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Highway franchising and real estate values

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Abstract

It has become increasingly common worldwide to auction the construction and operation of new highways to the bidder that charges the lowest toll. The resulting highway franchises often entail large increases in the value of adjoining land developments. We build a model to assess the welfare implications of allowing large developers to participate in these auctions. Developers bid more aggressively than independent construction companies because lower tolls increase the value of their land holdings. Therefore developer participation unambiguously increases welfare, yet this increase is not necessarily monotonic in the number of developers participating. Welfare also increases when large developers can bid jointly.

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1. Introduction and motivation

Highways leading to new land developments have been traditionally financed with general public funds. In principle, the outlays can be recovered by property taxation, as the benefits wrought by the new highways become capitalized in property values. Yet practical limitations of property taxation have increasingly led to private financing of roads in many countries.[1]

The private solution that has become increasingly popular is to auction so-called build-operate-and-transfer (BOT) contracts to the firm bidding the lowest toll. Under such a contract, a private firm builds and finances the road and then collects tolls for a long period (usually between 10 and 30 years).[2] When the franchise ends the road is transferred to the state.

In this paper we build a model to assess how the participation of large developers in the auction of the road that will increase the value of their land holdings impacts on social welfare. A recent example motivating the issues we consider is the Radial Nororiente project which joins Santiago, the capital of Chile, with the adjacent Chicureo Valley, which is expected to expand in coming years. In 1999 the Chilean government decided to franchise a US$170MM road.[3,4]

The idea of using open auctions instead of regulation—competition *for* the field as a substitute for competition *in* the field—goes back to Chadwick [1] and was popularized by Demsetz [2]. The claim is that competition in the auction will eliminate market power and yield a toll equal to average cost.[5] When applied in the setting considered in this paper, the Chadwick–Demsetz analysis assumes that franchise holders are firms that specialize in building roads. When land developers can participate in the auction, several issues in competition policy arise, as illustrated by the Chicureo project.[6] Some critics claimed

1 "The idea of taxing increases in the price of land [...] has a history stretching back to the mists of fiscal time. It is advocated passionately by some academic economists but politicians have been unenthusiastic, not least because of problems of implementation" (*The Economist*, August 23, 2002). Two "problems of implementation" stand out. First, when the road benefits undeveloped landholdings, there is ample space for opportunistic behavior because taxes normally can only be increased after the road is built and the developed land is sold. For example, developers have incentives to oversell the revenue potential of the highway to get the government to build, while after the road is built, households have incentives to vote down tax increases. Second, even if we ignore opportunism, the government may have a hard time determining whether a road will pay for itself before construction, since it is difficult to obtain precise estimates of the future commercial value of the land.

2 See, for example, Gómez-Ibañez and Meyer [9], and the collection of papers in Irwin et al. [12].

3 This project was in response to a proposal of a private group which owns substantial landholdings in Chicureo. According to the Chilean Concessions Law of 1994, anybody can propose a highway project and, if approved by the Ministry of Public Works, the project is franchised in a competitive auction.

4 It is common in Asia to allow property developers to build and charge for highways, see Guasch [10]. Also, the government of Uttar Pradesh in India recently included a band of about 500 meters alongside a 160 km proposed expressway from New Delhi to Aggra as an integral part of the project being auctioned. The corridor can be used for commercial, amusement, industrial, as well as township development (see the corresponding ad in *The Economist*, June 2, 2001).

5 But see Williamson [22,23] for a critique.

6 Participation of the land developers in the auction does not require them to build the road, as they can hire a construction company.

that developers should be excluded from the auction, because their land interests gave them an “undue” competitive advantage. Others argued that developers’ common interest would encourage them to collude in the auction. Finally, it was suggested that developers would price discriminate, charging low tolls to buyers of their land and high tolls to other users.

The basic economics of developer participation is best appreciated in the case where a developer is allowed to build the highway and set its toll at will (the *laissez-faire* case). Since tolls that are higher than marginal cost reduce road usage below the socially optimal level, they create a distortion which, in a competitive land market, reduces the value of land one-by-one. This fact creates the basic tradeoff facing a developer that owns the road and is free to choose the toll: on the one hand, she would like to charge a toll equal to marginal cost to those who buy her land; on the other hand, she would like to charge the monopoly toll to the remaining users. Consequently, her profit-maximizing toll will lie between the monopoly toll (if she owns no land) and a zero toll (if she owns all land and there are no through drivers).[7] Therefore, a developer who owns sufficient land would set tolls below average cost, as the losses she makes in the highway business are more than made up by the higher land prices. This is welfare-increasing, because tolls are closer to our assumption of zero marginal cost in the absence of operation and maintenance costs.

Consider now an auction. Competition forces independent construction companies to bid a toll equal to average cost. If only one large developer participates in the auction, he will bid more aggressively, choosing his laissez faire toll. As a result, developer participation yields tolls closer to zero and higher overall welfare.

When two large developers participate in the auction, it often happens that each developer is better off when the other one builds the road and charges his laissez-faire toll. We show formally that the auction outcome has two Nash equilibria when land holdings by both developers are not too dissimilar. The larger developer builds the road in one equilibrium, the smaller developer in the other one. In both cases, the franchise holder charges his laissez-faire toll. It follows that having two large developers participate in the auction may lead to higher tolls, and lower welfare, than when only one (the larger) developer participates. Developer participation unambiguously increases welfare, yet welfare does not necessarily increase monotonically with the number of developers.

