^H} + \frac{(1-\rho_0)}{q^L}]N^I + \frac{N^{UI}}{q^e}}. \tag{8}$$

According to (8) the optimal price depends on the prior belief of high quality given the number of consumers. Note that the optimal price increases with the prior belief concerning quality such that $\frac{\partial p^*}{\partial \rho} > 0$, where $q^H > q^L$.

Excess demand or excess supply may occur depending on the realized market demand and given output at the end of the period. Let x^i denote the level of inventory at the end of the period given realized quality *i*. Then,

$$x(\varepsilon, p^*, y^* \,|\, d^H) = x^H = a + b^H p^* - \varepsilon \quad \text{and}$$
$$x(\varepsilon, p^*, y^* \,|\, d^L) = x^L = a + b^L p^* - \varepsilon, \tag{9}$$

where $a = y^* - N$, $b^H = ((N^I / d^H) + (N^{UI} / d^e))$ and $b^L = ((N^I / d^L) + (N^{UI} / d^e))$. The inventory level x^i is a random variable normally distributed with mean $\mu^i = a + b^i p^*$, and variance σ_ε^2.

Now, let us expand the basic single-period setting to two periods. We assume that the firm and some consumers are uninformed regarding quality for both periods. In particular, uninformed consumers are assumed to be naïve. Naïve consumers view the firm’s price and quantity choices in the first period to be the optimal single-period levels described in the previous section. That is, they do not anticipate any manipulation attempts by the firm to influence their perception regarding quality, and they update their beliefs based on the observed inventory levels quality. Even if the uniformed consumers are naïve, they try to decide their purchases rationally based on the observed price and expected quality.[10] We assume also the continuums of consumers who enter the market and stay there for just one period for excluding the possible problems any intertemporal aspect of the consumer's decision.

We consider below the firm's manipulation of price and quantity in the first period in this setting. If consumers do not anticipate any manipulation by the firm in the market and simply update their posterior beliefs concerning quality through observed inventory levels, then following Bayes' updating process, the consumers' posterior probability that the good is high quality is as below, given the optimal price and output in the first period (p_1^*, y_1^*).

$$Pr(q^H \mid x_1) = \rho(x_1 \mid p_1^*, y_1^*) = \frac{\rho_0 \, f^H(x_1 \mid p_1^*, y_1^*)}{\rho_0 \, f^H(x_1 \mid p_1^*, y_1^*) + (1-\rho_0) f^L(x_1 \mid p_1^*, y_1^*)} \quad (10)$$

where $f^i(x)$ is a density function with mean $a + b^i p_1^*$ and variance σ_ε^2. Under the assumption of the strict monotone likelihood ratio property (strict MLRP), consumers' posterior beliefs concerning high quality $\rho(x_1 \mid p_1^*, y_1^*)$ decrease with the observed inventory levels at the end of the first period (x_1). That is,

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[10] We may consider that consumers are sophisticated under the assumption that inventory is perishable. Sophisticated consumers are defined as consumers who anticipate correctly the attempt by the firm to manipulate them in the first period. Even though consumers are sophisticated, it is assumed that they do not have any new information set to update their belief in the model.

Since consumers do not observe previous price and quantity in this model, sophisticated consumers need to have conjectures about them and use these conjectures to interpret rationally the inventory of the previous period as information of unknown quality. Their conjectures on past price and output are correct. That is, sophisticated consumers are not manipulated by prices or quantity that deviate from the optimal myopic levels. On the other hand, the uninformed firm tries to forecast consumers' beliefs about quality in order to maximize its expected profits given the belief updating structure. In fact, we assume perfect Bayesian equilibrium such that all agents maximize their expected payoffs at any point in time given the beliefs they have. As we indicated, the firm's expectation about consumers' beliefs is the same as consumers' beliefs about quality in this model.

