UNDERPRICING AND PERCEIVED SCARCITY

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Abstract

We analyze why firms might set prices below the market equilibrium levels and thereby create excess demand and a perception of scarcity. If the perception of scarcity is a demand shifter, it can result in higher cumulative profits over time. Our empirical application is based on data from the market for "cult wines." We implement a two-way fixed effects regression model. We find that the larger the difference between the primary and secondary market prices, the higher the market price will be for the next vintage of the same wine in the following year, consistent with a scarcity-pricing strategy.

Keywords: perception of scarcity, underpricing strategy, cult wines

JEL Codes: D21, D25, L11; L66

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1. Introduction

Why is the price charged for a product sometimes below the market-clearing price? The economic literature offers several explanations, including the existence of a price ceiling, e.g., rent control; predatory pricing to gain market power; "introductory offers" to get consumers to try the product and hopefully like it enough to buy it at a profit-maximizing price in the future; multi-product monopolies; and complementary products that are "tied" to another product.[2] In this paper, we offer a new explanation and conditions for when and why a profit-seeking firm should consider offering a product for sale at a price that is below its single-period profit-maximizing equilibrium price.

In setting a price that is lower than the market-clearing price, a capacity-constrained[3] firm with a differentiated product can generate excess demand that creates a perception of scarcity. We refer to this pricing strategy as "scarcity pricing."[4] This is not profit maximizing in the short run, but we articulate how it can cause demand to increase in future periods and potentially affect long-run cumulative profits favorably. Note that such underpricing often allows a secondary market to capture short-term foregone profits in the primary market. Such pricing phenomena occur in many mainstream markets, e.g., years of waiting for season tickets for some professional sports teams, popular restaurants where it is difficult to get a reservation, "cult wines" with long waiting periods to

[2] With "tie-in" sales, the seller of a fixed-quantity good generally gains by requiring that the customers purchase the complementary good from her as well. Higher consumption of the complementary good signals higher valuations for the fixed quantity good. The sale of the complementary good serves as a counting device. Similar to two-part pricing, this can result in price of basic good lower than marginal cost, where one product may be underpriced if the complementary product acts as a measure of intensity of use for the purpose of second-degree price discrimination. An example is a printer as the fixed-quantity good and ink as the complementary good.

[3] Related to our explanation is the concept of a capacity constraint. Several researchers have studied capacity constraints and pricing, including Brock and Scheinkman (1985), Deneckere and Kovenock (1992), and Lester (2011).

[4] The term "scarcity pricing" has also been used in the energy economics literature with a different meaning, where it refers to pricing electricity above the marginal cost during conditions of high system stress (see Papavasiliou, Smeers, and de Maere d'Aertrycke 2021).

become a member of allocation lists, and coveted special bourbon whiskeys that are allocated via lotteries or overnight queuing.[5]

In a study that is related to ours, Becker (1991) assumes that consumers' demand for a particular good depends on the demands of other consumers. Using this assumption, Becker shows it is possible to have an upward-sloping demand function over part of its domain. Karni and Levin (1994) apply a two-stage noncooperative game in the restaurant business where one restaurant is operating at capacity and has long queues of customers, and the neighboring restaurant operates with excess capacity. They find that there is no Bertrand equilibrium for the restaurant pricing game with Becker-type demand functions, while there are two types of equilibria in the Stackelberg game. Our research differs from these in that firms seek to maximize profits over an unbounded time horizon.

Also related to our research is the literature on dynamic competition in which price plays the role of an investment. A firm might set a lower price in order to increase the current quantity sold, which can result in greater demand or lower costs in future periods. In the former situation, a greater quantity sold in the current period can result in future higher demands if there are network externalities or switching costs. In the latter situation, if there is learning by doing, producing a greater quantity in the current period can result in lower costs in subsequent periods. Besanko, Doraszelski, and Kryukov (2019) analyze the welfare of dynamic competition in a learning-by-doing model.

The literature on dynamic competition with price setting as an investment is focused on increasing quantity sold in the current period. In contrast, we consider the scenario in which the quantity sold stays constant because it is capacity constrained. There are no externalities in our market context. Rather, the excess demand situation that is created from underpricing results in a perception of scarcity, which shifts demand.

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[5] Lennon and Shohfi (2021) offer an analysis of secondary markets for bourbon whisky. They write, "…bourbon aficionados must turn to secondary markets to obtain coveted products because producers are reluctant, for whatever reason, to significantly raise retail prices, leading to shortages of specific products," (p. 1028).

Our paper is also related to, but different than research on other scarcity situations, such as the "hot-toy" problem (Tabarrok 2008). The classic example of a hot toy is the Cabbage Patch Kids dolls in the holiday season of 1983. In a hot-toy scenario, the shortage is transitory, and consumers often have an expectation that the shortage will end quickly (e.g., after the holidays), which makes demand more elastic. In contrast, our paper considers a market in which excess demand is long-term.

Ticket scalping is also related to our work in that it can be caused by underpricing of tickets, which creates excess demand in the primary market. There is a large literature on ticket scalping. Courty (2003) offers explanations for underpricing of event tickets, including the promoter's uncertainty over sales; the social externality of a large crowd (i.e., a "mob good"); ticket buyers' perception of fairness; and attracting a loyal fan base. Related to the last point, Eichhorn and Sahm (2010) argue that ticket underpricing results in positive externalities, including sponsorships and regional development. DeSerpa and Faith (1996) analyze the market for "mob goods," which are events that are consumed jointly for which utility increases with the number of fans. They find that if crowd reactions are inversely correlated with reservation prices and a capacity constraint applies, then excess demand (and hence scalping) is a necessary condition for profit maximization.

