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A theory of multihoming in rideshare competition

Kevin A. Bryan | Joshua S. Gans

Rotman School of Management, University of Toronto, Toronto, Ontario, Canada

Correspondence
Joshua S. Gans, Rotman School of Management, University of Toronto, 105 St. George Street, Toronto, Ontario M5S 2E8, Canada.
Email: joshua.gans@gmail.com

Abstract

We examine competition among ridesharing platforms, where firms compete on both price and the wait time induced with idled drivers. We show that when consumers are the only agents who multihome, idleness is lower in duopoly than when consumers face a monopoly ridesharing platform. When drivers and consumers multihome, idleness further falls to zero as it involves costs for each platform that are appropriated, in part, by their rival. Interestingly, socially superior outcomes may involve monopoly or competition under various multihoming regimes, depending on the density of the city, and the relative costs of idleness versus consumer disutility of waiting.

KEYWORDS
Hotelling, idleness, platform, ridesharing

JEL CLASSIFICATION
L13, L51

1 | INTRODUCTION

Since Uber's introduction in 2009, ridesharing platforms, such as Uber, Didi, Grab, and Lyft, have radically transformed the taxi and limo industry. These services, which allow consumers to order a car to their location via a smartphone application, now control roughly one-third of the international taxi market. A ridesharing firm acts as a platform matching drivers to riders and setting the pricing terms between them. Like other platforms, the incentives of each group to join a platform are molded by those pricing terms as well as overall liquidity. Specifically, riders value reduced wait times, which comes from more driver availability on a platform. Likewise, the cost of attracting drivers is lower, the greater the density and availability of riders. Rideshare platforms can influence such wait times and, hence, the nature of cross-group network effects. Here we propose a tractable model of competition in ridesharing designed to understand how this shapes platform choices and show that welfare generated in this industry has rather subtle properties.

Subtleties in ridesharing welfare arise for three reasons. First, consumer demand depends both on price and wait time. Second, wait time depends on a two-sided match between platforms and consumers. Third, whether rideshare platforms compete using price or wait time depends critically on whether consumers, drivers, or both multihome. Wait times will be reduced either because more consumers are bound to a single platform, firms want to attract consumers from a rival platform, or firms want to make heterogeneous consumers more homogeneous in their demand and, hence, extract more consumer surplus with a fixed price. A social planner will pay to reduce wait time only when it increases consumer surplus, not when it simply permits business stealing or homogenizes demand. We will show that these different motives for competing on wait time versus price imply that welfare may be maximized in any of four different market structures: monopoly, consumer-only multihoming duopoly, driver-only multihoming duopoly, or full-multihoming duopoly.

In conducting this examination, we make several simplifying assumptions. First, we assume away any interaction between competition and driver welfare by fixing driver wages per ride and fixing the cost of employing idled drivers. This is justified in part by the empirical findings of Cook, Diamond, Hall, List, and Oyer (2018) and Hall, Horton, and Knoepfle (2018), who note that driver supply is so elastic that earnings per hour of work at Uber are constant in the effective payment per ride drivers are offered.[1] That is, there is some empirical reason to believe that driver earnings per hour are roughly constant under any market structure. We further assume that city density and consumer demand are thick enough that all potential consumers are served, perhaps at a high price and with a long wait time, under any of multihoming regimes we examine. We, therefore, abstract away from issues examined by Nikzad (2018) on how the size of the labor pool interacts with ridesharing matching technology and competition.

Second, we do not consider dynamic pricing considerations that are the focus of Levin and Skrzypacz (2016) and Castillo, Knoepfle, and Weyl (2017). Rather, we consider a static reduced form of the interactions between wait time and the costs of recruiting drivers. Finally, in considering both consumer and driver multihoming, we compare these as if they have exogenously arisen and, for instance, do not consider the mixed multihoming options that have been studied in other platform markets (see Anderson, Foros, & Kind, 2018 and Athey, Calvano, & Gans, 2018). In so doing, we understand that some of the multihoming scenarios we investigate—especially on the driver side—are not necessarily possible with current apps and information provision by ridesharing companies.[2]

The paper proceeds as follows. In the next section, we provide a model with endogenous wait time. The most tractable way to model these features in the context of a well-understood duopoly model is by modifying the Hotelling line such that the length of the line is a function of city density and idled drivers permit firms to shrink the effective length of their "side" of the line. We will then compare surplus under monopoly versus duopoly with each multihoming configuration. The final section relates our findings to current policy debates and offers suggestions as to future research.