Consequently, even if consumers are sophisticated, the uninformed firm will try to manipulate consumers' beliefs with quantity and price. This policy will increase the likelihood of excess demand in the market. However, this manipulation strategy will not be successful in systematically changing consumers' beliefs.

$$\frac{\partial\rho(x_1)}{\partial x_1} = \frac{\rho_0(1-\rho_0)(f_1^{H'} f_1^L - f_1^{L'} f_1^H)}{[\rho_0 f_1^H + (1-\rho_0) f_1^L]^2} < 0, \tag{11}$$

where $f_1^{i'} = \partial f_1^i / \partial x_1$ and $\partial f_1^{H'} / f_1^H < \partial f_1^{L'} / f_1^L$.

MLRP plays a major role in statistical theory, as described in most basic textbooks on the subject. Among the families of densities and probability mass functions with this property are the normal, the exponential, the Poisson, the uniform, the chi-square, and many others. We obtain the following explicit form for $\rho(x_1 | p_1^*, y_1^*)$ with the given inventory variable x_1 normally distributed with mean $\mu_1 = y_1 - d_1$ and variance $\sigma_{\varepsilon_1}^2$;

$$\begin{aligned}\rho(x_1|p_1^*, y_1^*) &= \frac{\rho_0 f^H(x_1|p_1^*, y_1^*)}{\rho_0 f^H(x_1|p_1^*, y_1^*) + (1-\rho_0) f^L(x_1|p_1^*, y_1^*)} \\ &= \frac{\rho_0}{\rho_0 + (1-\rho_0)\exp(\frac{\mu_1^L - \mu_1^H}{2\sigma_{\varepsilon_1}^2})(2x_1 - \mu_1^L - \mu_1^H)}\end{aligned} \tag{12}$$

Differentiating (12) with respect to x_1 yields (13), and it is always negative.

$$\frac{\partial\rho(x_1)}{\partial x_1} = \frac{-\rho_0(1-\rho_0)(\frac{\mu_1^L - \mu_1^H}{\sigma_{\varepsilon_1}^2})\exp(\frac{\mu_1^L - \mu_1^H}{2\sigma_{\varepsilon_1}^2})(2x_1 - \mu_1^L - \mu_1^H)}{\theta^2} < 0 \tag{13}$$

where $\theta = \rho_0 + (1-\rho_0)\exp(\frac{\mu_1^L - \mu_1^H}{2\sigma_{\varepsilon_1}^2})(2x_1 - \mu_1^L - \mu_1^H)$ and

$\mu_1^L - \mu_1^H = (\frac{1}{q^L} - \frac{1}{q^H}) N^I p_1 > 0$.

Given consumers' beliefs updating structure, the expected consumers' beliefs concerning high quality by the firm is

$$E(\rho(x_1|p_1^*, y_1^*)) = \bar{\rho} = \int_{-\infty}^{\infty} \rho(x_1|p_1^*, y_1^*) f(x_1|p_1, y_1) dx_1. \tag{14}$$

In this setting, the firm's deviations in price or quantity from the myopic optimal levels change the distribution function of inventory and thus affect consumers' perception about quality, and subsequently the demand anticipated by the firm.

First, we consider the quantity setting manipulation case, when the firm chooses quantity in the first period as a control variable to manipulate consumers' beliefs concerning quality given the myopic optimal price (p_1^*). The effect of the change of quantity in the first period on the expected consumers' beliefs about high quality is

$$\frac{\partial \bar{\rho}}{\partial y_1} = \int_{-\infty}^{\infty} \rho(x_1 \,|\, p_1^*, y_1^*) \frac{\partial f(x_1 \,|\, p_1^*, y_1)}{\partial y_1} dx_1 . \tag{15}$$

Note that a change in the quantity from the myopic optimal level results in a change in the average inventory level (μ_1) in the market. Given the normal distribution of inventory, we can rewrite (15) as

$$\begin{aligned}\frac{\partial \bar{\rho}}{\partial y_1} &= \frac{1}{\sigma_{\varepsilon_1}^2} \int_{-\infty}^{\infty} (x_1 - \mu_1) \rho(x_1) f(x_1) dx_1 \\ &= \frac{1}{\sigma_{\varepsilon_1}^2} [\int_{-\infty}^{\mu_1} (x_1 - \mu_1) \rho(x_1) f(x_1) dx_1 \\ &\quad + \int_{\mu_1}^{\infty} (x_1 - \mu_1) \rho(x_1) f(x_1) dx_1] < 0.\end{aligned} \tag{16}$$