Note that scarcity pricing is possible when the product is differentiated, entry of firms is restricted, and there is a capacity constraint. We note that a capacity constraint is not a necessary condition for scarcity pricing to occur, because a firm could create a "capacity constraint" by design if it chose to do so.[6] If the product is homogenous and any producer can supply it, it would be impossible to create scarcity without collusion. Moreover, preferences for acquiring the product will be enhanced if the product is perceived to be of high quality. If the product is perceived to be of average or low quality, then consumers will be less motivated to join a waiting list to buy it. In effect, the product would not

[6] An example of this possibility is a series of limited editions, e.g., Nike athletic shoes. The shoes are not the same product continuing forever; rather, they are a series of limited-edition shoe releases that sell in the secondary market for higher than higher than their retail prices. They routinely sell out quickly.

be "special enough" to generate a significant shift in demand. Because of these features and the fact that capacity is constrained, purchase of such products often requires a reservation via a waiting list or some other rationing mechanism. Thus, firms producing these goods and services primarily operate in a market structure resembling monopolistic competition.

To our knowledge, there are no studies that analyze the rationality of using pricing strategies to instigate persistent excess demand in a dynamic setting spanning multiple periods to maximize cumulative discounted long-run profits. This paper examines such strategies.

There are two main research questions: First, how does setting prices lower than market-clearing levels affect the firm's profits over time? Second, is there empirical evidence to support that firms underprice to create excess demand? In this study, we utilize a multiperiod optimization framework to analyze the firm's dynamic pricing strategy and then examine the market for "cult wines" as a case study.

The paper proceeds as follows: first, we present a conceptual model that motivates the use of a scarcity pricing strategy in a dynamic setting, including conditions under which it is profitable for a firm to set prices lower than market equilibrium levels. Then we present the data, empirical model, and estimation results that provide evidence in support of the dynamic pricing model having been implemented. Finally, we offer concluding thoughts and directions for future research.

2. CONCEPTUAL MODEL OF UNDERPRICING

It is assumed that the firm operates in a monopolistically competitive market where each firm sells a differentiated indivisible product. The final product can be differentiated in terms of brand, geographical location, reputation, or in other dimensions. The market demand curve is downward sloping and the firm's marginal cost (*MC*) curve is kinked at its capacity constraint. For simplicity, we assume a constant *MC* for the first Q^P units, which is the maximum potential amount of product that a firm can produce in a given year when all resources are fully utilized.[7] Beyond Q^P units the MC is vertical, which reflects the fixed capacity constraint. We further assume that *MC* is static for all periods under consideration.

Regarding demand considerations, and to focus on fundamental concepts, we assume that consumers' preferences remain static except for the potential effects of scarcity, other non-price determinants of demand remain the same for all periods under consideration, and quantity produced would be fully demanded at market equilibrium prices.

2.1. Two-Period Decision Horizon

To motivate fundamental ideas, we begin with a simple two-period illustration, elucidated by graphics in Figure 1, of underpricing behavior. In period 1, as shown in Panel (A) of Figure 1, the intersection of *MC* and MR_1 occurs at Q^P, the maximum quantity producible by the firm, and thus the static one-period profit-maximizing price P_1^{π} is determined by the intersection of MC and the demand curve D_1. Suppose in this period that the firm instead chooses to set the price at P_1, which is lower than P_1^{π}, where $\Delta P_1^{\pi} = P_1^{\pi} - P_1$ is the difference, or price gap, between the profit-maximizing price and the lower set price in period 1. The price P_1 leads to an excess demand of $ED_1 = Q_1 - Q^P$ in period 1, where $Q_1 = D_1(P_1)$ is the quantity demanded at price level P_1 based on

[7] Constant marginal cost is not required. It can be increasing or decreasing, or even equal to zero, for all $Q \le Q^P$. The important assumption here is that the marginal revenue curve intersects at the vertical portion of the marginal cost curve.

demand function $D_1(P)$. Because Q^P is insufficient to satisfy demand in period 1, the product is perceived as scarce.