Another interesting result obtains once we allow developers to bid jointly at no cost. Tolls are then reduced and welfare increases, because landholders maximize joint profits by asking for the same toll as a single developer who owns their combined land shares.

Our paper is related to the literature on franchise bidding pioneered by Chadwick [1] and Demsetz [2] (see also Stigler [21], Posner [17], Riordan and Sappington [18], Chapter 9 in Spulber [20], Chapters 7 and 8 in Laffont and Tirole [15], Harstad and Crew [11] and Engel et al. [4,6]). We add to this literature by exploring the consequences of including bidders whose downstream profits increase with lower tolls.

Somewhat less related is the limited literature on auctions of objects with externalities. For example, Jehiel et al. [13,14] solve a mechanism design problem in which the auctioned

[7] A zero toll maximizes the value of the land when there is no congestion and no variable costs, an assumption that simplifies the algebra. In Section 5 we show that results do not change when we allow for congestion.

object causes an identity-dependent externality on bidders that loose in the auction. We differ from them in that we model the origin of the externality—the winning toll affects the welfare of all landowners—which allows us to assess the welfare impact of alternative policies.

The rest of the paper is organized as follows. Section 2 describes the model. Section 3 analyzes the consequences of letting one landowner build the road and giving him a free hand to choose tolls ('laissez faire'). Section 4 examines the bidding behavior and outcome of the auction. Section 5 explores some extensions and applications. Section 6 concludes. Two appendices with formal proofs follow.

2. The model

We consider a static model with three types of agents: developers, construction companies and households. There is a land development area composed by many identical plots and a much larger number (a continuum) of households with identical preferences and income. The development is marginal within the relevant real-estate market and hence does not affect real estate prices elsewhere.[8] To simplify the notation we normalize the total area of land to one and assume that each household demands only one plot. The highway increases a household's willingness to pay for a plot, call it $V(p)$, depending on the number of trips each household makes, viz,

$$V(p) = \int_0^{D(p)} D^{-1}(s)\,\mathrm{d}s,$$

where $D(p)$ is the demand for trips when the toll is p, with $D' < 0$. Hence, a lower toll increases the number of trips made by the household, thereby raising members' welfare. For simplicity, we assume there is no congestion and ignore through drivers. Section 5 examines the case of through drivers, congestion and other extensions and shows that these assumptions do not imply a loss of generality.

As can be seen in Fig. 1, the increase in willingness to pay can be divided in two components: toll payments, $pD(p)$, and payment for the plot, which also depends on p and equals:

$$V(p) - pD(p) = \int_0^{D(p)} \left[D^{-1}(s) - p\right] \mathrm{d}s. \tag{1}$$

Note that because the land development is small and the number of households is large, in equilibrium all households who buy a plot will obtain the same utility as in any other location in the relevant real estate market. Hence, competition among households raises the price of each plot until the value of using the highway becomes fully capitalized in the land rent.[9]

[8] In terms of standard urban economic theory (see, for example, Fujita [8]), the development is located at one of a continuum of locations and hence is "small" in terms of the aggregate land market.

[9] More generally, the highway is a neighborhood good (see Chapter 6.5 in Fujita [8]).

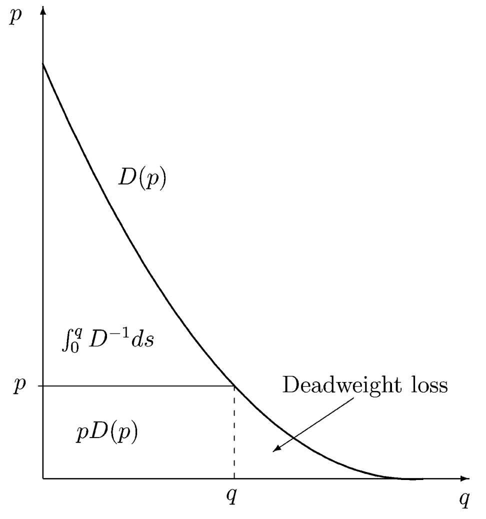

Fig. 1.

We index developers by the fraction of total plots they own. We examine the case of two developers, α and β, with $\alpha \geqslant \beta \geqslant 0$ and $\alpha + \beta \leqslant 1$.

We further assume that developers and a fringe of identical construction companies that do not own land, can build the road at cost I.[10] For simplicity, we ignore maintenance and operation costs. Finally, note that when the toll is p, the increase in welfare due to the road is:

$$W(p) \equiv V(p) - I. \tag{2}$$

We assume $W(0) > 0$, so that it would be efficient to build the road if it could be financed with lump sum transfers.