The negativity in (16) follows, since the first term on the right hand side is negative and the second term is positive, but $\rho(x_1)$ decreases with x_1. It is thus clear that the firm has an incentive to manipulate consumers' beliefs regarding quality. By undercutting its quantity in the first period, a firm decreases the average inventory levels in the market and consumers interpret low inventory levels as signals of high quality. The effectiveness of the manipulation by the firm on the expected consumers' beliefs, according to (16), depends on parameters such as the variance of the number of random consumers ($\sigma_{\varepsilon_1}^2$), the proportion of informed to total consumers in the first period (denoted by $I_1 = N_1^I / N_1$), and the quality differential ($q^H - q^L$).

In the case of price-setting manipulation, the firm sets price in the first period given the myopic optimal quantity (y_1^*). The effect of the change of price in the first period on the expected consumers' beliefs concerning high quality is given by

$$\begin{aligned}\frac{\partial\overline{\rho}}{\partial p_1} &= \int_{-\infty}^{\infty}\rho(x_1 \mid p_1^*, y_1^*)\frac{\partial f(x_1 \mid p_1, y_1^*)}{\partial p_1}dx_1 \\ &= \frac{(-d_1^{'})}{\sigma_{\varepsilon_1}^2}[\int_{-\infty}^{\mu_1}(x_1-\mu_1)\rho(x_1)f(x_1)dx_1 \\ &\quad +\int_{\mu_1}^{\infty}(x_1-\mu_1)\rho(x_1)f(x_1)dx_1] < 0,\end{aligned} \tag{17}$$

where $\partial d_1 / \partial p_1 = d_1^{'}(p_1,\rho_0) = -((\rho_0/q^H)+((1-\rho_0)/q^L))N_1^I-(N_1^{UI}/q^e) < 0$. Since (17) is always negative, the firm also has an incentive to manipulate consumers' beliefs concerning quality through price. However, different from the case of quantity-setting manipulation, the manipulation through price is influenced by the slope of the expected demand curve ($-d_1^{'}$). The effectiveness of price-setting manipulation also is affected by $\sigma_{\varepsilon_1}^2$, I_1, and $q^H - q^L$

With the expected consumers' beliefs, the firm tries to maximize its expected profits. The maximized value of period two expected profit in the first period is given by

$$E\pi_2(\overline{\rho}) = \int_{-\infty}^{\infty}\pi_2(\overline{\rho})f(x_1 \mid p_1, y_1)dx_1, \tag{18}$$

where $\pi_2(\overline{\rho}) = \underset{p_2,y_2}{Max}\,\overline{\rho}[\ p_2\int_{-\infty}^{m_2^H}D_2^H f(\varepsilon_2)d\varepsilon_2 + p_2y_2\int_{m_2^H}^{\infty}f(\varepsilon_2)d\varepsilon_2]$
$+(1-\overline{\rho})[p_2\int_{-\infty}^{m_2^L}D_2^L f(\varepsilon_2)d\varepsilon_2 + p_2y_2\int_{m_2^L}^{\infty}f(\varepsilon_2)d\varepsilon_2]-cy_2.$

Then, the effects of the change of quantity or price in the first period on the value function in the second period are given by (19). From the results of (16) and (17), these values are negative as follows:

$$\frac{\partial E\pi_2(\overline{\rho})}{\partial y_1} = E\pi_2^{'}(\overline{\rho})\frac{\partial\overline{\rho}}{\partial y_1} < 0, \tag{19a}$$

$$\frac{\partial E\pi_2(\overline{\rho})}{\partial p_1} = E\pi_2'(\overline{\rho})\frac{\partial \overline{\rho}}{\partial p_1} < 0 \tag{19b}$$

where $E\pi_2'(\overline{\rho}) = \dfrac{\partial E\pi_2(\overline{\rho})}{\partial \overline{\rho}} > 0$.