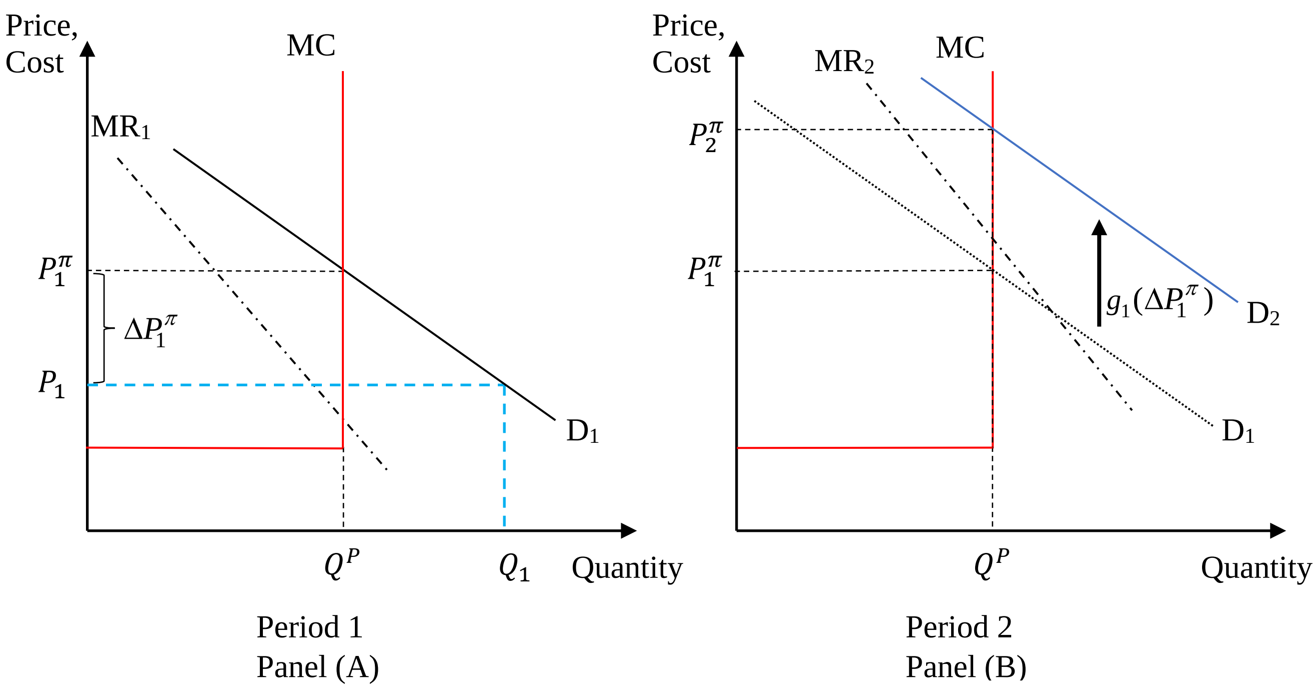

FIGURE 1
GRAPHICAL EXAMPLE OF DYNAMIC UNDERPRICING FOR TWO PERIODS

We assume that greater perceived scarcity increases its desirability and associated marginal utility (Lynn 1992; Verhallen 1982; Ditto and Jemmott 1989), where the utility function of the representative consumer exhibits the following properties:

$$\frac{\partial U}{\partial q_t} > 0 \;\; for\, t = 1, 2 \;\text{ and }\; \frac{\partial U / \partial q_2}{\partial ED_1} \equiv \frac{\partial^2 U}{\partial q_2 \partial ED_1} > 0 \qquad (1)$$

and q_t is the representative consumer's quantity demanded in period *t*.

We assume that period 1 is effectively the initiation of the sale of the commodity, which is why the second order derivative properties presented in (1) apply only to period 2. Among other things, the properties in (1) imply non-satiation in the product, so that a consumer's utility increases with quantity purchased (i.e., $\frac{\partial U}{\partial q_t} > 0$).[8] Moreover, the scarcer the product is perceived to be, the greater is the marginal utility of the product (i.e., $\frac{\partial^2 U}{\partial q_2 \partial ED_1} > 0$).

The preceding properties imply that a consumer's demand for the product will shift with perceived scarcity. Because the excess demand in period 1, ED_1, is a strictly monotonically increasing function of the price gap $\Delta P_1^{\pi} = P_1^{\pi} - P_1$ in period, the perception of scarcity can be represented alternatively as a function of the price gap, $ED_1 = m\left(\Delta P_1^{\pi}\right)$, where $\frac{\partial ED_1}{\partial \Delta P_1^{\pi}} > 0$. Thus, for this two-period illustration, the utility function properties (1) of the representative consumer can be expressed alternatively as

$$\frac{\partial U}{\partial q_t} > 0,\ t = 1, 2 \text{ and } \frac{\partial^2 U}{\partial q_2 \partial \Delta P_1^{\pi}} > 0 \tag{2}$$

which indicates that marginal utility of the product in period 2 increases with the size of the price gap in period 1.

Maximizing utility subject to the consumers' budget constraints and then aggregating over consumers results in a market demand function in period 2 of the general form

[8] For example, in the case of wine, the sources for non-satiation include both that wines can be either consumed now or they can be stored and saved for future consumption. In addition, wine can be collected and even can serve as an investment.

$$Q_2 = D_2\left(P_2, \Delta P_1^{\pi}\right) \tag{3}$$

Where $\frac{\partial D_2}{\partial P_2} < 0$ and $\frac{\partial D_2}{\partial \Delta P_1^{\pi}} > 0$, so that market demand in period 2, D_2, shifts to the right as shown in Panel (B) of Figure 1. For simplicity, we assume that demand shifts in a parallel fashion and represents the amount of the shift by $g_1\left(\Delta P_1^{\pi}\right) > 0$, which is a function of the value of $\Delta P_1^{\pi} > 0$.We call the amount of the demand shift the scarcity-pricing demand increment for period 1. The demand function in period 2 can then be represented as

$$Q_2 = D_2\left(P_2, \Delta P_1^{\pi}\right) = D_1\left(P_2\right) + g_1\left(\Delta P_1^{\pi}\right). \tag{4}$$

In period 2, P_2^{π} is the profit-maximizing price specific to period 2 conditions, which would result in no-excess quantity demanded. Rather than profit-maximize in period 2, the firm could contemplate setting P_2 such that $P_2 < P_2^{\pi}$ and create a new price gap of $\Delta P_2^{\pi} = P_2^{\pi} - P_2$. Then the demand curve in the following (third) period would shift rightward by the amount of the scarcity-pricing demand increment, $g_2\left(\Delta P_2^{\pi}\right) > 0$. Of course, such a pricing strategy in the second period would require more than a two-period decision horizon for pursuing the objective of increasing long-run cumulative profits.

We refer to the preceding type of price setting behavior as a *scarcity pricing strategy* because the firm sets a price that creates a perception of scarcity in the market. Whether such a strategy is rational depends on whether the pricing trajectory chosen results in a larger cumulative discounted profit over the decision horizon than setting prices each period at the static single-period profit-maximizing equilibrium level. In this two-period decision framework, the firm has an incentive to implement a scarcity pricing strategy if there exists a price in period 1 that leads to an excess demand in period 1 and associated equilibrium profit-maximizing price in period 2 that is large enough to produce two-period cumulative discounted revenues that are greater than the sum of the revenues from profit maximizing individually both periods. In mathematical terms, and recalling the capacity-constraint level Q_p,

$$Q_p\left(P^\pi + \beta P^\pi\right) < Q_p\left(P_1 + \beta P_2^\pi\right) \tag{5}$$

where $P_2^\pi = D_2^{-1}\left(Q^P, \Delta P_1^\pi\right)$, $P^\pi = P_1^\pi = P_2^\pi$, D_2^{-1} denotes the inverse demand curve in period 2, and $0 \le \beta < 1$is the time discount factor.