3. Laissez faire

Recall that laissez faire is the case when a developer α builds the road and chooses toll p without constraints. She maximizes a weighted average of toll revenues and land sales, viz

$$\Pi(p; \alpha, I) \equiv pD(p) + \alpha\big[V(p) - pD(p)\big] - I \tag{3}$$

$$= (1-\alpha)pD(p) + \alpha V(p) - I. \tag{4}$$

The term $(1-\alpha)pD(p)$ in (4) corresponds to the revenues obtained from users who do not buy the developer's land. Assuming a relatively inelastic demand for trips, as we do, this component of profits increases with p, as long as p is below the monopoly toll p_m. The term $\alpha V(p)$ in (4) is the total revenue obtained by the developer, via land sales or tolls

[10] This does not require that developers build the road themselves, since they can subcontract the project to a construction company if they are awarded the franchise.

from her buyers. It is straightforward to see that this component, which equals consumer surplus, is decreasing in p. The situation is summarized in Fig. 1, showing the distribution of consumer surplus between toll income and payment for land plots. The first component is maximized at the monopoly toll, the second component at $p = 0$. Figure 1 also depicts the deadweight loss from setting tolls above marginal cost.

We assume that the developer's maximization problem has a solution for all $\alpha \in [0, 1]$. Without additional assumptions it can be shown that the optimal toll correspondence, $\arg\max_p \Pi(p; \alpha)$, is decreasing in α, for $\alpha \in [0, 1]$.[11]

In what follows we simplify the analysis and assume that for each $\alpha \in [0, 1]$ the solution to the developer's maximization problem is unique (denoted by $p^*(\alpha)$) and satisfies the first-order condition:

$$p^* D'(p^*) + (1 - \alpha) D(p^*) = 0, \tag{5}$$

which leads to

$$\epsilon\big[p^*(\alpha)\big] = -(1 - \alpha), \tag{6}$$

where $\epsilon(p) \equiv pD'(p)/D(p)$ is the elasticity of the demand for trips at price p.[12]

It follows from (6) that, as $\alpha \to 1$, the elasticity tends to zero, i.e. to the case of a zero toll. Conversely, as $\alpha \to 0$, the elasticity tends to one, which corresponds to the case of a monopoly. Thus:

Result 1. When developer $\alpha \in [0, 1]$ owns the road, she sets a toll between 0 and the monopoly price. If she owns no land ($\alpha = 0$), she charges the monopoly toll, p_m. Conversely, if she owns all the land ($\alpha = 1$), she sets $p = 0$. Furthermore, the toll $p^*(\alpha)$ falls as α increases.

Result 1 summarizes the central tradeoff faced by the developer. She must choose between charging high tolls to those who do not buy her land and low tolls to those who do. When $\alpha = 1$, there is no tradeoff: the distortions created by charging tolls are borne by the developer. Therefore, since we assume no congestion, she sets $p = 0$, the marginal cost. Conversely, when $\alpha = 0$, the road operator sets the monopoly toll, because she does not internalize any of the efficiency losses caused by the distortion.

Total welfare equals

$$W\big[p^*(\alpha)\big] = V\big(p^*(\alpha)\big) - I, \tag{7}$$

which is clearly increasing in α. Hence:

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11 Using supermodularity results, many of the propositions that follow can be shown to hold with considerable more generality. See Engel et al. [7] for details.

12 We show in Appendix A that the solutions of (6) satisfy the second-order condition, for all α, if

$$\big[D'(p)\big]^2 > \frac{1}{2} D(p) D''(p)$$

for all p below the monopoly price. This holds, for example, for linear demand curves.

Result 2. Under laissez faire it is efficient to allocate the right to build the road to the developer who owns the largest amount of land. Moreover, since $p^*(1) = 0$, it follows that welfare is maximized when the road is built by a developer who owns all the land.

From a social perspective, tolls are just a distorting transfer. When $\alpha = 1$, the owner of the road fully internalizes the social cost of the price distortion, since she replicates the social optimum, acting like a social planner who can charge lump sum taxes.

The latter result illustrates a further advantage of concentrated landholdings. Consider the case where the road cannot generate enough revenue to finance its cost, even when monopoly tolls are charged (i.e., $p_m D(p_m) < I$). However, profits evaluated at the optimal toll, $\Pi^*_\alpha \equiv \Pi(p^*(\alpha); \alpha)$, are increasing in α.[13] And since, by assumption, $\Pi^*_1 = V(0) - I > 0$, we have that there exist an $\bar{\alpha} > 0$ such that for all $\alpha < \bar{\alpha}$ an α-landowner does not find it attractive to build the road, even if she is allowed to set the toll she desires. Thus, socially desirable roads may not be built when landholding is too dispersed.

To end this section, note the analogy with the standard double marginalization result of monopoly theory (Spengler [19]). As in the standard case, vertical integration into the downstream real estate market reduces the incentive to price monopolistically in the upstream road market and simultaneously increases firm's profits. Hence, it is socially desirable.

4. Highway auctions

This section analyzes competitive auctions for the franchise, where the bidding variable is the toll. Will a competitive auction improve welfare over laissez faire? To answer this question we study the following auction:

4.1. Time line of the game

- We assume that developers α and β and at least two construction firms (with no landholdings) participate in the auction.[14] Each participant bids a toll in $[0, \infty]$. A bid of ∞ is equivalent to not participating in the auction.
- The road is allocated to the lowest bidder, which offers a toll $\underline{p}$. In case of a tie, the winner is chosen by lot.
- The winner builds the road and charges at most $\underline{p}$ for each ride.

We study bidding behavior and then characterize auction outcomes.

[13] Let p^* denote $p^*(\alpha)$ and $q^* \equiv D(p^*)$. The envelope theorem implies that $\mathrm{d}\Pi^*_\alpha/\mathrm{d}\alpha = V(p^*) - p^*q^*$, which is the household's willingness to pay, net of tolls, and therefore strictly positive (see Eq. (1)).

