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Peak-load pricing in duopoly ☆

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ABSTRACT

In this paper, we consider peak-load pricing by duopolists that maximize profit (not social welfare). We compare price levels and profits across peak-load versus uniform pricing regimes. Our main result is that the introduction of peak-load pricing can plausibly reduce prices by making price competition more severe and thereby reducing profits. This result suggests that competing firms may engage in collusion by not committing to peak-load pricing. Therefore, from the regulator's perspective, it will be desirable to encourage firms to engage in peak-load pricing to intensify competition.

1. Introduction

Peak-load pricing is a type of second degree price discrimination whereby the service supplier charges a higher price for peak-time services than for off-peak services in order to disperse high peak-time demands.[1] It is especially likely when there are severe congestion problems due to limited capacity, as is common among public utilities such as electricity, gas, and transportation sectors. Because public utilities are, or have been in the recent past, run as regulated monopolies, the peak-load pricing strategy is commonly analyzed or regarded as a means to achieving social welfare maximization.

Recently, the congestion problem has been considered serious in the data communication industry (e.g. internet service, mobile wireless communication, and electronic price quotation networks with high-frequency trading)[2] as well as in traditional public utility industry.[3] Then, why don't private suppliers of bandwidth in the information network and mobile wireless industries[4] frequently use peak-load pricing as an alternative to flat-rate or usage-based pricing to resolve, or at least alleviate, delays in data transmission due to congestion?[5] It is puzzling. This paper attempts to answer the question.

The nowadays information network and telecommunication industries have two important features that distinguish them from the public utility sector. First, these industries are privately owned with a primary objective of maximizing profit (rather than maximizing a social-welfare objective). Second, due to privatization, the information networks and telecommunication industries have a competitive structure with multiple private owners rather than consisting of a single

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[1] The distinction between second degree price discrimination and third degree price discrimination lies in substitutability, i.e., whether or not consumers can choose between the two products. Off-peak services and peak-time services are usually substitutable.

[2] This industry has been moving from the public sector to the private sector.

[3] Congestion issues in electric grids are widely regarded as an important challenge for private grid operators (e.g., in addition to high-profile rolling blackouts in California in 2000 and 2001, there are less well-known electric utility operators, such as in New Zealand, that are actively experimenting with peak-load pricing as a tool for achieving primarily private but also public objectives among various stakeholders of the electric grid system). Also, see An and Zhang (2012) for a congestion problem in the transportation industry.

[4] There are some exceptions. Peak-load pricing has been used in telecommunications under a different name of night-time/weekend discounts. For example, Telecom and Vodafone (TelstraClear), which are duopolists in the international call market of New Zealand, both use peak-load pricing, and similarly for duopolists Korea Telecom (KT) and DACOM in the Korean market for international phone service.

[5] The Korean government is considering the policy to encourage peak-load pricing in order to spread a rapid increase in the data traffic volume due to network evolution. See KISDI (2014).

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monopolist.[6] Thus, in this paper, we consider two profit-maximizing competing firms that provide homogeneous information services, and examine the effect of peak-load pricing by comparing the outcome with that of uniform pricing.

Peak-load pricing assumes a situation in which service providers face a potentially binding capacity constraint.[7] So, the problem of peak-load pricing is equivalent to a two-sector extension of the Bertrand model where each firm faces a capacity constraint, which is referred to in the literature as the Bertrand–Edgeworth model. To the best of our knowledge, this equivalence has not been recognized in literature. Thus, our model extends the Bertrand–Edgeworth model in two directions. First, in our model, firms sell two goods, off-peak goods and peak-time goods. Second, in our model, firms are allowed to choose two prices (off-peak price and peak-load price) rather than one uniform price.

We could elicit some valuable insights for this model from two simpler cases. First, if there is a profit-maximizing monopolist, and it faces excess capacity (or, alternatively, excess supply) in the off-peak time, and excess demand in the peak-load time, then peak-load pricing will clearly increase this monopolist's profit by reducing both excess supply in the off-peak time and excess demand in the peak time. Second, if two profit-maximizing duopolists, each with its capacity constraint, compete using a single uniform price, then two results from the Bertrand–Edgeworth model are already known. If the capacity level is low enough relative to the market demand, then the model has a unique pure-strategy equilibrium in which the two firms produce up to their capacity levels and they both charge the market-clearing price, which is strictly greater than marginal cost. On the other hand, if the capacity level is binding but so large that there is no market-clearing price,[8] then the model has no pure-strategy equilibrium, but only a mixed-strategy equilibrium.[9]