2 | MODEL

We begin by introducing a stylized model of ridesharing platform competition in price and wait time. With this basic model in hand, we will introduce, in the following section, definitions of consumer and driver multihoming in terms of the basic model's parameters.

Consider the adapted Hotelling line in Figure 1. Two ridesharing firms $i \in \{1, 2\}$ are exogenously located at either end of the line $[0, \ell]$.[3] Rather than choose location and then price, as in a standard Hotelling model, these firms first simultaneously choose "idleness" parameters δ_i and then simultaneously choose prices p_i. After idleness and prices are chosen, a consumer location, drawn uniformly on $[0, \ell]$, is realized and the consumer with unit demand buys a ride from at most one service. We assume that firms cannot price discriminate on the basis of consumer location nor can they charge conditional on wait times.

Idleness δ_i decreases a consumer's "wait time"—the ridesharing analog of travel time in a traditional Hotelling model—in the following manner. For Firm 1, a consumer located at x would normally need to wait for a period x for the driver at 0 to reach them. When Firm 1 idles some drivers δ_1, we assume that the wait time is 0 if the consumer is in $[0, \delta_1]$, and is $x - \delta_1$ otherwise. Likewise, a consumer wishing to ride with Firm 2 has zero wait time if they happen to be located in $[\ell - \delta_2, \ell]$, and wait time $\ell - \delta_2 - x$ otherwise. Since expected profit calculations operate under the assumption that a consumer is located uniformly on $[0, \ell]$, this model of idleness represents a particularly tractable way of modeling the fact that idling drivers drops the expected wait time of consumers.

The cost of idleness is $c(\delta_i)$, where $c(0) = 0$, $c' > 0$, $c' \to 0$ as $\delta \to 0$, $c'' > 0$ and c is continuously differentiable. This cost is convex even when additional drivers can be hired at a constant wage because, intuitively, to reduce the wait time to zero ($\delta_i = \ell$) for all passengers, an infinite number of idled drivers would need to be engaged. That is, δ is not the absolute *number* of idle workers, but rather the extent to which idled workers reduce wait times a given amount.

In addition to paying for idleness, firms also pay an exogenously determined wage w to drivers per ride; we discuss below how to transform this modeling assumption into the more standard scenario where drivers are paid nothing while idle and only paid when a customer is engaged. Firm profit is, therefore,

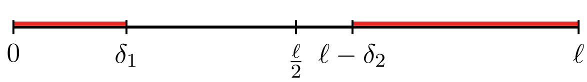

FIGURE 1 A Hotelling line with "idleness" δ_1 and δ_2 [Color figure can be viewed at wileyonlinelibrary.com]

$$\Pi_i = (p_i - w)Q_i - c(\delta_i),$$

where quantity Q_i is the probability that Firm i makes a sale.

Consumer demand is determined as follows. A consumer at position x has unit demand, getting utility from the service on the right equal to $u - p_2 - tD_2(x)$, where t parameterizes the disutility of waiting and, as described above, wait time $D_2(x) = 0$ if $x \geq \ell - \delta_2$ and $\ell - \delta_2 - x$ otherwise. Analogously, utility from the service on the left is $u - p_1 - tD_1(x)$ where wait time $D_1(x) = 0$ if $x \leq \delta_1$ and $x - \delta_1$ otherwise. This is simply the Hotelling line with linear transport costs, along with the potential to compete on wait time in addition to price. Note that for (p, δ), as usual, there is a cutoff agent who is indifferent between 1 and 2. Note also that since expected consumer wait times, holding δ constant, are increasing in ℓ, the length of the line ℓ can be interpreted as an exogenous measure of density of demand in a particular region.

