Strategic Curb and Garage Pricing in Urban Parking Markets

Amir Brudner*[1], Mehdi Nourinejad[2], and Opher Baron[3]

[1]Hebrew University of Jerusalem, Israel
[2]York University, Canada
[3]University of Toronto, Canada

Short summary

This paper studies a Stackelberg pricing competition between regulated public curb parking, subject to congestion, with a nearly guaranteed-access private parking garage alternative. The public authority regulator sets the curb price, anticipating the response of a profit-maximizing garage operator.
We assume that users differ in both their valuation of the service and their sensitivity to waiting, leading to endogenous sorting across the two parking options. We show that pricing regulation shapes market power in a counterintuitive way. When the curb is underpriced, congestion intensifies, causing the operator to raise garage prices and to target high-value, time-sensitive users. In contrast, higher curb prices may lead to lower garage prices and welfare.
The results help explain the common phenomenon of low curb prices and high garage fees, highlighting the role of curb pricing in shaping market outcomes.
Keywords: operations research applications, parking pricing, queueing, Stackelberg game, urban mobility

1 Introduction

Urban parking provides an interesting example of a service involving a limited-capacity facility operating alongside a more reliable but less convenient or more expensive alternative. Curb parking is a scarce and congestible resource, while off-street garages offer more reliable access, often at a higher cost and usually with additional walking. Users, on the other hand, trade off price, waiting time, and other attributes. Therefore, outcomes depend on demand and on how pricing is managed by the regulator and the private operators. This is especially important in parking markets, where pricing directly affects congestion. Shoup (2005) estimates that in some cases, up to 30% of downtown traffic consists of drivers cruising for underpriced curb spaces, generating delays, fuel waste, and emissions even when nearby garages remain underused.
The queueing literature provides the foundation for studying such trade-offs. Naor (1969), Knudsen (1972), and Edelson & Hilderbrand (1975) show how waiting costs shape equilibrium participation under different queueing observability. Mendelson (1985) studies how delay and user costs shape resource utilization, and Mendelson & Whang (1990) extend this framework to multiple user classes. Price competition across facilities has been studied by Luski (1976) and Levhari & Luski (1978), who considered homogeneous firms alongside users with endogenous waiting times and showed that users sort across facilities according to waiting sensitivity. Chen & Wan (2003) consider heterogeneous firms, while Deck et al. (2014) study competition between regular and express service. Public–private interaction was examined by Alves (2019), considering a zero-priced public provider alongside a private congested alternative, and by Zhou et al. (2023), who studied it with heterogeneity in service valuation. Stackelberg models appear in related work such as Guo & Hassin (2013), Wang et al. (2019), and Hu et al. (2024), but do not combine a public leader, a private follower, and two-dimensional user heterogeneity as in this study.
The parking literature sucs as Arnott & Inci (2006), Calthrop & Proost (2006), and Inci & Lindsey (2015) study pricing and regulation of parking. Yet most of this literature either

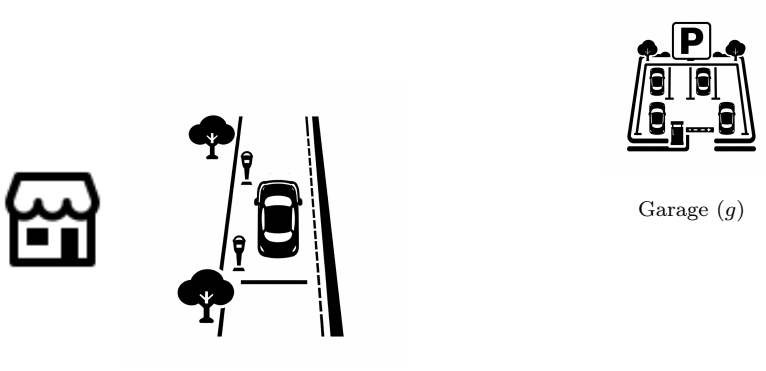


Figure 1: Illustration of the two parking alternatives. The garage, located farther from the destination, provides immediate access, while the closer street option may involve waiting.

abstracts from regulator–operator interaction or assumes homogeneous users. As a result, it remains unclear how curb pricing affects private garage pricing when users differ in both their valuations and their waiting sensitivity.

