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A lesson from Argentina: Setting transmission tolls in a competitive auction is much better than regulating them ☆

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Abstract

There are at least two procedures for setting the tolls paid by power line users. One consists of regulating them in a standard process. The other, which is used in Argentina, involves auctioning the lines to the lowest toll. In this paper we show that an auction yields higher expected social welfare if $n \geq 2$ bid. Expected social welfare is even higher if, as in Argentina, those who benefit from the line can also bid and build. Moreover, when the social welfare is utilitarian, an auction beats regulation even when the regulator can perfectly audit costs ex post.

We describe and examine the auction of the fourth Comahue transmission line in Argentina. Assuming that the regulator's information about costs is similar to the information held by the industry, the model suggests that had tolls been regulated, they would have been at least 61% higher.

JEL classification: L52; L94

Keywords: Comahue; BOM contract; GEEAC; Auctions; Transener; Transmission

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[1] Tel.: +56 2 686 8910; fax: +56 2 686 8990. During the auction process for the fourth Comahue line, Inostroza was representative in GEEAC of Central Puerto, and later Atalaya Energy, which submitted a bid in the auction.

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1. Introduction

How to charge for transmission lines in liberalized electricity markets is still a conceptually unresolved issue. For one, there is still no agreement on how to determine who "uses" a given line, let alone how to distribute tolls among different users. For another, while it is generally accepted that high-voltage transmission is a natural monopoly, there is a surprising variety of methods that are used around the world to set and regulate tolls.

On one end of the spectrum is the standard regulation of a planned transmission system owned by a monopolistic transmission company. Once the regulator decides that a line should be built, it estimates investment, operational and maintenance costs, and then sets tolls so that the assets of the transmission company earn a pre-specified rate of return. Cost assessments may be based on audited building costs or an exogenous standard, but they are done by the regulator.

On the other end of the spectrum is the competitive auction mechanism which was pioneered by Argentina. Once it has been decided that a new line should be built, an auction is called, and the winner is the firm offering to charge the lowest annual toll over a predetermined period (e.g. 30 years). Over that period users of the line pay this toll which is distributed according to some rule of use. In this paper we show formally that a competitive auction yields higher social surplus than regulation, and present evidence from Argentina that tolls are *much* lower when the line is auctioned rather than regulated.

Our starting observation is that the direct regulation of tolls is, in fact, a one-firm auction whenever information is asymmetric. To see why it is useful to consider the following setting. Assume a regulator who has decided that it is desirable to build a power line whose social value, υ_s, is greater than the maximum possible cost, c^+. To make the example simple, assume further that the regulator cares only about the surplus of the users of the line (the beneficiaries) and attaches no value to any dollar left in the pocket of the transmission company (in the paper we consider a continuum where this value, call it λ, can take any value in the interval [0, 1]). Also, from the regulator's perspective, the cost is a random variable with support $[c^-, c^+]$ and cumulative density F. Now, an "auction" with one firm where the regulator sets a maximum allowable toll π^r is equivalent to directly regulating the toll — with no competition the one firm will always bid the maximum allowable toll π^r. Thus, which toll should the regulator set?

The central regulatory trade-off can be appreciated with the help of Fig. 1, which plots the cumulative density on the horizontal axis, and both costs and benefits on the vertical axis. Suppose that the regulator fixes toll π^r and makes an all-or-nothing offer to the regulated firm.[2] With probability $F(\pi^r)$ the firm's cost will be in $[c^-, \pi^r]$, the line will be built and the regulator will achieve a surplus equal to $\upsilon_s - \pi^r$. But with probability $1 - F(\pi^r)$ the firm's cost will be higher than π^r, the firm will reject the offer and social surplus will be zero. Expected surplus, which is shown in Fig. 1, equals $F(\pi^r)(\upsilon_s - \pi^r)$. Thus the trade-off: the higher the toll the larger the probability that the line is built but the lower is the surplus $\upsilon_s - \pi^r$ if the line is built. It can be easily shown that under quite general conditions the optimal toll, call it π^r, is in (c^-, c^+), so that the line is not built with positive probability.

Now consider the possibility of putting the line to tender in an auction of n transmission firms. We show that expected social welfare is always higher with an auction for $n \geq 2$. Expected social welfare is even higher if, as in Argentina, those who benefit from the line can also bid and build. Moreover, when the social welfare function depends only on social costs and benefits, but not on

[2] An all-or-nothing offer gives the regulator all bargaining power subject to the constraint imposed by asymmetric information.