We assume that u is high enough that, under all multihoming scenarios below, all consumers buy. We further assume that wait time disutility t is low enough to avoid the equilibrium existence problem in d'Aspremont, Gabszewicz, and Thisse (1979).[4] Furthermore, we restrict our attention to pure strategy equilibria.

The nature of driver payments in our model is highly stylized and meant to clearly draw the distinction between the supply a ridesharing firm needs to provide minimum acceptable wait times to riders and the additional cost needed to reduce wait times with increased supply. In practice, ridesharing firms tend to pay drivers per ride completed, and not to pay anything for idleness. Paying drivers a wage v per ride and engaging them on a ride at any given time with probability ρ gives the drivers a wage per unit of time of $v_2 = v\rho$. In that setting, increasing idleness means decreasing ρ, which is done by directly increasing the price v per ride, and letting elastic driver supply adjust. Under the assumption that drivers cannot take actions to increase demand (by, e.g., choosing better routes or better parts of the city to wait for riders), this is identical to the contract where engaged and idled drivers are both paid $w = v_2$ whether they are engaged or not. Our model can, therefore, be reinterpreted without loss of generality, but with some loss of clarity, to one where rideshare services choose wage per ride and, hence, induce an equilibrium probability a given driver is engaged. However, by modeling idleness directly with the generic convex cost function $c(\delta)$, we avoid having to specify analytically the precise link between additional drivers, wait time, and the probability a given driver is engaged. Furthermore, by separating w and $c(\delta)$, we can directly examine the extent of idleness under various market structures, rather than try to back out the implied equilibrium idleness a wage per ride v generates.

2.1 | Modeling multihoming

With the basic model in mind, we turn to alternative multihoming scenarios. By restricting parameters in the above-mentioned model, we can generate competition under monopoly and under duopoly with consumer multihoming, driver multihoming, both forms of multihoming, or neither. In particular, if consumers multihome, then there is strategic competition by firms to attract these consumers by lowering wait time or decreasing price. If consumers do not multihome, they are assumed to be exogenously locked into a particular app with equal probability, and as there is no strategic interaction, firms will lower wait time only to increase the price that can be charged to "their" consumers.[5] If drivers multihome, we will assume that drivers pick up the closest customer demanding a ride on either app and, hence, that idleness paid for by either firm "spills over" to the other firm. If drivers do not multihome, then idled drivers

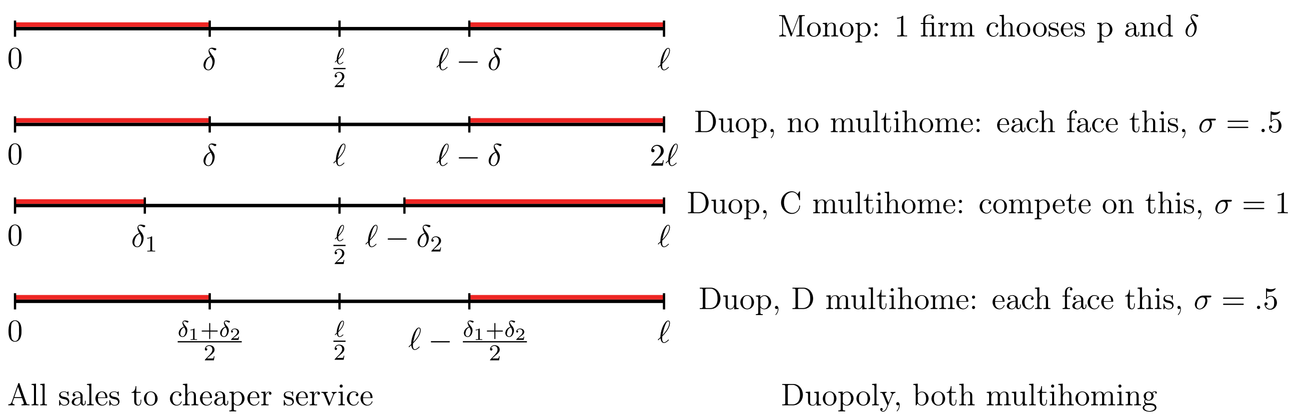

FIGURE 2 Hotelling line under five multihoming assumptions, where σ is measure of consumers [Color figure can be viewed at wileyonlinelibrary.com]

paid for by a given firm only reduce wait time for that firm's customers. Figure 2 shows the parameter assumptions in each scenario graphically.