[14] All results extend trivially to the case of more than two developers and more than two construction firms.

4.2. Bidding strategies

The key strategic interaction in the auction is that a developer may prefer to free ride and let someone else build the road. To see this, note that conditional on winning the auction, developer α would like to set $p = p^*(\alpha)$. Nevertheless, α may prefer to let β win. While tolls would be higher than $p^*(\alpha)$, she would save I in construction costs.[15]

To analyze this tradeoff, it is useful to compare profits when building and not building the road. If developer α wins the auction with toll $\underline{p}$, her profits are

$$\Pi^b(\underline{p};\alpha) = \underline{p}D(\underline{p}) + \alpha\big[V(\underline{p}) - \underline{p}D(\underline{p})\big] - I,$$

where superscript 'b' stands for 'build.' This function is plotted in Fig. 2 and from the previous section we know that it peaks at $p^*(\alpha)$. On the other hand, if another bidder wins the auction and sets toll $\underline{p}$, then α earns

$$\Pi^n(\underline{p};\alpha) = \alpha\big[V(\underline{p}) - \underline{p}D(\underline{p})\big], \tag{8}$$

where superscript 'n' stands for 'not build.' This function is also plotted in Fig. 2, and is decreasing and convex in the winning toll: the higher the toll, the lower the value of α's plots.

Clearly $\Pi^n(p;\alpha) \equiv \Pi^b(p;\alpha) - pD(p) + I$, because building the road enables α to obtain $pD(p)$ in toll revenue at the cost of investing I. Thus, if both curves intersect, the smallest toll at which they cross, denoted by $p_c(I)$, satisfies

$$p_cD(p_c) = I. \tag{9}$$

Note that p_c is independent of α. More importantly, it follows from Fig. 2 that developer α would rather have someone else build the road for all tolls below p_c, since in that range $pD(p) < I$. Below we will show that this may lead to an inefficiency.

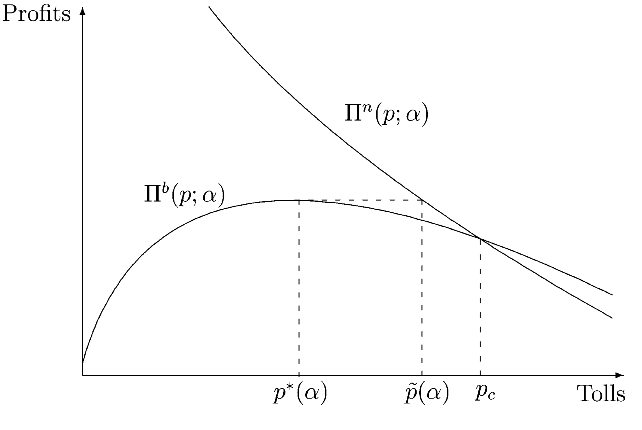

Fig. 2.

[15] Recall that, since $\alpha \geqslant \beta$, it follows from Result 1 that $p^*(\alpha) \leqslant p^*(\beta)$.

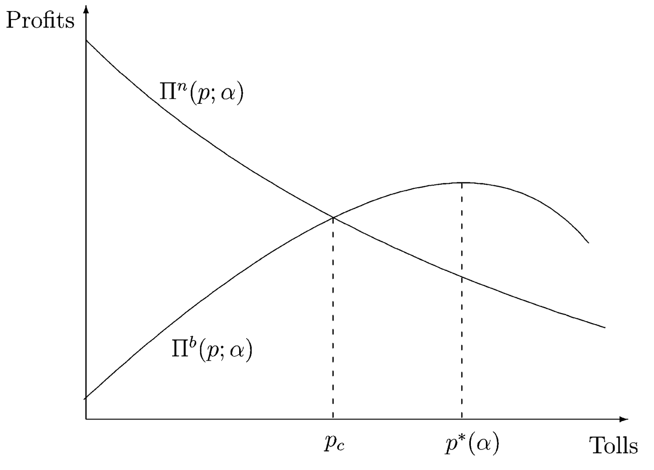

Fig. 3.

We note in passing that when the road, viewed as a separate project, is not profitable, Π^n remains above Π^b for all (finite) tolls. Letting $p_c = \infty$, the results that follow can be extended to this case with little effort, so we do not consider it separately in what follows.

Since many of the results in this section hinge on the dispersion of land ownership, we introduce the definition of a "small developer," where "small" is defined relative to the cost of building the road.

Definition 1. A developer α is small if $p^*(\alpha) \geqslant p_c(I)$.

Figure 3 depicts the case when α is "small." If allowed to build the road and charge whatever toll she wants, a small developer charges more than p_c. By contrast, a large developer, who is depicted in Fig. 2, prefers to charge less than p_c because the loss in property values is larger than the toll revenue at the higher toll value. We are now ready to analyze the auction.

4.3. *Auction outcomes*

It is straightforward to see that the winning bid can never be higher than p_c when at least two independent building companies participate. Hence:

Result 3. $p \leqslant p_c$ in equilibrium.