Conclusively, the results in (19) indicate that the adjustment of price or quantity in the initial period affects consumers' perception of quality through the change of observable inventory levels and thus alters subsequent demand such that $\dfrac{\partial d_2}{\partial \overline{\rho}} = (\dfrac{1}{q^L} - \dfrac{1}{q^H})N^I p_2 + \overline{\rho}\dfrac{\partial d_2^H}{\partial \overline{\rho}} + (1-\overline{\rho})\dfrac{\partial d_2^L}{\partial \overline{\rho}} > 0$ where $\dfrac{\partial d_2^H}{\partial \overline{\rho}} = \dfrac{\partial d_2^L}{\partial \overline{\rho}} = \dfrac{(q^H - q^L)p_2}{(q_2^e)^2}N^{UI} > 0$ and given p_2. Thus, the firm charging a lower price or having reduced quantity than the myopic optimal levels in the first period can expect a higher profit in the next period.[11]

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[11] In the case of storable good in the model, the unsold inventory acts as supply in the second period. However, it also may affect the likelihood that consumers will perceive that the product is high quality in the second period in the model. Since positive and negative inventory in the previous period affect differently the value function in the next period, we need to separate the previous level of inventory in two parts: excess supply and excess demand. Denote excess supply at the end of time t (positive inventory: $x_t > 0$) as x_t^+ and excess demand at the end of time t (negative inventory: $x_t < 0$) as x_t^-. More generally, define excess supply at the end of time t as $x_t^{i+} = \max(y_t - D_t^i, 0)$ and excess demand at the end of time t as $x_t^{i-} = \max(0, D_t^i - y_t)$ where $i = L, H$. Further, we assume that there is a storage cost for inventory and let the unit storage cost δ.

In such setting, the maximized value of period two expected profit in the first period is given by $E\overline{\pi}_2(\overline{\rho}) = \int_{-\infty}^{\infty} \overline{\pi}_2(\overline{\rho}) f(x_1 | p_1, y_1) dx_1 = E\pi_2(\overline{\rho}) + (c-\delta)\int_0^{\infty} x_1 f(x_1) dx_1$,

Note that we denote the expected profit when inventory is storable as $\overline{\pi}_2$ in order to compare with the expected profit (π_2) when inventory is perishable. We find that there is no difference between these two expected profit functions except that the new expected profit function considers the supply effect of inventory. Then, the effect of the change of price or quantity in the first period on the value function in the second period is as follows:

$$\frac{\partial E\overline{\pi}_2(\overline{\rho})}{\partial y_1} = E\pi_2'(\overline{\rho})\frac{\partial \overline{\rho}}{\partial y_1} + (c-\delta)\frac{\partial}{\partial y_1}\int_0^{\infty} x_1 f(x_1) dx_1,\ \frac{\partial E\overline{\pi}_2(\overline{\rho})}{\partial p_1} = E\pi_2'(\overline{\rho})\frac{\partial \overline{\rho}}{\partial p_1} + (c-\delta)\frac{\partial}{\partial p_1}\int_0^{\infty} x_1 f(x_1) dx_1$$

The second terms mean, in the above functions, the supply effect of remained inventory in the first period on the expected profit in the second period. As we found out, the first terms are negative, but the second terms are positive as below:

$$(c-\delta)\frac{\partial}{\partial y_1}\int_0^{\infty} x_1 f(x_1) dx_1 = (c-\delta)\frac{\partial}{\partial y_1}\int_{-\infty}^{y_1 - d_1} (y_1 - d_1 - \varepsilon_1) f(\varepsilon_1) d\varepsilon_1 = (c-\delta)F(y_1 - d_1) > 0,$$