This gap is the motivation behind our study. We develop a queueing-based model of a public–private parking market in which the regulator sets the curb price and a private garage responds strategically while users are heterogeneous in parking valuation and waiting sensitivity. Our objective is to examine how regulated curb pricing shapes sorting, participation, parking congestion, and private market power, and to identify when regulatory pricing can improve welfare not only by reducing queues but also by incentivizing the private operator's response.

The analysis shows that underpricing the curb may strengthen, rather than weaken, private market power. Hence, when curb parking is cheap, congestion intensifies and the garage can target high-valuation, time-sensitive users with high prices. In contrast, sufficiently high curb prices reduce congestion and induce the garage to lower its price to remain competitive.

2 Methodology

Model environment

We study a parking market with two alternatives that differ in their access and congestion characteristics (illustrated in Figure 1). Drivers arrive according to a Poisson process with rate λ. Street parking (option s) is congestible and is modeled as an M/M/1 queue. Users who choose the street incur an expected waiting time w, which depends on the arrival rate and the service rate μ, representing the inverse of average parking duration. Access to the street is priced at p_s.

Garage parking (option g) provides immediate service and is modeled as an M/M/∞ facility, so no queue forms. Users pay a price p_g and incur an additional fixed inconvenience cost $d > 0$, capturing access time such as walking distance.

User preferences and sorting

Users are heterogeneous along two dimensions: their valuation for parking and their sensitivity to waiting. Let $\mathcal{K}$ denote the set of valuation types, where each type k has reward r^k and population share P^k. In addition, each user draws a waiting cost parameter

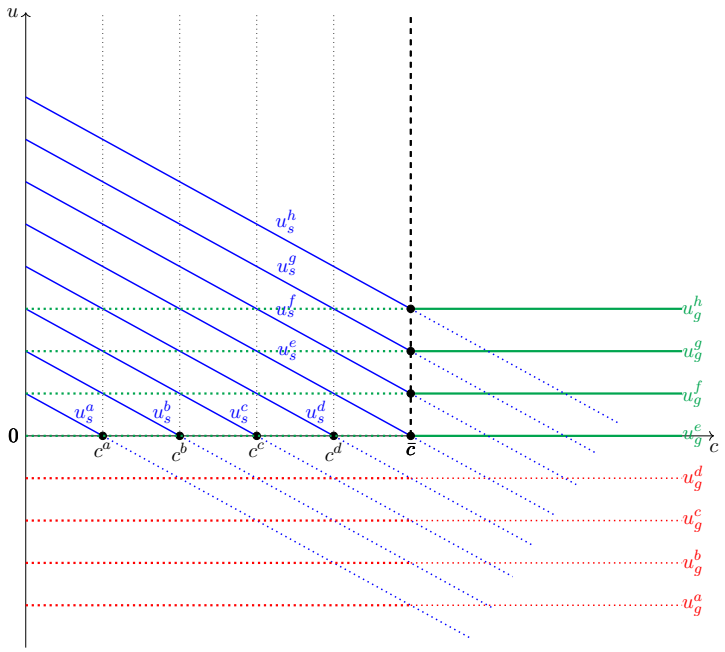


Figure 2: Participation and sorting across facilities. Lower-valuation types (a–d in this case) may opt out, while higher-valuation types (e–h in this case) choose between street and garage based on waiting sensitivity.

$c \sim U[0,1]$. Given prices (p_s, p_g) and waiting time w, utilities are given by

$$u_s^k = r^k - p_s - c \cdot w, \tag{1}$$

$$u_g^k = r^k - p_g - d, \tag{2}$$

$$u_o = 0. \tag{3}$$

Users choose the option that yields the highest utility. This structure induces sorting between the street parking, the garage, and skipping the trip (option o). A key implication is that participation is monotone in valuation, meaning that if a lower-valuation type participates, then all higher-valuation types also participate. To describe the sorting structure, we define

$$\mathcal{K}^H = \{k : r^k \geq p_g + d\}, \qquad \mathcal{K}^L = \{k : r^k < p_g + d\}.$$

Types in $\mathcal{K}^H$ choose between street and garage, while types in $\mathcal{K}^L$ choose between street and opting out.