In Appendix B we show that this game always has a Nash equilibrium in pure strategies. Recall that under laissez faire the toll that results is either $p^*(\alpha)$ or $p^*(\beta)$, depending on which developer builds the road. Thus, if both developers are small, the toll that results under laissez faire is above p_c. Hence, when α (and therefore β) is small, welfare is higher with an auction than with laissez faire—Demsetz auctions are welfare improving when developers are small. Building companies force developers to compete away part of the rents they could obtain under laissez faire by exploiting the road's monopoly power.

It is also apparent from Fig. 3 that no agent will bid less than p_c in equilibrium when α is small: should a developer win with $p < p_c$, she could increase her profits by unilaterally deviating and bidding p_c. By doing so profits increase to $\Pi^b(p_c, \alpha) = \Pi^n(p_c, \alpha)$ (see Fig. 2), independent of whether deviating leads to winning or loosing the auction. Hence:

Result 4. When developers are small, $p = p_c$ in equilibrium. Moreover, it is irrelevant whether developers participate in the auction.

What happens when developer α is large? It can be seen from Fig. 2 that p_c can no longer be the equilibrium toll—it would pay the developer to unilaterally deviate bidding $p = p^*(\alpha)$. On the other hand, if developer β is small, she is not willing to bid less than p_c (as is implied by Fig. 3). Hence:

Result 5. If only one developer is large, then in equilibrium $\underline{p} = p^*(\alpha) < p_c$.

It can easily be shown (see Appendix B) that when α is much larger than β, α wins the auction in all Nash equilibria by bidding $p^*(\alpha)$. Thus, additional bidders who own little or no land do not force lower tolls below those obtained under laissez faire. The reason is that a large developer internalizes the effect of higher tolls on land values and this gives him a decisive "advantage" in the auction. It is clearly welfare increasing to let the developer benefit from this advantage. For this reason, large developers should not be excluded from the auction.

Consider now the case of one large developer as a benchmark. Can competition between large developers buy an extra reduction in tolls and increase welfare? To answer this question, note that when developers α and β are large, $p^*(\alpha) \leqslant p^*(\beta) < p_c$. Now suppose that α does not participate in the auction (i.e., α "bids" $p = \infty$). Given that strategy, β has no incentive to deviate and (optimally) bids $p = p^*(\beta)$. The same holds for α as long as $p^*(\beta)$ is "sufficiently close" to $p^*(\alpha)$, where Fig. 2 suggests that the precise meaning of "sufficiently close" is that

$$p^*(\beta) \leqslant \tilde{p}(\alpha), \tag{10}$$

where $\tilde{p}(\alpha) < p_c$ is the toll such that the loss of value of α's real estate is exactly compensated by saving investment cost I, that is

$$\Pi^n\big(\tilde{p}(\alpha); \alpha\big) = \Pi^b\big(p^*(\alpha); \alpha\big).$$ [16]

This condition implies that

$$\Pi^n\big(p^*(\beta); \alpha\big) > \Pi^n\big(\tilde{p}(\alpha); \alpha\big) = \Pi^b\big(p^*(\alpha); \alpha\big);$$

[16] That $\tilde{p}(\alpha) < p_c$ follows from: $\Pi^n(\tilde{p}(\alpha); \alpha) = \Pi^b(p^*(\alpha); \alpha) > \Pi^b(p_c; \alpha) = \Pi^n(p_c; \alpha)$, where the first equality follows from the definition of $\tilde{p}$; the following inequality from α being large and Π^b strictly decreasing for $p > p^*(\alpha)$; and the second equality from the definition of p_c. Hence, since Π^n is decreasing in p, $\tilde{p}(\alpha) < p_c$.

the inequality follows from condition (10) and Π^n being decreasing; the equality follows from the definition of $\tilde{p}$. Thus condition (10) ensures that α is made better off by not bidding, letting β build the road while charging tolls $p^*(\beta)$; the higher toll charged by β is more than compensated by not having to pay I to build the road. And given that α bids ∞, it is optimal for β to bid $p^*(\beta)$ and build the road. Similarly, one can show that there exists a Nash equilibrium where α bids $p^*(\alpha)$ and β does not participate in the auction (see Appendix B). Thus

Result 6. Competition among large developers does not necessarily increase welfare; it may bring about higher tolls and lower welfare.

One can even go beyond Result 6. Not only may competition among large developers be socially harmful, but collusion through joint bidding is clearly welfare improving. To see this, suppose that α and β costlessly collude and bid to maximize joint profits (this will occur if bargaining is efficient). Then they would bid $p = p^*(\alpha + \beta) < p^*(\alpha)$, thereby winning the auction. Hence

Result 7. Costless collusion among large developers brings about lower tolls and unambiguously increases welfare.

The benefits from collusion are twofold. First, it eliminates the socially inefficient equilibrium where β builds the road. Second, it is profitable for large developers to bid below $p^*(\alpha)$. Hence, regulators should not only allow large developers to participate in the auction, but should also encourage them to offer a single joint bid.[17]

To sum up this section, allowing developers to participate in the auction never hurts and is welfare increasing when at least one developer is large. Moreover, the participation of several large developers does not necessarily increase, and may reduce welfare. For this reason, allowing developers to act jointly is socially desirable. Far from discouraging joint bidding, auction design should facilitate coordination and side payments among land owning bidders.

5. Extensions and policy implications

In this section we discuss some extensions and policy implications.