To illustrate the above findings, we can show that the manipulation price in the first period (denoted by p_1^M) is relatively lower than the myopic optimal price in the single period (p^*) and the price in the second period (denoted by p_2^M) under the manipulation strategy in the model. It implies that the expected inventory level in the first period with manipulation is lower than the expected inventory levels in the myopic single-period strategy and in the second period with manipulation. For simplicity, if we assume that the marginal cost is 0 and the number of consumers in both periods is not changed, the optimization problem in the first period is

$$\begin{aligned}\pi_1(\rho_0) = \underset{p_1, y_1}{Max}\, \rho_0 [\, p_1 \int_{-\infty}^{m_1^H} D_1^H f(\varepsilon_1) d\varepsilon_1 + p_1 y_1 \int_{m_1^H}^{\infty} f(\varepsilon_1) d\varepsilon_1] \\ + (1-\rho_0)[\, p_1 \int_{-\infty}^{m_1^L} D_1^L f(\varepsilon_1) d\varepsilon_1 + p_1 y_1 \int_{m_1^L}^{\infty} f(\varepsilon_1) d\varepsilon_1] + \beta E \pi_2(\bar{\rho}),\end{aligned} \tag{20}$$

where β is a discount factor. Then, the equilibrium prices sequence over two periods under the monopoly manipulation are derived in a straightforward way as below:

$$p_1^M(\rho_0) = \frac{1}{2} \frac{N_1 + \beta \dfrac{\partial E \pi_2(\bar{\rho})}{\partial p_1}}{[\dfrac{\rho_0}{q^H} + \dfrac{(1-\rho_0)}{q^L}] N_1^I + \dfrac{N_1^{UI}}{q_1^e}} \tag{21}$$

$$p_2^M(\bar{\rho}) = \frac{1}{2} \frac{N_2}{[\dfrac{\bar{\rho}}{q^H} + \dfrac{(1-\bar{\rho})}{q^L}] N_2^I + \dfrac{N_2^{UI}}{q_2^e}}. \tag{22}$$

From the results of (8), (21), and (22), we observe that the manipulation price in the first period is lower than the price in the single-

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$$(c-\delta)\frac{\partial}{\partial p_1}\int_0^{\infty} x_1 f(x_1) dx_1 = -(c-\delta)\frac{\partial d_1}{\partial p_1} F(y_1 - d_1) > 0.$$

Thus, if we assume that inventory is storable, the effect of the change of price or quantity in the first period on the value function in the second period depends on these two factors. However, if the storage cost is sufficiently high, we can expect that the firm has an incentive to manipulate consumers even in the storable good case.

period setting without manipulation (i.e., $p_1^M(\rho_0) < p^*(\rho_0)$ since $\frac{\partial E\pi_2(\bar{\rho})}{\partial p_1}$<0). Further, the manipulation price strategy invites that the optimal price in the initial period is lower than the price in the next period (i.e., $p_1^M(\rho_0) < p_2^M(\bar{\rho})$ where $\bar{\rho} > \rho_0$ and $\frac{\partial E\pi_2(\bar{\rho})}{\partial p_1}$<0). It implies that the expected inventory-to-sales ratio in the first period under manipulation [$E(x_1/s_1)^M$] is relatively lower than the expected inventory-to-sales ratio in the single-period model without manipulation [$E(x/s)$] and the expected inventory-to-sales ratio in the second period under manipulation [$E(x_2/s_2)^M$]. Note that sale is denoted by s.

These discussions lead to the following proposition.

Proposition 1: *Under the asymmetric information among consumers about product quality and assuming other things being equal, the firm charges a price or quantity in the first period below the level associated with myopic profit optimization in an attempt to manipulate uninformed consumers' perception of quality and consequently increase its expected profits in the second (final) period. This manipulation strategy increases the likelihood of excess demand in the first period relative to the second period.*