Figure 2 illustrates this structure. Types in $\mathcal{K}^L$ do not use the garage since $r^k < p_g + d$. Each type has a cutoff c^k separating users between street parking and opting out. As r^k decreases, this cutoff decreases, and participation declines. Types in $\mathcal{K}^H$ compare street and garage and share a common cutoff given by

$$\bar{c} = \frac{p_g + d - p_s}{w},$$

so that users with $c \leq \bar{c}$ choose the street, while those with higher waiting costs choose the garage.

Congestion and equilibrium

Aggregate demand for street parking depends on these cutoffs. The resulting arrival rate to the street is

$$\lambda_s(p_s, p_g, w) = \lambda \left(\sum_{k \in \mathcal{K}^L} P^k c^k + \bar{c} \sum_{k \in \mathcal{K}^H} P^k \right). \tag{4}$$

Because arrivals are Poisson and routing decisions are independent, the street remains an M/M/1 queue. The expected waiting time is therefore

$$w = \frac{1}{\mu - \lambda_s(p_s, p_g, w)}, \tag{5}$$

which defines the relationship between prices, sorting, and congestion. Under interior conditions, this system admits a closed-form solution:

$$w(p_s, p_g) = \frac{1 + \lambda A(p_s, p_g)}{\mu}, \tag{6}$$

where

$$A(p_s, p_g) = \sum_{k \in \mathcal{K}^L} P^k (r^k - p_s) + \left(\sum_{k \in \mathcal{K}^H} P^k \right) (p_g + d - p_s).$$

This expression shows how prices influence congestion through both participation and sorting between the street and the garage.

Public–private Stackelberg interaction

Pricing is modeled as a Stackelberg game. The public authority regulator sets the street price p_s, anticipating the response of a private garage operator. The garage then sets p_g to maximize profit given the induced demand and congestion. For a given p_s, the garage solves

$$\max_{p_g \geq 0} \ \pi_g = p_g \lambda_g,$$

where λ_g depends on the share of users who select the garage based on the induced cutoffs. Because different subsets of valuation types may participate in the garage depending on prices, the operator effectively considers different participation regimes and selects the one that yields the highest profit. In simple terms, it trades off higher prices against a smaller customer base.

The regulator anticipates this response and chooses p_s to maximize social welfare, defined as the sum of user utilities subtracted by waiting and access costs, formally given by

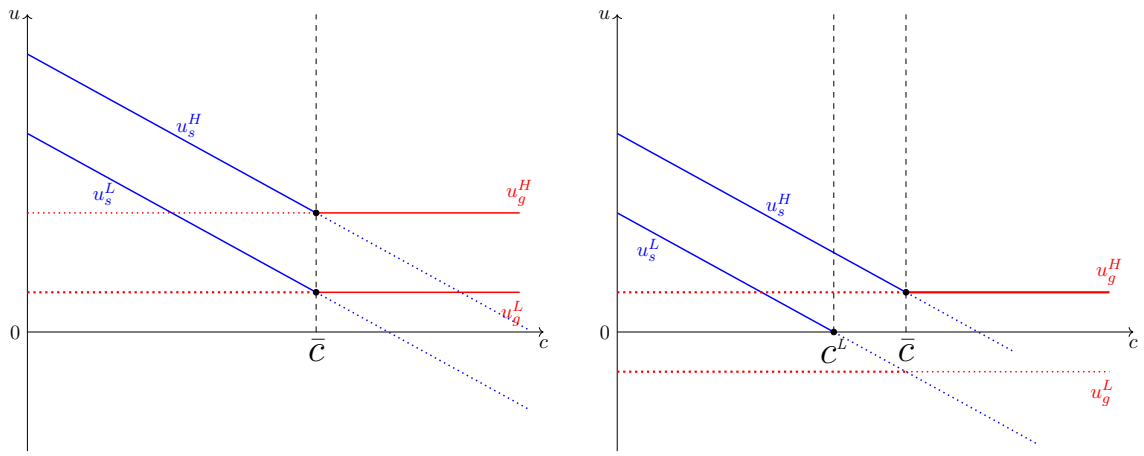
$$p_s^* \in \arg\max_{p_s} W\big(p_s, p_g^*(p_s)\big), \tag{7}$$