5.1. Subsidies

Governments often subsidize road franchises because of externalities, even though the externalities due to the road are usually capitalized in the value of the land.[18] If the benefits

[17] This prescription changes when toll discrimination is allowed, see Section 5.2.

[18] In many cases the subsidy takes the form of a state contingent minimum income guarantee. See Engel et al. [3] for a discussion of government guarantees in infrastructure franchises.

from land appreciation are larger than the cost of building the road, it is doubtful that a subsidy is required.

To see why note that a subsidy may raise welfare if it leads to the construction of a socially desirable road (i.e., one that satisfies $W(0) > 0$, see Eq. (2)); or if the resulting tolls are lower than without the subsidy.[19]

Now consider bidding behavior in the auction. The subsidy, S, affects neither α's nor β's optimal bid, because neither $p^*(\alpha)$ nor $p^*(\beta)$ depends on $(I - S)$, since developers' optimal bids (given participation in the auction) depend only on the demand for the road, and not on construction cost, I. Nevertheless, the subsidy lowers the bid of the competitive fringe from $p_c(I)$ to $p_c(I - S)$, where $p_c(I)$ was defined in (9). Graphically, this amounts to a shift to the left of the Π^n function in Figs. 2 and 3, thus making it more likely that developer β, or even both developers, become "small" in the sense of Definition 1. In that case the subsidy will reduce tolls and increase welfare.

On the other hand, consider the case when $p_c(I - S) > p^*(\beta)$ (or $p_c(I - S) > p^*(a)$ when only α is large). In this case, the subsidy does not change the outcome of the auction and results in a pure wealth transfer to a developer. Thus subsidies are undesirable unless they lead to a significant improvement in the competitive position of independent construction companies.

5.2. Toll discrimination

Regulators often prohibit price discrimination by imposing equal access rules. But in the context of this paper, developer α would like to commit to charge a zero toll to those who buy her land and the monopoly toll to the rest of plot owners. More generally, a developer would also like to monopolistically exploit through drivers. Should price discrimination be prohibited?[20]

Under laissez faire it is clear that the welfare effect of toll discrimination is ambiguous. On the one hand, it creates wealth by eliminating the distortion to those who buy α's land. On the other hand, it reduces the value of the rest of the land. Now if α is close to one discrimination is clearly welfare decreasing: the optimal uniform tolls is already very close to zero; thus, the increase in α's land value is slight, while the rest of the land loses a lot in value. The opposite occurs if α is close to zero and the optimal uniform toll is close to the monopoly toll. When α is allowed to discriminate her land increases a lot in value, while the price of the rest of the land barely falls. In intermediate cases, whether one or other effect is stronger will depend on the shape of the demand curve for trips.

Toll discrimination also affects the bidding behavior of developers. Consider a large developer α (in the sense of Definition 1). For any given toll, it increases the attractiveness of winning the auction and building the road because α can now fully eliminate the toll distortion that reduces the value of her land. On the other hand, contingent on winning the auction, α would now like to charge as high a toll as possible—high tolls no longer reduce the value of her land. From all this it follows that α will win the auction and limit price the

[19] Note that, within the model presented in this paper, the sole beneficiaries of the increases in welfare described above are landowners, since they extract all rents from toll users when selling their plots of land.

[20] See Engel et al. [7] for a formal analysis of toll discrimination.

second-highest bid—be it β's or a construction firm's p_c. As with laissez faire, the effect of toll discrimination on welfare is ambiguous.

5.3. Congestion

To simplify the algebra we assumed free flow on the toll road. But it is straightforward to extend our model and add congestion.

As is well known, untolled congestion introduces a wedge between the private and social cost of an additional trip—the marginal driver slows down inframarginal drivers and creates an externality. Consequently, it raises the socially optimal toll from zero to a level such that the marginal driver fully internalizes the additional delay caused to inframarginal drivers. At the same time, it can be shown that a monopolist who owns no land fully internalizes the fact that higher congestion reduces the willingness to pay for an additional trip.[21] When setting tolls it thus fully internalizes the social cost caused by the marginal driver. But, as any monopolist, it sets the toll too high and as a result traffic and congestion are lower than their socially optimal level.

It is then straightforward to show that a developer who owns all land now maximizes the sum of consumer surplus *and* toll revenues and sets exactly the socially optimal toll. At the other extreme, a road owner who owns no land would like to charge the monopoly toll. In between, and as in the case with no congestion, developers optimally trade off the negative effect of higher tolls on the value of their land, with the profits made from exploiting drivers who do not buy their land: the smaller α, the closer is $p^*(\alpha)$ to the monopoly toll. Last, *mutatis mutandis*, the behavior of developers in the auction is analyzed in exactly the same fashion.

5.4. Pass-through drivers

In our analysis we have ignored the possibility that the road may be used by pass-through drivers who do not buy land. Nevertheless, nothing changes in our formal analysis if we include them, as long as their demand curve *for trips* is the same as that of land buyers. Formally, this is analyzed just as the case when $\alpha + \beta < 1$.