Simulations allow us to illustrate optimal prices, quantities, expected profits, and expected excess supply or excess demand levels in the context of the above model. To simulate the model, we adopt the following parameters;[12]

$$\begin{aligned}&\rho_0 = .5,\ q^H = .8,\ \ q^L = .2,\ c = .05,\ N_1^I (= N_2^I) = 20,\\ &N_1^{UI} (= N_2^{UI}) = 80,\ \bar{N}_1^{IR}\ \ (= \bar{N}_2^{IR}) = 0,\ \ \sigma_{\varepsilon_1} (= \sigma_{\varepsilon_2}) = 5.\end{aligned} \tag{23}$$

In the case of the single period model (i.e., if the firm maximizes the myopic profit for one period), the firm's optimal price, quantity, expected profit, and the expected inventory-to-sales ratio are

[12] The qualitative results of these simulations are robust to alternative parameters.

$$p^* = .244,\ y^* = 56.0,\ \pi^* = 8.176,\ E[(x/s)] = .225. \tag{24}$$

Since the firm faces uncertainty, it is expected that the firm holds positive inventory (excess supply) to be about 22 percent of sales at the end of the period.

Now, consider the monopoly manipulation case for two periods. The firm's optimal prices, quantities, expected profits, and the expected inventory-to-sales ratio for both periods are

$$\begin{aligned} p_1^M &= .226,\ y_1^M = 43.8,\ \pi_1^M = 7.751,\ E[(x_1/s_1)^M] = -.136, \\ p_2^M &= .421,\ y_2^M = 50.4,\ \pi_2^M = 12.089,\ E[(x_2/s_2)^M] = .068. \end{aligned} \tag{25}$$

Note that we ignore the discount factor in the calibration. As expected, the manipulation price/output in the first period is lower than the myopic price/output for the single period. The firm thus expects excess demand at the end of the first period and a higher price (and profits) based on updating beliefs regarding quality in the second period. In the second period, since the firm does not have an incentive for manipulation, the firm expects excess supply again.

V. EMPIRICAL TEST

In this section, using an extensive data set of inventories and sales for new brand luxury/sports cars over the past 15 years in the US, we test the model's predictions. Specifically, the testable hypothesis that arises from this discussion is that we should observe the ratio of inventory to sales for luxury/sports cars as relatively low during initial periods, implying a higher likelihood of excess demand, with an increase over time.

We select 13 brands as our test sample based on the availability of panel data for luxury/sports cars which were newly introduced to the market after 1987, since we focus on observing inventory levels for newly introduced brands and their trends over time. Carmakers announce sales and inventories data for all brands every month, and these data are obtainable for extended time from *Automobile News.*

Carmakers' manipulation can be influenced by other variables that may influence inventories or sales over time. The first to be considered is whether the car is domestic or foreign (Japanese). Since Japanese cars are more attractive to consumers in the US, we expect that the ratio of inventory to sales is relatively lower in Japanese cars than in domestic cars. The price variable of a car is also one considerable determinant for the ratio. We use the relative real price index computed by relative sales shares in the market and real prices adjusted to inflation using the consumer price index of new cars. The price included in the test is the list price of the basic model, which comes from *Automobile News Market Data Book* or *Consumer Reports*.

The inventory levels for manipulating consumers' beliefs can be affected by other variables related to market uncertainty. Specifically, when a new brand is introduced, consumers may conjecture the magnitude of quality uncertainty about the newly introduced car based on obtainable overall quality data for existing brands and models of carmakers. If the quality differential for existing cars produced by a specific carmaker is high, consumers expect that the newly introduced car also may have relatively high uncertainty for quality. To capture the magnitude of expected quality uncertainty for the newly introduced car, we use a quality dummy variable to indicate the relative standard deviation of qualities for cars produced by carmakers in each year. It is equal to 1 if the standard deviation of qualities for all models produced by a specific carmaker is higher than the average standard deviation of the quality for all models produced by all carmakers. The reliable survey data about quality for cars are obtainable from *J. D. Power and Associates.*

Carmakers not only launch new brands in the market, but they introduce new models in existing brands. For examples, they may introduce a two-door coupe to accompany an existing four-door sedan, or add a new model to a brand. In such cases, we can expect that quality uncertainty increases even if these cars keep the same brands. Therefore, whether carmakers introduced new models or not can affect carmakers' manipulation policy and the inventory levels for manipulation. We use a dummy variable to indicate whether a new model is introduced or not, given a brand.