where $p_g^*(p_s)$ is the garage best response. This structure illustrates the central interaction of interest as how public pricing influences congestion and user sorting, which in turn affects the private operator's pricing incentives. The equilibrium reflects both heterogeneous users' behavioral responses and the strategic interaction between the two parking providers in the market. Given the scope here, we next focus primarily on the numerical implications of the model, which allow us to illustrate the main mechanisms and policy insights.

3 Results and discussion

Two-type setting

To make the general mechanism more transparent, we consider a case with two valuation types, $\mathcal{K} = \{L, H\}$, where type-H users derive a higher reward from securing a parking space than type-L users ($r^H > r^L$). The population shares are $P^L = P$ and $P^H = 1 - P$. In this setting, the garage may operate under two distinct participation regimes. First is the *inclusive* regime, where both types are willing to use the garage, so all users participate and sort across the two facilities based on their waiting sensitivity. Second is the *priority* regime where the garage serves only type-H and type-L users choose between street parking and opting out. These two regimes are illustrated in Figure 3.



(a) Inclusive participation

(b) Priority participation

Figure 3: Threshold structure under the two-type model.

The distinction between the two regimes is economically important. Under inclusive participation, the garage serves a broader market but must price more moderately. Under priority participation, it serves a narrower segment of users and may charge a higher price. The selected regime depends on the street price, because it affects congestion and thus the value of guaranteed access.

Numerical illustration

To illustrate the interaction between the public authority and the private garage operator, we use the following parameters:

$$\lambda = 30, \qquad \mu = 15, \qquad d = 1, \qquad r^L = 9, \qquad r^H = 14, \qquad P = 0.2.$$

In this example, high-valuation users represent a large share of demand, and the street can become substantially congested when curb prices are low.

We first examine the garage operator's best response where for each street price p_s, the garage compares profits across the two participation regimes and chooses the regime–price pair that yields the highest profit. The result is shown in Figure 4.

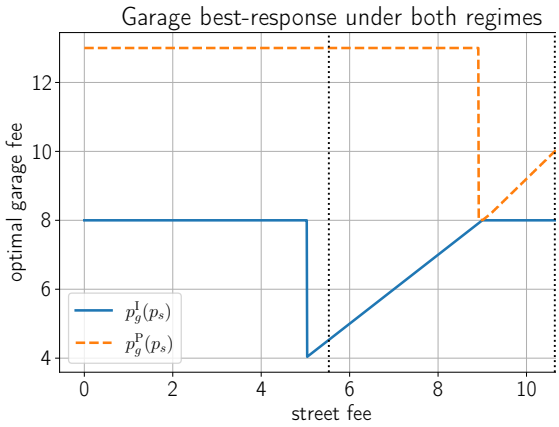
The numerical example highlights a central mechanism. When the street price is low, congestion on the street is severe, and the garage finds it profitable to operate under the priority regime. In this region, it charges a high price and serves mainly high-valuation, time-sensitive users. In other words, cheap curb parking does not necessarily constrain the garage. Instead, by sustaining congestion at the public facility, it may increase the garage's pricing power.

As the street price rises, congestion declines and the garage's incentives change. At intermediate street prices, the garage may switch to the inclusive regime and lower its price in order to attract a broader pool of users. This implies that increasing the curb price can, over some range, reduce the garage price. This result runs against the common intuition that lower public prices necessarily discipline private prices.