Pure monopoly: In a monopoly setting, there is a single firm located at both ends of the line, $\delta_1 = \delta_2 = \delta$ and $p_1 = p_2 = p$. Firms maximize $(p_i - w)Q_i(p_i, \delta_i) - c(\delta_i)$, where $Q_i \leq 1$ represents the probability of making a sale given prices and induced wait times.[6]

Duopoly with no multihoming: In a duopoly with no multihoming, we analyze outcomes identically to the monopoly case, except that each firm faces a measure 0.5 of potential customers and the length of the line is 2ℓ. This assumption models the situation where consumers and drivers are effectively allocated exogenously to rideshare firms and where neither price nor wait time differences induce substitution. That is, there is no strategic interaction between firms but the total number *and* density of potential customers are both halved compared to monopoly.

Duopoly with consumer multihoming: When consumers multihome while drivers do not, δ_i and p_i are independently chosen by each firm, line length is ℓ, and consumers buy from the platform that provides the highest utility, which is a function of both wait time and price. That is, duopoly with customer multihoming is precisely the game described in the previous subsection, with no restrictions.

Duopoly with driver multihoming: When drivers can multihome and supply both firms, but consumers do not multihome, we again analyze outcomes identically to the monopoly case except that idled drivers spill over ($\delta_{\text{DM}} = (\delta_1 + \delta_2)/2$) and the measure of potential customers on the line is 0.5 instead of 1.[7] That is, if Firm 1 adds an idle driver, and that driver happens to be closer to a potential customer endowed with Firm 2's app than any of Firm 2's idled drivers, the multihoming driver can simply switch apps and picks up the customer. Even though consumers do not multihome, the fact that drivers multihome means that consumers, nonetheless, are picked up by drivers from the "closer" service, and, hence, the length of the line is ℓ and not 2ℓ as in the case of duopoly with no multihoming.

Both sides multihome: When both drivers and consumers multihome, then all idled drivers spill over ($\delta_{\text{DM}} = (\delta_1 + \delta_2)/2$), all consumers have identical wait time from all drivers no matter what platform is offered, all consumers have access to both apps, and hence *all* rides go to the firm which sets the lowest price.

We will assume that these market structures are exogenous and will examine the welfare, consumer surplus, and profit differences between each. This exogeneity is maintained because our core interest is in understanding how different market structures—whether imposed by law or otherwise—affect outcomes, rather than investigating the emergence of those market structures per se. Furthermore, to the extent profit varies, comparing profit levels gives insight as to what might drive the emergence of a particular market structure.

2.2 | Equilibrium outcomes

To begin, we consider outcomes where there is no multihoming (NM) on either side of the market. In doing this, we can prove the following two propositions.

Proposition 1. *Under monopoly, prices are* $p_{\text{MON}} = u + \delta_{\text{MON}} t - \frac{\ell t}{2}$, *where the equilibrium idleness satisfies* $t = c'(\delta_{\text{MON}})$. *If* $c(\delta) = \delta^2$, *under monopoly, the price is* $p_{\text{MON}} = u + t\frac{t-\ell}{2}$ *and idleness* $\delta_{\text{MON}} = \frac{t}{2}$.

Proof. The monopolist maximizes $2[(p_i - w)\frac{Q_i}{2} - c(\delta_i)]$, where the term inside the brackets represents profits on either $[0, \frac{\ell}{2}]$ or $[\frac{\ell}{2}, \ell]$. In the second stage, the monopolist chooses p_i. Without loss of generality, the cutoff consumer x on the left side of the interval $[0, \ell]$ buys if and only if $u - p_i - t(x - \delta_i) \geq 0$. Therefore, all consumers on $[0, \frac{\ell}{2}]$ buy if $\frac{u - p_i}{t} + \delta_i \geq \frac{\ell}{2}$. As noted, assume u high enough that monopolists sell to all consumers. In this case, $\frac{u - p_i}{t} + \delta_i \geq \frac{\ell}{2}$ holds with equality, and hence $p_i = u + \delta_i t - \frac{\ell t}{2}$.