6. Conclusion

Highways, and more generally infrastructure projects, change the value of land, because their benefits are capitalized into its price. This paper has examined the strategies of large real estate developers and how these strategies affect social welfare. Our results depend on the fraction of the land that is owned by the largest landowners, and on the possibility of discrimination between different users of the road. Since it is always in the interest of the real estate developer to charge a zero toll on buyers of her land, she always prefers to discriminate in tolls. If she is not allowed to discriminate, and this rule is enforceable,

[21] See Engel et al. [5].

we show that welfare is maximized when large landowners are allowed to combine and bid jointly (i.e. they are allowed to collude), and that competition may lower welfare. On the other hand, when discrimination is possible, competition among small landowners leads to higher welfare than under uniform tolls.

In the light of this analysis, it is interesting to examine the aftermath of the auction for the road to Chicureo, which we described in the Introduction. As predicted by our model, the largest landowners formed a group to present a single bid.[22] In the end, however, no one showed up for the auction. The landowners complained that contingent subsidies against losses in the highway project were too small, making the franchise unprofitable. Our analysis, however, suggests that profitability of the highway itself is not a true measure of the overall private value of the project for large developers. There are two possible explanations. Since large landowners internalize most of the social benefits of the highway, building the highway might not have been socially desirable. If this were the case, the fact that there was no participation was welcome. More plausibly however, the large landowners were lobbying for a larger government handout, and were willing to wait given the then low prices for real estate, due to an economic slowdown at the time which made waiting costless. A subsidy in this case would be a pure wealth transfer with no allocation effects.[23]

Finally it is worth considering whether the issues considered in this paper are quantitatively relevant. Consider the case in which there are 6000 plots of land, and assume that families make three trips a day in the equilibrium and that the cost of the road is $170 million.[24] If there is no toll discrimination, no collusion and there are no other users for the road, small landowners would have to finance the road out of tolls, which implies a toll of $2.59. If we assume linear demand, we can calculate the benefits from having a single landowner as compared to dispersed landowners, by measuring the effect of reducing tolls to zero. The increase in welfare depends on the toll at which plot owners stop using the road (i.e., the vertical intercept). It varies between 29 and 91% of the construction cost when the intercept varies between $7 and $4.

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[22] This consortium considered a scheme by which buyers of her land would not have to pay tolls during the first few years (Magni [16]), thus justifying considering both uniform and discriminatory tolls, as we did in this paper.

[23] A confirmation of this interpretation is that as the economy picked up, a group of landowners was willing to offer US$21 million to the winning bidder.

[24] These figures come from the Chicureo example. We will use a discount rate of 10%, and no maintenance and operation costs.

Appendix A. Results in Section 3

Proposition A.1. *Assume that*

$$\left[D'(p)\right]^2 > \frac{1}{2} D(p) D''(p)$$

for all p below the monopoly price. Then any p satisfying the first-order condition (6) *also satisfies the corresponding second-order condition.*

Proof. The second-order condition corresponding to $\max_p \Pi_\alpha(p)$ is:

$$(2-\alpha) D'(p) + p D''(p) < 0.$$

Substituting the expression for p that follows from the first-order condition (6) in the expression above and rearranging terms shows that the second-order condition is equivalent to:

$$\frac{2-\alpha}{1-\alpha}\left[D'(p)\right]^2 - D(p) D''(p) > 0. \tag{A.1}$$

If the inequality above holds for all $p < p_m$ it will also hold for $p^*(\alpha)$, $\alpha \in [0,1]$. The proof concludes by noting that the minimum value of $(2-\alpha)/(1-\alpha)$ over $\alpha \in [0,1]$ is 2. □

Appendix B. Results in Section 4

We now characterize the Nash equilibria of the auction with uniform tolls. This characterization follows directly from the following lemma, where we derive developer γ's best-response correspondence:

Lemma B.1. *Let $\underline{p}^-$ denote the smallest bid among all bidders, excluding γ. Without loss of generality we may assume $\underline{p}^- \leqslant p_c$ (see Result* 5). *Then, if γ is small her best response correspondence is*

$$\mathcal{P}(\underline{p}^-; \gamma) = \begin{cases} [p_c, \infty] & \text{if } \underline{p}^- = p_c; \\ (\underline{p}^-, \infty] & \text{if } p_c > \underline{p}^-. \end{cases}$$

And if γ is large, it is:

$$\mathcal{P}(\underline{p}^-; \gamma) = \begin{cases} p^*(\gamma) & \text{if } \underline{p}^- \in [\tilde{p}(\gamma), \infty]; \\ (\underline{p}^-, \infty] & \text{if } \underline{p}^- < \tilde{p}(\gamma), \end{cases}$$

where $\tilde{p}(\gamma)$ is defined by $\Pi^n(\tilde{p}(\gamma); \gamma) = \Pi^b(p^*(\gamma); \gamma)$.

Proof. Suppose $p^*(\gamma) \geqslant p_c$, i.e., γ small. Then $\Pi^b(p, \gamma) \gtreqqless \Pi^n(p; \gamma)$ for $p \gtreqqless p_c$. Hence, if $\underline{p}^- < p_c$ then $\Pi^b < \Pi^n$ and γ is better-off not building the road, so that any $p \in (\underline{p}^-, \infty]$ is a best response. If $\underline{p}^- = p_c$ then $\Pi^b(\underline{p}^-, \gamma) = \pi^n(\underline{p}^-; \gamma)$ and γ is indifferent between building and not building the road, so that any $p \in [\underline{p}^-, \infty]$ is a best response.