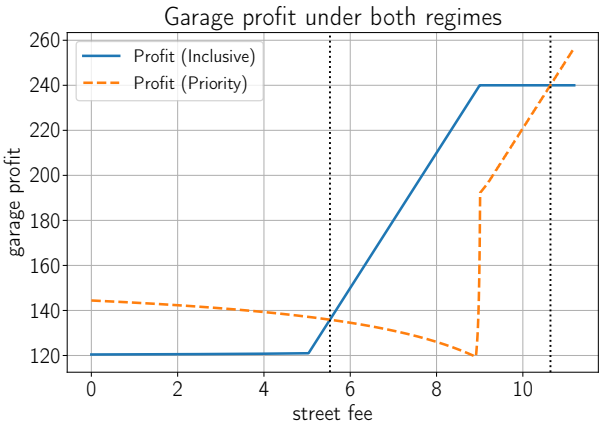
The bottom panel of Figure 4 summarizes the consolidated best response. The relationship between p_s and p_g is clearly non-monotone. At low p_s, the garage cream-skims the market. At higher p_s, it may need to reduce prices to remain competitive.

Turning to the planner's problem, the public authority chooses the street price anticipating the garage's regime-dependent response. Figure 5 reports the resulting welfare, consumer surplus, and waiting time.

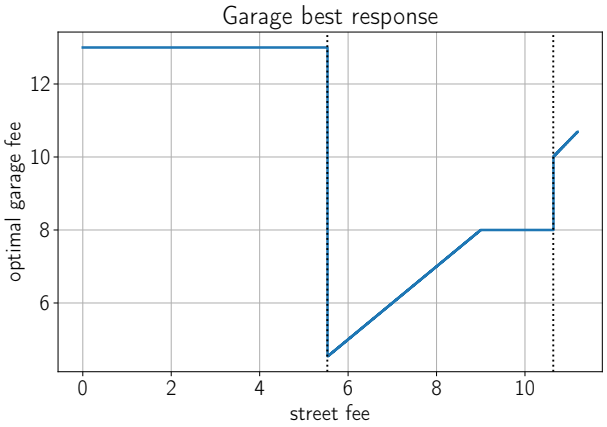
The welfare results show that low curb prices may be counterproductive. In the present calibration, the inclusive regime yields higher welfare than the priority regime, but inducing that outcome requires the planner to set the street price high enough to alter the garage's



(a) Garage best response by regime



(b) Garage profit by regime



(c) Consolidated best response

Figure 4: Garage best-response pricing across regimes.

incentives. Hence, if the regulator keeps street parking too cheap, the garage keeps a high price regime and overall welfare is lower.

Consumer surplus follows a somewhat different pattern. In general, it declines with the street price because users pay more and some low-valuation users stop participating. At the same time, consumer surplus can change discretely at regime switches when the garage changes its pricing strategy, thereby reallocating demand across facilities.

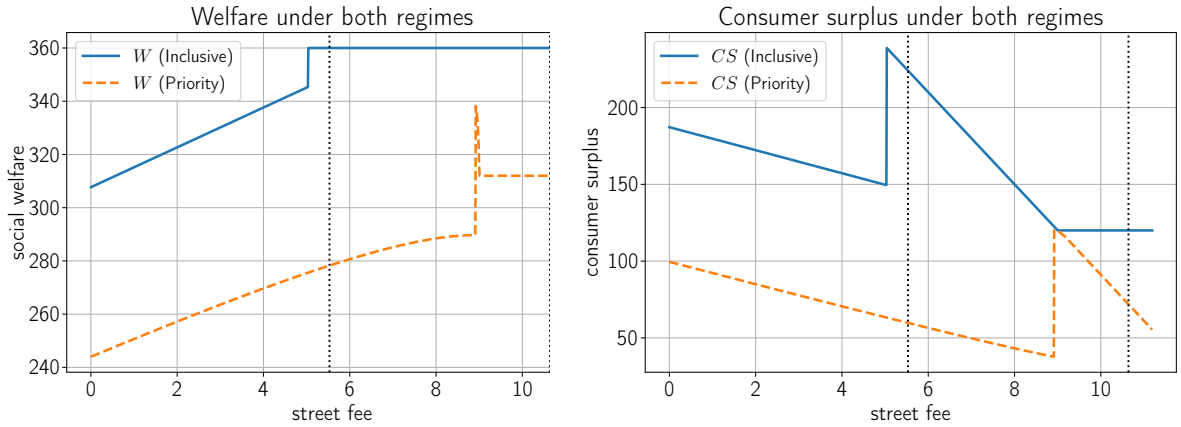
The waiting-time panel clarifies the congestion mechanism. As the street price increases, waiting time falls because demand is priced off the curb. Again, waiting time may shift discretely when the garage switches regimes and absorbs a different share of demand. Hence, the planner affects congestion both directly, through curb pricing, and indirectly, through the garage's response.