In the case of our two-good extension of the Bertrand–Edgeworth model, similar phenomena occur, but an interesting new feature emerges. The new implication is that there is demand substitution from peak-load to off-peak times. This substitution occurs when the peak-load price is greater than the off-peak price, whereas it does not occur under uniform pricing, because uniform pricing implies that there can be no price difference between the two products and thus no demand substitution in response to price differentials between different firms' offerings. Due to this substitution effect, peak-load pricing (i.e., any positive difference in the peak-load versus off-peak prices) has the effect of shifting the peak-time demand curve inward and the off-peak demand curve outward relative to uniform pricing. Of course, this result is exactly what is intended by peak-load pricing. Depending on the magnitude of these demand shifts in response to peak-load pricing, however, various possibilities occur. For example, if the capacity level is K_1 as depicted in Fig. 1, then firms that engage in peak-load pricing will choose to use mixed strategies possibly over a range of lower prices in the peak-time sector because of consumers' reduced demand due to the price differential, and charge zero price or mixed strategies over a range of even lower prices in the off-peak sector. In either case, prices in both sectors could be lower than under uniform pricing. This result of lower prices is not a special case but rather holds for a large range of parameter values representing the firm's capacity constraint. It is also important to recognize that firms are, in most cases, made worse off by introducing peak-load pricing. Intuitively, this is because peak-load pricing effectively intensifies price competition since it gives them the leverage of two prices rather than one uniform price. The result suggests that firms may engage in collusion by committing to not engage in peak-load pricing. Viewed from the benevolent regulator's perspective, peak-load pricing likely has the effect of promoting competition which therefore should be encouraged to ensure more efficient pricing than would occur under uniform pricing.

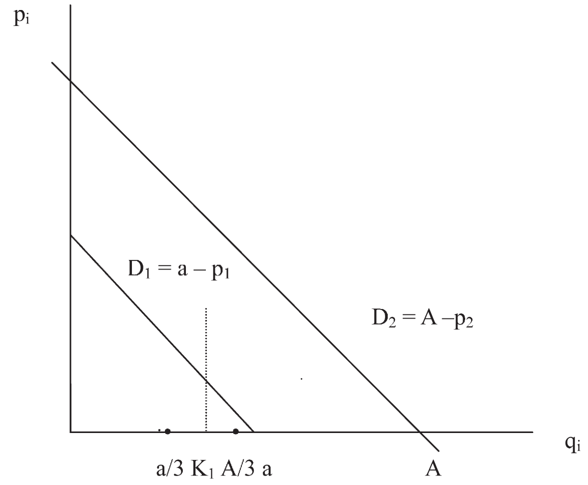

Fig. 1. Demands and capacity.

Similar results can be found in the literature of oligopoly price discrimination. Holmes (1989) and Corts (1998) also showed that competition by price discrimination may make firms worse off in oligopoly in a symmetric model (Holmes, 1989) and in an asymmetric model (Corts, 1998). However, both used a model of differentiated products. We have a similar effect of peak-load pricing on prices and profits in a model of homogeneous products. Also, their models are concerned with third-degree price discrimination so there is no demand substitution which is a crucial feature of our model. Furthermore, the mechanism driving the result is totally different. Capacity constraints are the crucial factor that gives rise to our result, whereas no such constraints are assumed in those previous models.[10]

Our model is also related to the literature on capacity and price choices in duopoly with demand uncertainty. Hviid (1990) considers (ex ante) price decisions before demand is realized. Thus, there is no peak-load pricing in his model. Moreover, price decisions are not simultaneous but sequential, so pure strategy equilibria exist for any capacity pairs in his model. Reynolds and Wilson (2000) consider a model of (ex post) price decisions after demand is realized. So, it is closer to our model, but they focus more on the expected equilibrium revenues in the price subgame rather than equilibrium price strategies. Thus, one could elicit little implication on peak-load pricing. Lepore (2012) also considers ex post price decisions and pays more attention to equilibrium price strategies. Although it is even closer to our model in that sense, it does not compare the differentiated prices (interpretable as peak-load prices and off-peak prices) with uniform prices, so it does not address the issue of the peak-load pricing effect (whether peak-load pricing intensifies or reduces competition). de Frutos and Fabra (2011) analyze both ex ante and ex post price decisions, but they focus on the case that demands are price inelastic. Fabra et al. (2002, 2006) compare uniform auctions and discriminatory auctions in electricity wholesale markets. However, uniform auctions are different from our uniform pricing. Under uniform auctions, all bidders are paid

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[6] Nagle (1984) was among those who, early on, recognized the real-world relevance of studying peak-load pricing among privately owned firms such as restaurants, hotels, movie theaters, and airlines.

[7] Nie and Chen (2012) assume that producers face a capacity constraint in inputs, which indirectly implies a capacity constraint in outputs. But the constraints they consider are not for a single firm's inputs but rather consist of an industry-wide constraint (i.e., the sum of the inputs used by all firms in the industry cannot exceed an exogenously given industry-level resource constraint). Moreover, there is no price discrimination in their model.

[8] There is a third possibility, too. If the capacity level is not binding for any price level, then, price is driven down to marginal cost as a result of severe price competition.

[9] The existence of a mixed-strategy equilibrium corresponds with the so-called Edgeworth cycle.

[10] Layson (1998) also shows that price discrimination by a monopolist supplying two markets can cause prices to rise or fall in both markets with interdependent demands. But, in contrast to ours, Layson's (1998) model features no competition nor capacity constraints. In Layson's model, the effect of price discrimination on price depends on the strength of demand interdependence, the curvature of the demands, and the slope of marginal cost rather than on the competition as is the case in our model. Therefore, the insights are quite different.