In the first stage, the monopolist chooses δ_i to maximize $2[(p_i - w)\frac{Q_i}{2} - c(\delta_i)]$. If $x = \frac{\ell}{2}$ and, therefore, $Q_i = 1$, the first-order condition requires that $t = c'(\delta)$. □

Proposition 2. *Under duopoly with no multihoming, prices are* $p_{\text{NM}} = u + \delta_{\text{NM}} t - \ell t$, *and the equilibrium idleness satisfies* $\frac{t}{4} = c'(\delta_{\text{NM}})$. *If* $c(\delta) = \delta^2$, *under duopoly with no multihoming,* $p_{\text{NM}} = u + t(\frac{t}{8} - \ell)$ *and* $\delta_{\text{NM}} = \frac{t}{8}$.

Proof. In the duopoly case, with no multihoming, each rideshare platform is endowed with half of all potential consumers, and there is no strategic interaction across platforms. Following the above-mentioned proof, but noting that selling to all consumers for a given duopolist means $Q_i = .5$ and inducing demand from consumers ℓ away from the edge of the Hotelling line, we have that price p_i is $u + \delta_i t - \ell t$. Via the first-order condition $\frac{t}{4} = c'(\delta_i)$, the extent of idleness and, therefore, the equilibrium price falls. □

Intuitively, by increasing δ, the demand of consumers at the middle and at the edge of the Hotelling line become more similar. With more homogenous demand, the fraction of surplus that can be extracted with a fixed price increases. The benefit of more homogeneous demand for the monopolist is weighed against the marginal cost of idled drivers. Under duopoly, since the measure of potential customers is smaller, idleness is lower and, hence, wait time higher for all consumers, while total quantity demanded remains 1. Industry profit is, of course, lower under this duopoly than under monopoly.

Now consider what happens when there is consumer multihoming (CM).

Proposition 3. *Under duopoly with consumer multihoming (only), prices* $p_i = t\ell + w + \frac{(\delta_i - \delta_{-i})t}{3}$ *and idleness* δ_{CM} *solves* $\frac{t}{3} = c'(\delta_i)$. *If* $c(\delta) = \delta^2$, *price is* $p_{CM} = t\ell + w$ *while idleness is* $\delta_{\text{CM}} = \frac{t}{6}$.

Proof. Consumers buy from i only if $u - p_i - t(\ell - \delta_i - x) \geq \max(0, u - p_j - t(x - \delta_j))$. Again, assume u is high enough that in equilibrium all consumers buy from at least one service. In that case, the cutoff consumer $x^* = \frac{\ell}{2} + \frac{\delta_j - \delta_i}{2} + \frac{p_j - p_i}{2t}$. Quantities are, therefore, $Q_1 = \frac{\ell - x^*}{\ell} = \frac{\ell}{2} + \frac{\delta_1 - \delta_2}{2\ell} + \frac{p_2 - p_1}{2t\ell}$ and $Q_2 = \frac{\ell - x^*}{\ell} = \frac{\ell}{2} + \frac{\delta_1 - \delta_2}{2\ell} + \frac{p_2 - p_1}{2t\ell}$.

Taking the first-order condition of profit $\Pi_i = (p_i - w)Q_i - c(\delta_i)$ with respect to p_1 holding p_2 constant, and solving for equilibrium prices, we have that $p_1^* = t\ell + w + \frac{(\delta_1 - \delta_2)t}{3}$ and $p_2^* = t\ell + w + \frac{(\delta_2 - \delta_1)t}{3}$. Therefore, $Q_1^*(\delta_1, \delta_2) = \frac{1}{2} + \frac{\delta_1 - \delta_2}{6\ell}$ and likewise for $Q_2^*(\delta_2, \delta_1)$.