Taken together, the two-type illustration supports the main message that underpricing the public facility may strengthen private market power, while higher public prices may improve welfare not only by reducing queues but also by reducing the private operator's market power.

Empirical context

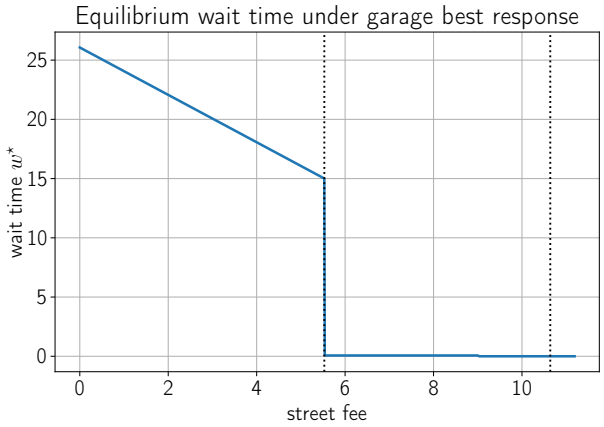
To connect the mechanism to reality, Figure 6 reports a comparison between garage and street parking fees from the Parkopedia Global Parking Index.

The figure reveals substantial variation across cities and a pattern difference between continents. In many European cities, on-street prices are relatively high and often close to



(a) Total welfare

(b) Consumer surplus



(c) Equilibrium waiting time

Figure 5: Welfare outcomes and congestion across participation regimes.

garage prices. In contrast, in North American and Australian cities, we observe the opposite pattern as curbside parking is comparatively cheap, while garage parking is much more expensive. We do not claim that these differences are generated only by the mechanism in our model. Institutional rules, urban form, and parking supply all matter. Still, the pattern seems consistent with the idea developed here that when street parking is underpriced, congestion at the curb may preserve or even enhance the pricing power of private garages.

4 Conclusions

This paper develops a framework for pricing street parking subject to congestion, namely, drivers waiting for a vacant spot, that coexists alongside a private, nearly-guaranteed-access alternative. Combining endogenous congestion, two-dimensional user heterogeneity, and strategic pricing, we show how public prices shape private market power through waiting times and sorting.

A central result is that underpricing the curb may strengthen the private garages' ability to extract surplus. When curb congestion is severe, the private operator raises its prices and targets high-value, time-sensitive users. In this sense, low curb prices can sustain high private markups. Conversely, sufficiently high street parking prices may discipline the private operators to reduce prices and improve welfare. The model may provide a theoretical explanation for the frequent coexistence of cheap curb parking and expensive garages.