2.2. *N*-Period Decision Horizon

The two-period model generalizes in a natural and straightforward manner to *n*-periods. Regarding relationships (1) – (4), the consolidated generalization are

$$\frac{\partial U}{\partial q_t} > 0 \ \forall t, \ \frac{\partial U / \partial q_t}{\partial ED_{t-1}} \equiv \frac{\partial^2 U}{\partial q_t \partial ED_{t-1}} > 0 \ \ and \ \ \frac{\partial^2 U}{\partial q_t \partial \Delta P_{t-1}^\pi} > 0 \ \forall t \ge 2 \tag{6}$$

and

$$Q_1 = D_1\left(P_1\right), \ Q_t = D_t\left(P_t, \Delta P_{t-1}^\pi\right) = D_{t-1}\left(P_t\right) + g_{t-1}\left(\Delta P_{t-1}^\pi\right) \ \forall \ t \ge 2 \tag{7}$$

where $\Delta P_t^\pi = P_t^\pi - P_t$ *and* $ED_{t-1} = Q_{t-1} - Q^P$. We underscore that the time subscript *t* on the demand increments, $g_t\left(\Delta P_t^\pi\right)$, allows for variable levels of demand shifts over time, including the possibility of diminishing returns beginning at a given point in time. Moreover, it is assumed that the shifts in demand persist over time due to the accumulating perception of the specialness of the product. It is further assumed that $\lim_{t\to\infty} g_t\left(\xi\right) = 0,$ where $\xi > 0$ represents any finite price gap value, so there is a limit to the degree that scarcity pricing can continue to shift demand upward. That is, positive demand increments will not continue to infinity. Consequently, $\lim_{t\to\infty} P_t^\pi = \tilde{P}$ where $\tilde{P} \geq P_t^\pi, \forall t$ is some convergent price, i.e., $\tilde{P}$ is a long-run equilibrium price resulting from a scarcity pricing strategy.

Given that the firm is selling at the capacity level Q^P, and the marginal cost remains static, profit maximization is equivalent to maximizing the firm's total accumulated discounted revenues over time. The optimal trajectory of prices over an unbounded decision horizon is given by

$$\left\{P_1^*, P_2^*, \ldots\right\} = \underset{P_t > 0, \forall t}{\arg\max}\ Q^P \sum_{t=1}^{\infty} \beta^{t-1} P_t \tag{8}$$

$$\text{s.t. } Q_1 = D_1\left(P_1\right),\ Q_t = D_t\left(P_t, \Delta P_{t-1}^\pi\right) = D_{t-1}\left(P_t\right) + g_{t-1}\left(\Delta P_{t-1}^\pi\right)\ \forall\ t \geq 2,$$

$$P_t^\pi = D_t^{-1}\left(Q^P, \Delta P_{t-1}^\pi\right)\ \ \forall t,\ \Delta P_0^\pi = \varnothing, \text{ and}$$

$$Q_t = D_t\left(P_t, \Delta P_{t-1}^\pi\right) \geq Q^P,\ \forall t$$

where β is a discount factor, such that $0 \leq \beta < 1$, and the last inequality constraint represents upper bounds for how high prices can be set in any period.

Alternatively, if the firm were to set prices equal to the single-period profit-maximizing levels for all periods (and thus never induce excess demand), the demand functions would be $Q_t = D(P_t)$, where the $g_t(\Delta P_t^\pi)$ demand increments are irrelevant and omitted. Continuing the implicit assumption that consumers preferences remain static except for any scarcity pricing effect, the demand curve does not shift in this pricing strategy. Consequently, total revenue over the decision horizon will be determined by the equilibrium price $P_t^\pi = P^\pi \ \forall t$, which will be the same for all *t* and total revenue over the unbounded decision horizon would be

$$\sum_{t=1}^{\infty} \beta^{t-1} P^\pi Q^P = \frac{P^\pi Q^P}{1-\beta} \text{ since } \sum_{t=1}^{\infty} \beta^{t-1} = (1-\beta)^{-1}. \tag{9}$$

We refer to this as the *stationary pricing strategy*.

To define conditions under which the scarcity pricing is superior to stationary pricing, we focus on conditions for which the optimal scarcity pricing strategy (8) yields greater profits than the stationary pricing strategy profits identified in (9). The scarcity pricing strategy will be preferred *iff*

$$\frac{\sum_{t=1}^{\infty} \beta^{t-1} P_t^*}{P^\pi \sum_{t=1}^{\infty} \beta^{t-1}} = \frac{P_w^*}{P^\pi} > 1 \tag{10}$$

where $P_w^* = \sum_{t=1}^{\infty} w_t P_t^*$ is a weighted-average price of the scarcity pricing trajectory with weights

$w_t = \beta^{t-1} / \sum_{j=1}^{\infty} \beta^{j-1} = \beta^{t-1} / (1-\beta)$.

In the extreme case of $\beta = 0$, so that the future is fully discounted and irrelevant, then the stationary pricing strategy is preferred, as is intuitively clear. In all other cases, it follows from (10) that there is a tradeoff between how high the discount factor is and how high future prices must eventually be to achieve the inequality condition.

A straightforward existence condition for the superiority of scarcity pricing can be obtained by assuming the number of time periods for which demand increments induced by scarcity pricing are positive is bounded and occurs at some finite time T (no matter how large). Under this condition the aforementioned long-run scarcity strategy equilibrium price $\tilde{P} > P^{\pi}$ prevails for all $t \geq T$. Then the following proposition characterizes the conditions under which the scarcity pricing strategy will be the optimal strategy.

Proposition: *For sufficiently high values of the discount rate $\beta \in [0,1)$ and future equilibrium price $\tilde{P}$, there exists a scarcity pricing strategy that is superior to the stationary pricing strategy.*

Proof: See the appendix.

The intuition for the proof is shown in Figure 2. This figure shows revenues over time. The lower horizontal line depicts the constant revenue from the stationary-pricing strategy, and the curved line shows the revenues from a scarcity-pricing strategy.[9] The upper horizontal line is the limit price.

[9] Note that we are not assuming any functional form or properties of the scarcity-price strategy price sequence, except that it is weakly monotonically increasing over time. Figure 2 is intended only to provide intuition.