Conclusively, to examine the hypothesis related to manipulation through inventory for luxury/sports cars, the following equation is estimated:

$$\begin{aligned} Inventory\ ratio_{i,t} &= \beta_0 + \beta_1 Years_{i,y} + \beta_2 DummyJ_i + \beta_3 Price_{i,y} \\ &+ \beta_4 DummyQ_{j,y-1} + \beta_5 (DummyQ_{j,y-1} \times Years_{i,y}) \\ &+ \beta_6 DummyNM_{i,y} + \gamma DummyM_t + \lambda\, DummyB_i + \varepsilon_{i,t}, \end{aligned} \tag{26}$$

where $Inventory\, ratio_{i,y}$ is the log of car i's ratio of inventory to sales in period t (month). $Year_{i,y}$ is the log of the time (years) variable to indicate years passed from the newly introduced year (1, 2, 3, …) for car i. $DummyJ_i$ takes 1 if the car is Japanese. $Price_{i,y}$ is the log of relative real price index for car i in year y. $DummyQ_{j,y-1}$ takes value 1 if the standard deviation of the quality for all models produced by carmaker j is higher than the average of standard deviation of the quality for all models produced by all carmakers in year $y-1$. $DummyNM_{i,j}$ is 1 if a new model was launched for the first time in year y. $DummyM_t$ and $DummyB_i$ indicate seasonal (monthly) and car brand dummy variables.

We expect that β_1 is positive and β_2 is negative. β_3 is expected to be positive. As we mentioned, the inventory level for manipulation depends on the magnitude of quality uncertainty. If the quality uncertainty is high, carmakers have a strong incentive to manipulate consumers' beliefs. Therefore, we expect that β_4 is negative. β_5 is expected to be positive, since if the magnitude of quality uncertainty for a new car is high, we can expect that the quality uncertainty decreases relatively quickly over time. In other words, we expect that the inventory level for a new car with high uncertainty for quality is relatively low for the initial periods, but the increase rate of inventory for this car is relatively fast. β_6 is expected to be negative.

Table 1 shows estimated results for estimation equations in (26). Our particular interest is in the hypothesized relationship between the inventory-to-sales ratio and a time variable that indicates years passed from the newly introduced year. As expected, the relationship between the inventory-to-sales ratio and time (yearly) variable in table 1 is positive, and the estimate is highly significant in column, (I) and (II). The results would have been surprising outside of our manipulation model. For instance, typical studies on inventory are based on the idea that the firm holds inventory to smooth production in the face of fluctuating sales. These studies emphasize that the firm has an inclination to hold relatively high inventory when the firm faces high uncertainty in the market. Therefore, from the view of typical inventory theory, there is no reason for carmakers to hold relatively low inventories during the initial periods when demand uncertainty is relatively high.

[Table 1] Regression Results (Dependent variable: The log of inventory-to-sales ratio)

Independent Variables	Coefficients	
	(I)	(II)
Constant	.9098 (11.04)**	1.0045 (10.62)**
Log of years (Period from the introduced year)	.2154 (7.14)**	.1420 (3.91)**
Japan car dummy (1 if Japanese car)	-.0745 (-1.80)*	-.1744 (-3.01)**
Log of relative real price index	.0023 (.01)	-.0908 (-.36)
Quality dummy (1 if standard deviation ≥ average)		-.1964 (-2.46)**
Quality dummy × Log of years		.1074 (2.15)**
New model dummy (1 if new model is introduced)		-.1563 (-4.66)**
Seasonal dummy variables:		
Jan	.2049 (3.28)**	.2327 (3.64)**
Feb	.0967 (1.55)	.1178 (1.86)*
Mar	-.0148 (-.24)	.0223 (.35)
Apr	.0926 (1.49)	.1363 (2.15)
May	.0462 (.74)	.0716 (1.13)
June	.0254 (.41)	.0535 (.85)
July	-.0237 (-.38)	.0101 (.16)
Aug	-.0889 (-1.44)	-.0752 (-1.20)
Sep	-.0430 (-.70)	-.0272 (-.43)
Oct	-.0577 (-.94)	-.0470 (-.75)
Nov	.0532 (.87)	.0800 (1.28)
Car brand dummy variables:		
Acura	-.3835 (-4.02)**	-.0531 (-.41)
Aurora	-.0161 (-.17)	.0534 (.52)