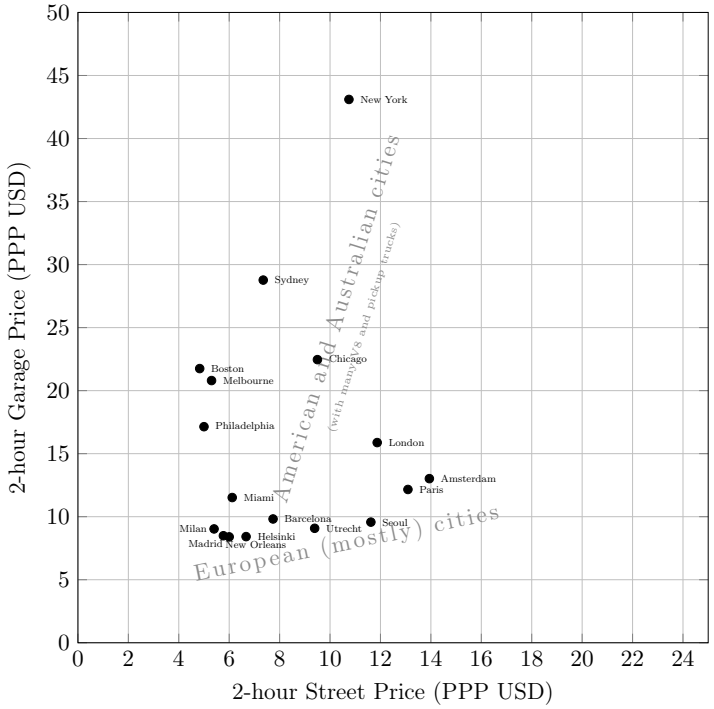


Figure 6: Garage parking fee to street parking fee (Parkopedia Global Index, 2022).

References

Alves, V. F. (2019). Pricing and waiting time decisions in a health care market with private and public provision. *Journal of Applied Economics*, *22*(1), 174–195.

Arnott, R., & Inci, E. (2006). An integrated model of downtown parking and traffic congestion. *Journal of Urban Economics*, *60*(3), 418–442.

Calthrop, E., & Proost, S. (2006). Regulating on-street parking. *Regional Science and Urban Economics*, *36*(1), 29–48.

Chen, H., & Wan, Y.-W. (2003). Price competition of make-to-order firms. *IIE Transactions*, *35*(9), 817–832.

Deck, C., Kimbrough, E. O., & Mongrain, S. (2014). Paying for express checkout: Competition and price discrimination in multi-server queuing systems. *PloS one*, *9*(3), e92070.

Edelson, N. M., & Hilderbrand, D. K. (1975). Congestion tolls for poisson queuing processes. *Econometrica: Journal of the Econometric Society*, 81–92.

Guo, P., & Hassin, R. (2013). On the advantage of leadership in service pricing competition. *Operations Research Letters*, *41*(4), 397–402.

Hu, M., Huang, W., Liu, C., & Zhou, W. (2024). Regulation of privatized public service systems. *Production and Operations Management*, *33*(4), 979–994.

Inci, E., & Lindsey, R. (2015). Garage and curbside parking competition with search congestion. *Regional Science and Urban Economics*, *54*, 49–59.

Knudsen, N. C. (1972). Individual and social optimization in a multiserver queue with a general cost-benefit structure. *Econometrica: Journal of the Econometric Society*, 515–528.

Levhari, D., & Luski, I. (1978). Duopoly pricing and waiting lines. *European Economic Review*, *11*(1), 17–35.

Luski, I. (1976). On partial equilibrium in a queuing system with two servers. *The Review of Economic Studies*, *43*(3), 519–525.

Mendelson, H. (1985). Pricing computer services: Queueing effects. *Communications of the ACM*, *28*(3), 312–321.

Mendelson, H., & Whang, S. (1990). Optimal incentive-compatible priority pricing for the m/m/1 queue. *Operations research*, *38*(5), 870–883.

Naor, P. (1969). The regulation of queue size by levying tolls. *Econometrica: journal of the Econometric Society*, 15–24.

Shoup, D. C. (2005). *The high cost of free parking*. Chicago, IL: Planners Press, American Planning Association.

Wang, J., Cui, S., & Wang, Z. (2019). Equilibrium strategies in m/m/1 priority queues with balking. *Production and Operations Management*, *28*(1), 43–62.

Zhou, W., Huang, W., Hsu, V. N., & Guo, P. (2023). On the benefit of privatization in a mixed duopoly service system. *Management Science*, *69*(3), 1486–1499.

Use of AI tools. AI-based tools were used to assist with language editing and presentation.