Although the scarcity prices are initially lower than the stationary price, the scarcity prices increase as demand shifts out in response to the perceived scarcity. If the present value of the area in B is greater than the present value of the area in A, then the scarcity pricing strategy can be optimal.

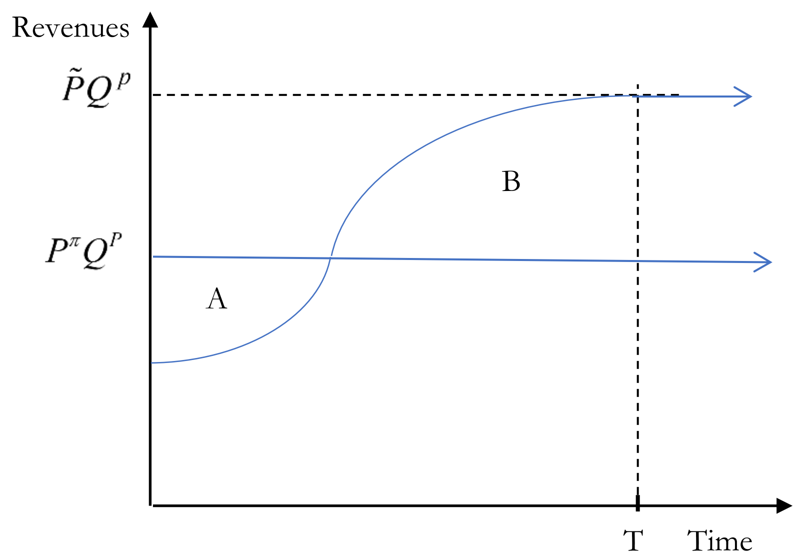

FIGURE 2
INTUITION OF EXISTENCE OF OPTIMAL SCARCITY PRICING STRATEGY

Now that we have shown that a scarcity-pricing strategy can be revenue maximizing under certain conditions, we turn to our empirical case study.

3. Case Study: The Market For "Cult Wines"

We now examine the "cult wine" market as a case study to evaluate whether there is empirical evidence of a scarcity-pricing strategy. Gaither (2021) states that cult wines can be described by their scarcity, high prices, and quality. A consumer can only buy a cult wine if 1) he or she is on the allocation list or 2) via the secondary market. Getting on allocation lists often involves multi-year waiting periods. For example, in describing Cayuse Vineyards in the Walla Walla American Viticultural Area (AVA), Settle (n.d.) writes, "A local tasting room manager from another winery mused – Cayuse boasts the most exclusive waiting list in the world. While not sure if that is completely accurate, I do know my brother has been on the waiting list for eight years now."

Cult wines would appear to be an appropriate market for analyzing whether there is any empirical evidence of scarcity pricing strategies being implemented. The market for these wines has two of the principal characteristics that can support such a pricing strategy, including being differentiated by quality and also being capacity constrained.[10] The wines are associated with a specific vineyard/winery, which cannot be expanded while maintaining the special quality associated with the wine.

Given that supply emulates perfect inelasticity, an increase in price is essentially equivalent to an outward shift in demand. Evidence of scarcity induced by vintner pricing in primary markets for cult wines and the potential existence of incentives for implementing scarcity pricing can be reflected by price gaps between primary and secondary (resale) market prices, and subsequent period effects on the level of market prices. In particular, the existence of a positive price gap between secondary market prices and vintners' release (primary market) prices in a given period is prima facie evidence of scarcity, and if market prices in a subsequent period increase with the level of the price gap, there is evidence that perceived scarcity shifts the demand curve outward.

Several researchers have estimated hedonic price functions (Rosen, 1974) for wine. By regressing price on wine attributes, the hedonic functions provide estimates of the implicit price impact of each characteristic on the equilibrium price, embedding both supply and demand factors (Nerlove, 1995). Many studies have used the natural log of price as the dependent variable (Ashenfelter, 2008; Cardebat and Figuet, 2004; Ali and Nauges, 2007). As for explanatory variables, Ashenfelter (2008) includes climate variables; Cardebat and Figuet (2004) includes taste, vintage, and appellation; Ali and Nauges

[10] We note that there can be some changes in the number of cases based on weather or other phenomena in any given year, such as wildfire smoke, but expansion is not feasible.

(2007) includes vintage, wine rating score and age; and Costanigro *et al.* (2007) includes wine rating score, age, cases, and region.

Guided by the general tenets of the conceptual model presented above, we empirically evaluate how the average retail secondary market price of a bottle of cult wine (*market equilibrium price*) in time period *t* is affected by the price difference (*price gap*) in the previous period *t*-1. To be clear, the price gap is the difference between the secondary market price and vintners' release price. We use a longitudinal dataset containing information on annual releases of wines by winemakers (*vintage*). The panel data set spans a five-year period, from 2016 to 2020.

3.1 Data

We define the "cult wine" market to be wines for which vintners require their customers to be on an allocation list in order to purchase wines directly from them and there is a waiting list to be on the allocation list. We focus attention on cult wines originating from the Napa and Sonoma AVAs in California and the Walla Walla AVA in the State of Washington. At the time of this research, the allocations lists for all winemakers included in the data were fully enrolled, and additional interested buyers had to add their names to waiting lists.

The dataset includes observations from fourteen winemakers: eight from the Napa region of California, four from the Sonoma region of California and two from the Walla Walla region of Washington/Oregon. While for some vintners, we include only one variety, for others we include several varieties depending on how many types of wine the vintner offers that have waiting lists for joining the allocation lists. Appendix Table A1 provides the list of all companies and the products included in this study.

The U.S. average retail price for each wine was obtained from *Wine-Searcher*. The average retail price reflects the average market price of a U.S. bottle of wine in the year when it was released to customers. For example, if a particular vintage wine was released in 2017, then the average retail price refers to that year. Wine *release* prices are set by individual wineries. Data on release prices, region, wine score and the number of cases produced were obtained from *Wine Spectator*. Finally, we defined the variable *company age* as years since the first commercial vintage release by a winemaker, which was obtained directly from each vintner's official web site.