Substituting into the profit equation, we have that $\Pi_1 = (t\ell + \frac{(\delta_1 - \delta_2)t}{3})(\frac{1}{2} + \frac{\delta_1 - \delta_2}{6\ell}) - c(\delta_1) = 2t\ell Q_1^2 - c(\delta_1)$. To solve for first-stage choice of δ, we take the first-order condition of Π_1 with respect to δ_1 holding δ_2 constant: $\frac{1}{3}(1 + 2t\frac{\delta_1 - \delta_2}{6\ell}) = c'(\delta_1)$. In the symmetric equilibrium, $\frac{t}{3} = c'(\delta_1) = c'(\delta_2)$. Recall from d'Aspremont et al. (1979) that there is no equilibrium price solution in the second stage until the firm location is in the outer quarter of the Hotelling line, so we require that t,c are such that $\frac{t}{3} = c'(\delta_i)$ is solved with $\delta < \frac{\ell}{4}$. Finally, note that since equilibrium $\delta_1^* = \delta_2^*$, equilibrium prices are simply $t\ell + w$. □

Note that vis-a-vis monopoly, idleness δ is *lower*. While higher idleness allows the platform to capture more consumer surplus by making customers more homogeneous, it also increases price competition in the second stage for the same reason: homogenized demand is more valuable for a monopolist, who is merely concerned with the ability to extract surplus under a uniform price constraint, than for competing duopolists, who worry about incentivizing rivals to steal customers by undercutting on price.

When there is driver multihoming (with driver-only, DM, or full, FM), these outcomes change dramatically, as the following two propositions show.

Proposition 4. *Under duopoly with driver multihoming (only), prices* $p_{\text{DM}} = u + \frac{\delta_i + \delta_{-i}}{2}t - \frac{\ell t}{2}$ *and idleness* δ_{DM} *solves* $\frac{t}{2} = c'(\delta_i)$. *If* $c(\delta) = \delta^2$, *price is* $p_{\text{DM}} = u + t(\frac{\frac{t}{2} - \ell}{2})$ *while idleness provided by each firm* $\delta_{\text{DM}} = \frac{t}{4}$ *and hence equilibrium effective idleness* $\delta = \frac{\delta_1 + \delta_2}{2}$ *also equals* $\frac{t}{4}$.

Proof. With driver-only multihoming, idled drivers paid by one platform can pick up consumers on any platform and, hence, idleness spills over such that demand-effective idleness $\delta = (\delta_1 + \delta_2)/2$. Furthermore, selling to all customers on a given platform generates $Q_i = .5$. Following the proof in Proposition 2, we have that price $p_i = u + \frac{\delta_i + \delta_{-i}}{2}t - \frac{\ell t}{2}$, and hence the first-order condition for idleness implicitly solves $\frac{t}{2} = c'(\delta_i)$ □

When only drivers multihome, more idleness is generated than when only consumers multihome. On the one hand, some of the benefits of idleness spill over to the other firm when idled drivers pick up a customer on a rival's app, and hence this positive externality is undersupplied. On the other hand, since customers do not directly multihome, there is no strategic interaction in pricing between the platforms. This encourages the use of idleness to homogenize the demand curve without worrying that the more homogenous demand will prove tempting to rivals looking to steal business.

Proposition 5. *When both drivers and consumers multihome, $p = w$ and $\delta_1 = \delta_2 = 0$.*

Proof. When both consumers and drivers multihome, the distance between a given consumer and the nearest car on either platform is identical regardless of δ. Therefore, all consumers buy from the lowest price platform, $\delta_1 = \delta_2 = 0$, and Bertrand competition pushes prices to w. □

What this demonstrates is that when both sides of the market fully multihome, in equilibrium, ridesharing platforms choose to have no idleness. Consequently, consumers must wait longer to obtain a ride. In other words, the equilibrium outcome is the same as the standard Hotelling model with maximal differentiation. The intuition for this is as follows: Because drivers multihome, they will opt to accept rides from either platform. Thus, if one platform is "paying" them for idleness, that payment has a positive spillover on their competitor platform. Each platform, therefore, because it only appropriates part of the return to idleness, chooses to reduce their chosen level. This sets in motion a form of unraveling, driving idleness to zero. This result is, of course, extreme and is a consequence of the fact that *all* consumers and *all* drivers multihome. In real-world settings, this extent of multihoming is perhaps unlikely, yet for the purposes of theoretical analysis, we find it cleaner to show precisely how stark the competitive effects of full multihoming are likely to be. Note also that while strong *price* competition is unambiguously positive, strong *idleness* competition forces both firms to omit spending resources reducing wait time. That latter effect may be socially harmful, as we note in the following subsection.