Now suppose $p^*(\gamma) < p_c$, i.e., γ is large. If $\underline{p}^- \in [\tilde{p}(\gamma), p_c]$, then $\Pi^n(\underline{p}^-; \gamma) \leqslant \Pi^b(\tilde{p}(\gamma); \gamma)$ (see Fig. 2). Hence, it is optimal for γ to build and charge $p^*(\gamma)$, which is a best response. On the other hand, if $\underline{p}^- < \tilde{p}(\gamma)$, then $\Pi^n(\underline{p}^-; \gamma) > \Pi^b(\tilde{p}(\gamma); \gamma)$ and γ is better-off not building the road. Hence, bidding more than $\underline{p}^-$ is optimal for γ in this case. □

Proposition B.1. *Denote by $\underline{p}$ the lowest (and therefore winning) bid in the auction. Then*:

(i) *In any Nash equilibrium $\underline{p} \leqslant p_c$.*
(ii) *If α (and therefore β) is small, then any set of bids where two are equal to p_c and the remainder is larger or equal than p_c is a Nash equilibrium. Furthermore, this characterizes all Nash equilibria in pure strategies. It follows that the resulting toll is p_c.*
(iii) *If α is large and $p^*(\alpha) < \tilde{p}(\alpha) \leqslant p^*(\beta)$, then any set of bids such that α bids $p^*(\alpha)$ and the remaining bidders bid above $\tilde{p}(\alpha)$ is a Nash equilibrium of the auction. Furthermore, this exhausts all Nash equilibrium in pure strategies.*
(iv) *If $p^*(\beta) < \tilde{p}(\alpha)$, then any set of bids such that (a) α bids $p^*(\alpha)$ and the remainder bids above $\tilde{p}(\alpha)$ or (b) β bids $p^*(\beta)$ and the remainder bids above $\tilde{p}(\beta)$ is a Nash equilibrium of the auction. Furthermore, both possibilities exhaust the set of Nash equilibria in pure strategies.*

Proof. (i) Suppose that in a Nash equilibrium the winning bid, $\underline{p}$, is larger than p_c. Since, by definition, $p_c D(p_c) = I$, it follows that if $\underline{p} > p_m$, a builder who unilaterally deviates bidding p_m would win the auction and make a profit. If $\underline{p} \leqslant p_m$, then a builder who unilaterally deviates bidding a shade below $\underline{p}$ would win the auction and make a profit. It follows that in a Nash equilibrium the winning bid cannot be above p_c.

(ii) Clearly in a Nash equilibrium the winning bid, $\underline{p}$, cannot be below p_c, because it would pay to that bidder to unilaterally deviate (see Lemma B.1). Furthermore, Lemma B.1 (which also holds for $\gamma = 0$) shows that bidding in $[p_c, \infty]$ is a best response to $\underline{p}^- = p_c$ for any bidder.

(iii) Strategies induce $\underline{p} > \tilde{p}(\alpha)$, and Lemma B.1 implies that $\mathcal{P}(\underline{p}; \alpha) = p^*(\alpha)$. Moreover, Lemma B.1 implies that $\mathcal{P}(p^*(\alpha); \beta) = (p^*(\alpha), \infty]$, since $\underline{p} = p^*(\alpha) < p^*(\beta) < \tilde{p}(\beta)$; and $\mathcal{P}(p^*(\alpha); 0) = (p^*(\alpha), \infty]$, since $p^*(0) = p_m > p_c$. Hence any toll above $\tilde{p}(\alpha)$ is a best response for β and for the building companies.

(iv) We consider each case separately:

(a) Strategies induce $\underline{p} > \tilde{p}(\alpha)$, and Lemma B.1 imply that $\mathcal{P}(\underline{p}; \alpha) = p^*(\alpha)$. Consider next developer β. Since $p^*(\alpha) < p^*(\beta)$, it follows that $\Pi^n(p^*(\alpha); \beta) > \Pi^b(p^*(\beta); \beta) > \Pi^b(p^*(\alpha); \beta)$, which is the highest profit that β can make when building the road. Therefore, $\mathcal{P}(p^*(\alpha); \beta) = (p^*(\alpha), \infty]$ and any toll above $\tilde{p}(\alpha)$ is a best response to $p^*(\alpha)$. Last, $\mathcal{P}(p^*(\alpha); 0) = (p^*(\alpha), \infty]$, since $p^*(0) = p_m > p_c$ and any toll above $\tilde{p}(\alpha)$ is a building company's best response.

(b) According to strategies, $\underline{p} > \tilde{p}(\beta)$, and a Lemma B.1 implies that $\mathcal{P}(\underline{p}; \beta) = p^*(\beta)$. Consider next developer α. Since $p^*(\beta) < \tilde{p}(\alpha)$, it follows that $\Pi^n(p^*(\beta); \alpha) > \Pi^b(p^*(\alpha); \alpha)$, which is the highest profit that α can make when building the road. Therefore, $\mathcal{P}(p^*(\beta); \alpha) = (p^*(\beta), \infty]$, and any toll above $\tilde{p}(\beta)$ is a best response to $p^*(\alpha)$. Last, $\mathcal{P}(p^*(\beta); 0) = (p^*(\beta), \infty]$, since $p^*(0) = p_m > p_c$ and any toll above $\tilde{p}(\beta)$ is a building company's best response. □

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