[Insert Table 1 Here]

Table 1 presents summary statistics for all the variables involved in this study. On average, the secondary market retail prices are 62% more expensive than the release prices over the entire study period. The average wine rating score of these "cult wines" according to *Wine Spectator* is 92.8 points, which is indicative of high-quality wine based on the Wine Spectator's 100-point scale, where it is stated that "90-94 Outstanding: A wine of superior character and style". All companies have been operating in the market for at least 13 years. Finally, note that on average, only 901 cases of each vintage were produced, making these high-quality wines also difficult to obtain.

3.2 Methods

Given the panel format of our data, we implement a two-way fixed effects (FE) model that controls for unobservable firm and year fixed effects. Specifically, we estimate the following model via least squares and implement two specification variations to assess robustness, one using only fixed effects and the other using both fixed and time effects:

$$\ln\left(\textit{Market Price}_{ijt}\right) = \alpha + \left(\textit{Price Gap}_{ijt\text{-}1}\right)\eta + \mathbf{X}_{it}\boldsymbol{\delta} + \mu_i + \lambda_t + \varepsilon_{ijt} \tag{11}$$

where i is a wine maker; j is a type of wine produced by the wine maker i; t is a time index; **X** is a vector of other explanatory variables; μ_i and λ_t are firm and time fixed effects, respectively; and ε_{ijt} is an error term. The principal coefficient of interest is η, which is the coefficient on the price gap. We define the price gap in percentage terms as follows:

$$Price\ Gap_{ijt} = \frac{Secondary\ Market\ Price_{ijt} \text{-} Release\ Price_{ijt}}{Release\ Price_{ijt}} \times 100 \tag{12}$$

The reason for representing the price gap in percentage terms, rather than in nominal dollar terms, is because expensive wines tend to have a notably larger price difference in nominal (dollar) terms than less expensive wines, which could distort the estimation and interpretation of the coefficients as well as the fit of the model. The other explanatory variables, **X**, include the annual wine score, and the number of cases produced by a vineyard for each type of wine, region, and age.

4. Results and Discussion

Tables 2 and 3 present estimation results. The results in Table 2 implement only firm fixed effects, while Table 3 includes both fixed firm effects and time effects. In both Tables 2 and 3, it is evident that the main variable of interest, *Price Gap* (*t*-1), has a statistically significant positive effect at the 5% level of significance or better in all cases. We consider this main result to be robust, since the conclusion is maintained across all models, including the use of various sets of covariates, as well as for models that include firm fixed effects only, and both firm fixed effects and time fixed effects.

[Insert Table 2 Here]

[Insert Table 3 Here]

The estimated magnitudes of the coefficients on the price gap variable are notably quite stable, ranging between 0.0021 and 0.0025 for the models with firm fixed effects; and 0.0022 to 0.0026 for the models with both firm fixed effects and time fixed effects. The estimated values of the coefficients suggest that a one percent increase in the price gap in the previous year is associated with between a 0.21 and 0.26 percent increase in the secondary market price of a bottle of wine of the same type in the subsequent period. The results are consistent with the tenets of the scarcity pricing model. Since the cult winemakers are producing at their capacity-constrained levels, this finding provides evidence that demand shifts in response to a price gap in the previous period.[11]

Also from the estimation results, it is also evident that *wine score* and *region* play important roles in determining the market price for wine since these variables remain strongly statistically significant across all models. The result on the impact of expert ratings is consistent with previous studies, which find that wines that have higher scores tend to be more expensive (Hilger, Rafert, and Villas-Boas 2011). And given that Walla Walla is specified as the base region, wines from the Napa region have higher prices than from Walla Walla on average, but the opposite is true when comparing wines from Sonoma to Walla Walla wines.

Regarding the other covariates, in some cases the variables *company age* and *vintage* are also statistically significant, although they are not persistent throughout the analysis. In Appendices 2 and 3, we also present the results of applying a Box-Cox transformation to the dependent variable *Market*

[11] For intuition, refer back to Figure 1, which shows that if the firm is producing at the capacity-constrained quantity, then an increase in price is equivalent to a shift in demand. We acknowledge that in the real-world, this is only approximate.

Price to explore robustness with respect to the functional form or the dependent variable. The results are similar to those in Table 2 and 3, lending additional support to the robustness of estimated results.

5. Conclusions

This paper offers an economic rationale for why firms set prices below static single-period profit-maximizing levels. We call the strategy "scarcity pricing." The idea is that firms follow such a pricing strategy in order to create excess demand, which then results in a perception of scarcity. In a dynamic decision-making context, we show that if the perception of scarcity shifts the demand curve outward in future periods, it can potentially be profit-maximizing over time to underprice the product for a number of periods. For this to be the case, the future price increases and the time-discount factor must be sufficiently high.

In the empirical application, we analyze the market for "cult wines," where scarcity pricing may have the potential to be a profit-maximizing strategy. The wines in our data set all have significant waiting lists that would-be consumers must join in order to eventually be placed on the allocation list, i.e., a list of people who can actually buy a specified amount of the wines and pay the winemakers' release prices. The wines can be re-sold on the secondary market, with the potential for significantly higher prices than the release prices paid by those on allocation lists.

Empirically we find that the larger the difference between the secondary market price and the release price in the previous period (i.e., the price gap), the higher the secondary market price for the same wine in the subsequent period. Because market prices increase in future periods due to their positive association with previous period price gaps, this has the potential to benefit the firm in the long run. As Becker (1991) points out, "…*[C]onsumers get utility from competing for goods that are not available to everyone who wants them*."