2.3 | Surplus and profit comparisons

Comparing these outcomes, we have the following:

$$\begin{gathered}\delta_{\mathrm{MON}} > \delta_{\mathrm{DM}} > \delta_{\mathrm{CM}} > \delta_{\mathrm{NM}} > \delta_{\mathrm{FM}} = 0\\ p_{\mathrm{MON}} > p_{\mathrm{DM}} > p_{\mathrm{NM}} > p_{\mathrm{CM}} > p_{\mathrm{FM}}\\ \Pi_{\mathrm{MON}} > \Pi_{\mathrm{DM}}, \Pi_{\mathrm{CM}} > \Pi_{\mathrm{FM}}\end{gathered}$$

Price is highest under monopoly and lowest when both consumers and drivers multihome. Profit is, by definition, maximized under monopoly, and profit is competed to zero when both consumers and drivers multihome.

Turning to the impact on overall social welfare, note that, since by assumption u is high enough that in all competitive structures, all consumers are served, they are also all served in the social optimum. Any social planner optimally does this by choosing idleness, which minimizes the sum of idleness cost $2c(\delta)$ and consumer transport cost $2t(\frac{\frac{\ell}{2}-\delta}{2}\frac{\frac{\ell}{2}-\delta}{\frac{\ell}{2}})$. The first term is the average transport cost paid by customers on $[\delta, \ell - \delta]$, and the second term is the fraction of customers who lie in that interval. Recall that customers on $[0, \delta]$ and $[\ell - \delta, \ell]$ pay no transport cost. Taking the first-order condition with respect to δ, we have that equilibrium δ solves the implicit equation $2t = c'(\delta) + \frac{4t\delta}{\ell}$.

The planner solution often involves less idleness than the monopolist but more than the competing duopolists under *any* multihoming structure. Unlike the monopolist, the planner is not willing to pay for idleness that merely homogenizes demand, making it easier to extract consumer surplus with a uniform price. The planner is, however, willing to pay for idleness without regard to how it affects the strength of "price" competition. For example, if $c(\delta) = \delta^2$, the planner chooses $\delta = \frac{\ell t}{\ell + 2t}$, the monopolist $\delta = \frac{t}{2}$, the driver-multihoming duopolists $\delta_1 = \delta_2 = \frac{t}{4}$, the consumer-multihoming duopolists $\delta_1 = \delta_2 = \frac{t}{6}$, and full-multihoming duopolists $\delta_1 = \delta_2 = 0$. Note that the social planner's optimal idleness δ can take arbitrarily small non-negative values. Hence, any of those four market structures can be socially optimal for a given set of parameters.

If the disutility of waiting t is small relative to wait times parameterized by ℓ, *monopoly* is socially optimal compared with any of the duopolistic market structures. Intuitively, when ℓ is larger, the fraction of potential riders who are currently waiting a nonzero amount of time is higher for any given δ. Therefore, the reduction in wait time from a small increase in δ is higher, and hence the planner chooses more idleness. Neither the monopolist nor duopolists care about consumer disutility from waiting. Yet, the incentive of the monopolist to homogenize demands using wait times and, hence, to extract more consumer surplus with a fixed price ride is stronger than the incentive of any duopolist to either steal business by providing lower wait times (in the case of consumer multihoming) or homogenize a smaller measure of demand (in the case of consumer single-homing). On the other hand, when ℓ is small relative to the disutility of waiting, fewer consumers are waiting a nonzero amount of time for any given δ; hence the planner does not want to use resources reducing wait time with many idled drivers. In this case, the monopolist will be overproviding idled drivers out of her attempt to homogenize demand, while the duopolists will be providing less idleness in line with the social optimum.