Catera	.1409 (1.59)	.1219 (1.30)
Concord	-.2166 (-2.29)**	-.2417 (-2.27)**
Fleetwood	-.0461 (-.44)	.0296 (.26)
Infiniti	-.1943 (-1.85)*	.0756 (.59)
Lexus	-1.1708 (-9.16)**	-.9010 (-5.64)**
LS	-.0380 (-.37)	-.0057 (-.05)
LHS	-.2088 (-2.53)**	-.2021 (-2.42)**
Prowler	.4252 (3.77)**	.4752 (3.75)**
Allante	.4886 (2.27)**	.6154 (2.50)**
Escalade	-.2952 (-2.23)**	-.1939 (-.22)
Navigator	-.3879 (-3.15)**	-.3496 (-2.33)**
Observations	1203	1124
R^2	.5097	.5186

Note: ( ) are values of t-statistics. * is significant at the 10% level and ** is significant at the 5% level.

The estimated coefficients for the Japanese car dummy, quality dummy, and new model dummy have expected signs and statistically significant results. The coefficient estimate of the quality dummy variable (β_4) is negative, and the coefficient estimate of the quality dummy variables and time (years) interaction (β_5) are positive. It means that carmakers keep relatively low levels of inventory for new cars with high uncertainty for quality for initial periods, but increase inventory levels relatively quickly over periods as the incentive for manipulation dilutes. The coefficient estimate of relative real price is positive or negative depending on estimation equations; however, it is not statistically significant.

VI. CONCLUSION

This paper analyzes an interesting economic phenomenon, excess demand, in a specific market. We adopt the assumption of a consumption externality among consumers, where some individuals use excess demand conditions to judge quality of unknown products. This assumption captures an important feature of practical experience. In many markets, past demand is observable and informative for subsequent consumers. In such a case, it is rational for a firm introducing a new product to intentionally adjust price or quantity in an effort to affect potential consumers' perception of quality. This strategy increases the likelihood of excess demand in the market.

We often observe that carmakers use rationing as a marketing strategy to build up their reputation, specifically when they introduce new brands or models. In fact, in recent years, the number of cars and models has grown in every product segment. At the same time, the once vast gaps in performance, safety, fuel efficiency, and amenities have all closed. Carmakers realize that although variations in physical quality and performance persist, the remaining possibilities for differentiating products, and thus achieving competitive advantages, revolve around styling and other intangibles and the emotional benefits they confer on the customer. J.D. Power and Associates' recent report concerning consumers' new-car buying behavior demonstrates that many consumers did not seriously consider all other models and stated that they chose their model because they "fell in love with it."[13] Therefore, when carmakers cannot observe potential consumers' taste, there exists a motive to exploit excess demand as a marketing strategy in an attempt to make an unknown quality product more attractive to uninformed consumers who look to the purchasing behavior of informed consumers as a way to identify the a desirable good.

We have developed a model that demonstrates this result in the context of a market with demand and quality uncertainty. The model explicitly shows that the firm has an incentive to adjust its price or quantity in the first period to increase the likelihood of excess demand in the market. We test the model's predictions using an extensive data set of inventory and sales for new brands of models of luxury/sports cars over 15 years in US The empirical results confirm the theory. Specifically, empirical results show that the inventory levels for newly introduced cars are relatively low to increase the likelihood of excess demand during the initial periods, but they gradually increase over time.

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[13] J.D. Power and Associates, 2001 Escaped Shoppers and Owner Loyalty Study, January 4, 2002.

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