The concept of scarcity pricing can be applied more broadly to other markets in which firms offer a differentiated product and face a capacity constraint. For example, in future research, it would be interesting to understand the role of scarcity pricing in the sales of season tickets for specific sports teams over time. Like the role quality plays for cult wines, a strong winning percentage is likely to be necessary for scarcity pricing to benefit sports teams in the sale of game tickets. The rationale for underpricing provided in this paper articulates a motivation that is different from predatory pricing. It may also be helpful as an alternative explanation when considering antitrust issues, in addition to other applications.

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TABLE 1-DESCRIPTIVE STATISTICS

Variables	Obs	Mean	St. Dev.	Min	Max
Year	252	2017.93	1.38	2016	2020
Market Price	251	306.84	379.67	64.82	3118.00
Price Gap	251	62.37	37.55	2.59	229.4
Wine Score	230	92.8	2.27	85	98
Cases	223	901.62	653.91	115	2,897
Company Age	252	27.98	8.66	13	42
Napa	252	0.38	0.49	0	1
Sonoma	252	0.42	0.49	0	1
Vintage	252	2015.27	1.43	2013	2018
Release Price	252	189.91	185.58	39	1,050

TABLE 2 -PANEL FIXED EFFECTS ESTIMATION WITH FIRM FIXED EFFECTS ONLY

	(1)	(2)	(3)	(4)	(5)	(6)
Price Gap (t-1)	0.0023**	0.0022**	0.0022**	0.0023**	0.0025***	0.0021**
	(0.0009)	(0.0010)	(0.0010)	(0.0009)	(0.0009)	(0.0010)
Cases		-0.00005				-0.00005
		(0.00005)				(0.00005)
Wine Score			0.0337***			0.0349**
			(0.0125)			(0.0138)
Company Age			0.0232			0.0211
			(0.0192)			(0.0195)
Napa				1.7134***		1.6313***
				(0.0840)		(0.2079)
Sonoma				-0.2983***		-0.2141*
				(0.0972)		(0.1134)
Vintage					0.0318*	
					(0.0175)	
Constant	6.4325***	6.4527***	2.4171**	4.7191***	-57.5638	0.7628
	(0.0309)	(0.0387)	(1.2187)	(0.0859)	(35.2859)	(1.3692)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO	NO
Observations	192	169	174	192	192	168
Adjusted R^2	0.8923	0.8840	0.8928	0.8923	0.8939	0.8899
F Statistic	114.089***	86.3415***	91.0953***	114.089***	108.256***	80.4231***

Note: Robust standard errors in parenthesis.
*p<0.1
**p<0.05
***p<0.01

TABLE 3 -PANEL FIXED EFFECTS ESTIMATION WITH FIRM AND TIME FIXED EFFECTS

	(1)	(2)	(3)	(4)	(5)	(6)
Price Gap (t-1)	0.0026***	0.0024**	0.0023**	0.0026***	0.0026***	0.0022**
	(0.0009)	(0.0010)	(0.0010)	(0.0009)	(0.0009)	(0.0010)
Cases		-0.00005				-0.00005
		(0.00005)				(0.00005)
Wine Score			0.0345***			0.0353**
			(0.0126)			(0.0139)
Company Age			0.0272			0.0257
			(0.0204)			(0.0207)
Napa				1.6617***		1.6800***
				(0.0915)		(0.2166)
Sonoma				-0.3254***		-0.1927*
				(0.0980)		(0.1170)
Vintage					-0.0632	
					(0.0512)	
Constant	6.3272***	6.3430***	2.2072*	4.6655***	133.536	0.5161
	(0.0585)	(0.0669)	(1.2550)	(0.0920)	(103.010)	(1.3953)
Firm FE	YES	YES	YES	YES	YES	YES
Time FE	YES	YES	YES	YES	YES	YES
Observations	192	169	174	192	192	168
Adjusted R^2	0.8934	0.8849	0.8919	0.8934	0.8932	0.8891
F Statistic	95.1869***	72.7665***	80.320***	95.1869***	89.7385***	71.4755***

Note: Robust standard errors in parenthesis.
*p<0.1
**p<0.05
***p<0.01

APPENDIX

Proof of Proposition On Existence of a Superior Scarcity Pricing Strategy

Proof: Let $\{1, 2, \cdots, T-1\}$ be the period in which scarcity pricing is imposed and let $\left\{P_1^*, P_2^*, \cdots, P_{T-1}^*\right\}$ be the associated scarcity-level pricing levels set during the period, so that $P_t^* < P^\pi \;\; \forall t < T$. Rewrite condition (10) as

$$\left(\frac{\sum_{t=1}^{T-1} \beta^{t-1} \frac{P_t^*}{P^\pi}}{\sum_{t=1}^{\infty} \beta^{t-1}} + \frac{\tilde{P}}{P^\pi} \frac{\sum_{t=T}^{\infty} \beta^{t-1}}{\sum_{t=1}^{\infty} \beta^{t-1}} \right) > 1 \tag{A1}$$

Letting $\rho_{\min} = \min\left(\frac{P_t^*}{P^\pi}, \, t \le T-1 \right) < 1$ and $\tilde{\rho} = \frac{\tilde{P}}{P^\pi} > 1$, it follows that a sufficient condition for (A1) to hold is that

$$\left(\rho_{\min} \frac{\sum_{t=1}^{T-1} \beta^{t-1}}{\sum_{t=1}^{\infty} \beta^{t-1}} + \tilde{\rho} \frac{\sum_{t=T}^{\infty} \beta^{t-1}}{\sum_{t=1}^{\infty} \beta^{t-1}} \right) > 1 \tag{A2}$$

.

Now note that $\frac{\sum_{t=1}^{T-1} \beta^{t-1}}{\sum_{t=1}^{\infty} \beta^{t-1}} \to 0 \;\; and \;\; \frac{\sum_{t=T}^{\infty} \beta^{t-1}}{\sum_{t=1}^{\infty} \beta^{t-1}} \to 1 \; as \;\; \beta \to 1$. It follows that there exists a β large enough and a $\tilde{P}$ large enough so that (10) holds, and the scarcity pricing strategy is superior to the stationary pricing strategy. *QED*.