3 | CONCLUSION AND FUTURE RESEARCH

Multihoming in ridesharing is potentially a significant policy issue. In 2016, a California court found that Uber drivers were employees and hence, were entitled to various benefits under labor law. If this were to become universal, then drivers would be tied to platforms and multihoming by them would not be possible. Our analysis here demonstrates that a labor policy of this type also has nontrivial consumer market implications, and, in particular, it is possible that restricting driver multihoming can *reduce* total surplus, by affecting both equilibrium price and wait time.[8]

Given the importance of wait time in determining the nature and, indeed, social desirability of ridesharing competition (recall that monopoly can be socially superior to competition here), our results here suggest that moving beyond a simple Hotelling model would be a useful direction for further analysis. Our own forays into this suggested substantial technical difficulties with providing analytically tractable extensions which do not run in the d'Aspremont et al. (1979) equilibrium existence problem. However, perhaps in a more structural framework, these issues could be examined more fruitfully. This may also allow matching with empirical analyses. For instance, in a structural exercise, Frechette, Lizzeri, and Salz (2016) show that the reduction in wait time from more efficient matches when taxis are replaced by rideshare services benefits both consumers and drivers. We also suspect that different information structures that give both consumers and drivers different knowledge about their matches (e.g., whether a particular driver is clearly the closest to a given consumer) may also lead to a richer set of competitive outcomes. Extending analyses of this type to account for multihoming choices is fundamental to understanding how platforms will trade-off price and wait-time competition, and hence whether policymakers ought to permit, or facilitate, multihoming on the consumer or driver margins.

ENDNOTES

1 In particular, preliminary follow-up analysis by Cook et al. suggests that adding tipping to Uber did not change wages at all because of the supply response. See the discussion at http://freakonomics.com/podcast/what-can-uber-teach-us-about-the-gender-pay-gap/

2 Most notably, while consumers can compare alternative prices quite readily, they may not be able to see wait times—these may come from experience. For drivers, it may be technically difficult to be logged on to two platforms at the same time and, indeed, may be contractually prohibited. That said, apps such as the Y Combinator-backed Mystro are able to automate ride-sharing among multiple platforms at present.

3 One interpretation of these locations is that if two ridesharing services evenly spaced their drivers throughout a city and chose prices so that all consumers desiring a ride, in fact, demanded a ride and had precisely enough cars that demand exactly equaled supply, then the maximal wait time of any consumer for the nearest car would be $\frac{\ell}{2}$.

4 In particular, we assume that u is high enough and t is low enough, given the cost function $c(.)$ and that in the first stage both firms locate on the outer quartile of the Hotelling line. In the duopoly solutions derived below, the extent of idleness grows in t, and hence the relative induced wait times between firms faced by a given consumer become more similar as t rises. In the second-stage pricing derivation in d'Aspremont et al. (1979), equilibrium nonexistence is caused by the precisely this similarity in induced wait times, and the condition for second-stage price equilibrium existence is that firms locate far enough apart. In our context, of course, the firms are always "located" at the ends of the line, but the difference in wait times from the consumer point of view depends on how much idleness firms choose, which is a function of t.

5 What of the case of strategic single-homers, who choose a platform given the price/wait bundles offered by various services? While our main reason for omitting endogeneity of market structure is that we want to examine the welfare consequences of structures that arise for whatever reason, we also note that for an individual strategic consumer, multihoming weakly dominates single-homing if one is free to choose either. The same is true for drivers.

6 Recall that firm locations being at the end of the line is an assumption exogenous to the model. Intuitively, $\frac{\ell}{2}$ is the maximal distance a car needs to travel to pick up a rider when the supply of cars and number of riders demanding rides is exactly equal, and a firm optimally spaces their drivers across a city. For this reason, the usual result that a multiproduct monopolist would locate at 0.25 and 0.75 does not apply: Firms are not choosing their location.

7 A referee notes that this is akin to spillovers, the elimination of which motivates exclusive contracts.

8 Hagiu and Wright (2018) examine the classification of sharing economy workers as independent contracts or employees and argue for an intermediate classification. Examining this intermediate classification would be a fruitful area for research along the lines of the present paper as well.

ORCID

Joshua S. Gans http://orcid.org/0000-0001-6567-5859

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