TABLE A1 -CULT WINES USED IN THIS ANALYSIS

Company	Region	Wine Products
Eisele Vineyard	Napa	Cabernet Sauvignon, Altagracia, Syrah
Cayuse	Walla Walla	Armada Vineyard Syrah, Bionic Frog Syrah, Cailloux Vineyard Syrah, En Cerise Vineyard Syrah, En Chamberlin Vineyard Syrah, Flying Pig, Widowmaker Cabernet-Sauvignon, God Only Knows Grenache, The Lovers
Screaming Eagle	Napa	Cabernet Sauvignon Oakville
Scarecrow Wine	Napa	Scarecrow
Colgin	Napa	Tychson Hill, Cariad, IX Estate, IX Estate Syrah
Dalla Valle	Napa	Cabernet Sauvignon, Maya
Grace Family	Napa	Cabernet Sauvignon
Schrader Cellars	Napa	Beckstoffer To Kalon Vineyard Cabernet Sauvignon, CCS Cabernet Sauvignon, GIII Cabernet Sauvignon, LPV Cabernet Sauvignon, RBS Cabernet Sauvignon, T6 Cabernet Sauvignon
Abreu	Napa	Cappella St. Helena, Madrona, Thorevilos
Leonetti Cellars	Walla Walla	Merlot, Cabernet Sauvignon, Reserve Blend, Sangiovese
Aubert	Sonoma	Chardonnay Eastside, Chardonnay Lauren, Chardonnay Powder House, Chardonnay UV-SL, Pinot Noir UV, Pinot Noir UV-SL, Pinot Noir Sonoma Coast
Kistler	Sonoma	Chardonnay Dutton, Chardonnay Trenton Roadhouse, Chardonnay Vine Hill, Chardonnay Durell, Chardonnay Stone Flat, Chardonnay McCrea, Chardonnay Cuvée Cathleen, Pinot Noir Laguna Ridge, Pinot Noir Silver Belt Cuvée Natalie
Williams Selyem	Sonoma	Pinot Noir Russian River Valley, Pinot Noir Olivet Lane Vineyard, Pinot Noir Westside Road Neighbors, Pinot Noir Sonoma Coast, Pinot Noir Sonoma County, Zinfandel Bacigalupi Vineyard, Chardonnay Heintz Vineyard
Rochioli	Sonoma	Chardonnay River Block, Pinot Noir Little Hill

TABLE A2 -EFFECTS ESTIMATION WITH BOX-COX TRANSFORMATION OF THE DEPENDANT VARIABLE AND FIRM FIXED EFFECTS ONLY

	(1)	(2)	(3)	(4)	(5)	(6)
Price Gap (t-1)	0.0007**	0.0007**	0.0007**	0.0007**	0.0008***	0.0005**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0002)
Cases		-0.00002				-0.00001
		(0.00001)				(0.00001)
Wine Score			0.0116***			0.0086***
			(0.0039)			(0.0031)
Company Age			0.0073			0.0046
			(0.0059)			(0.0042)
Napa				0.5237***		0.3475***
				(0.0297)		(0.0478)
Sonoma				-0.1055***		-0.0584**
				(0.0345)		(0.0297)
Vintage					0.0102*	
					(0.0055)	
Constant	3.5050***	3.5126***	2.1493***	2.9813***	-17.0119	1.7016***
	(0.0093)	(0.0117)	(0.3833)	(0.0303)	(10.9871)	(0.3042)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	NO	NO	NO	NO	NO	NO
$\varphi^{\dagger}$	-0.2121	-0.2121	-0.2121	-0.2121	-0.2121	-0.2727
Observations	192	169	174	192	192	168
Adjusted R^2	0.8833	0.8749	0.8856	0.8833	0.8850	0.8805
F Statistic	104.233***	79.3339***	84.6941***	104.233***	99.0295***	73.4032***

Note: Robust standard errors in parenthesis.
*p<0.1
**p<0.05
***p<0.01

† The Box-Cox transformations are calculated as $y(\varphi)=\begin{cases}\dfrac{y^{\varphi}-1}{\varphi} & if \ \varphi \neq 0 \\ \ln(y) \ if & \varphi = 0\end{cases}$.

TABLE A3 - EFFECTS ESTIMATION WITH BOX-COX TRANSFORMATION OF THE DEPENDANT VARIABLE AND TIME AND FIRM FIXED EFFECTS

	(1)	(2)	(3)	(4)	(5)	(6)
Price Gap (t-1)	0.0008***	0.0008**	0.0007**	0.0008***	0.0008***	0.0005**
	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0003)	(0.0002)
Cases		-0.00002				-0.00001
		(0.00001)				(0.00001)
Wine Score			0.0118***			0.0087***
			(0.0040)			(0.0031)
Company Age			0.0086			0.0057
			(0.0063)			(0.0045)
Napa				0.5063***		0.3578***
				(0.0317)		(0.0500)
Sonoma				-0.1142***		-0.0540*
				(0.0347)		(0.0303)
Vintage					-0.0222	
					(0.0177)	
Constant	3.4717***	3.4785***	2.0860***	2.9654***	48.1115	1.6457***
	(0.0183)	(0.0205)	(0.3960)	(0.0321)	(35.6213)	(0.3116)
Firm FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
$\varphi^{\dagger}$	-0.2121	-0.2121	-0.2121	-0.2121	-0.2121	-0.2727
Observations	192	169	174	192	192	168
Adjusted R^2	0.8845	0.8760	0.8845	0.8845	0.8844	0.8795
F Statistic	87.0419***	66.9223***	74.6076***	87.0419***	82.1469***	65.1722***

Note: Robust standard errors in parenthesis.
*p<0.1
**p<0.05
***p<0.01

† The Box-Cox transformations are calculated as $y(\varphi) = \begin{cases} \dfrac{y^{\varphi} - 1}{\varphi} \; if \;\; \varphi \neq 0 \\ \ln(y) \; if \;\; \varphi = 0 \end{cases}$.