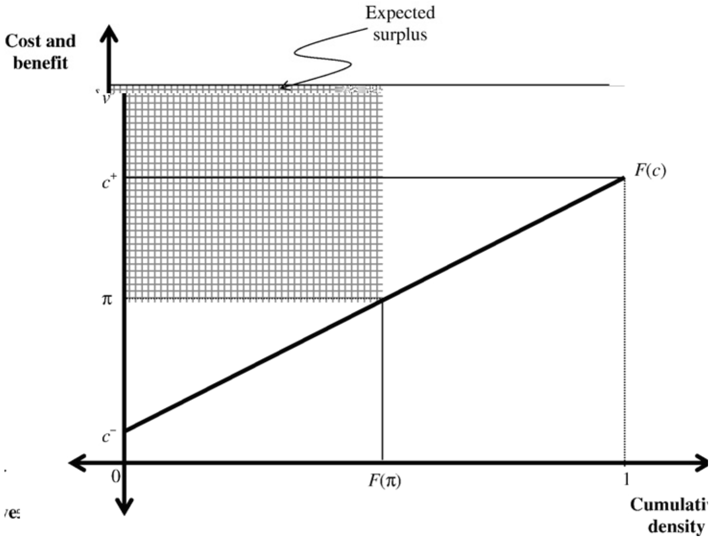

Fig. 1. Regulation is a one-firm auction.

who receives rents ($\lambda = 1$ in that case), expected social welfare is higher with an auction even when the regulator can perfectly audit costs ex post.

In addition, a virtually direct application of Bulow and Klemperer (1996) shows that the optimal regulated toll π^r is necessarily higher than the expected toll if the line is awarded in an English auction with two bidders. The revenue-equivalence theorem can then be used to show that the expected toll is lower in any revenue-equivalent auction, in particular in the sealed-bid first-price auction used in Argentina. Needless to say, the larger the number of firms challenging the monopolist in the auction, the lower the eventual toll will be.

How much lower are tolls with an auction? The model can be used to show that the bid of the beneficiaries of the line is a lower bound of the toll that would have been obtained, had the line been regulated. Hence, the difference between the beneficiaries' bid and the winning bid is a lower bound of the savings that were obtained by auctioning the line instead of regulating it.

We use this result to analyze the outcome of the auction of the fourth Comahue line in Argentina. Four consortia bid in the auction, including one formed by the beneficiaries themselves. The line was awarded to Transener, the leading transmission firm, which bid US$24.52 million per year, compared to a second-lowest bid of US$24.99 million, a third lowest of US$38 million, and a worst bid of US$39.47 million, which was submitted by the consortium forming part of the generator group that proposed the line (Atalaya Energy). Thus, a conservative estimate of the toll-saving arising from the competition induced in the auction is the US$15 million difference between the winning bid and that of Atalaya. In other words, if the line had been regulated, the toll would arguably have been at least 61% higher and probably even higher still.

The idea of auctioning on a lowest-toll basis, instead of regulation, has a long history. It was originally proposed by the British economist Edwin Chadwick in 1859 and popularized later by Harold Demsetz (1968).[3] Nonetheless, until now it has only been used on an exceptional basis, because auctioning is only appropriate when the project can be precisely defined. This is hard to do when regulating, for example, a firm that supplies drinking water or fixed-line phone services.

[3] See also Posner (1972) and Stigler (1968).

But it is possible to specify what a new power transmission line – and even an extension of an existing line – consists of and thus an auction is appropriate.

The rest of this paper is organized as follows. In Section 2, we provide a brief explanation of Bulow and Klemperer (1996); we then apply this to the auctioning of transmission line expansions, and we deduce a series of results that are needed to interpret the outcome of the auction. In Section 3 we briefly explain the mechanism used to expand electric power transmission in Argentina, and we describe the Comahue project. We also describe the auction and analyze its results. Section 4 concludes. In the three appendices, we firstly describe the transmission prices regulation system in Argentina (Appendix A); we then explain, in greater detail than in the text, the mechanism used to expand transmission in Argentina (Appendix B); and lastly we provide formal proofs for the results stated in the text (Appendix C).

2. Auctions vs. regulation

2.1. The model

2.1.1. The transmission project

Consider a transmission line project $\mathcal{T}$ whose technical characteristics (e.g. capacity, voltage, design, route) have already been determined. Suppose there are $n+1$ firms that could potentially build, operate and maintain the line, including the current transmission firm, a, and the project beneficiaries, b. The annual capital, operation and maintenance cost of firm i, c_i, is a random variable that is independent of the other firms' costs. For any firm i the support of this random variable is $[c^-, c^+]$, its density function is f, and its cumulative density is F. Assume this distribution is continuous, strictly increasing and that the function $\text{MC} = c + \frac{F}{f}$ is increasing in c throughout the range $[c^-, c^+]$.[4] F and MC are plotted in Fig. 2.

It is common knowledge that: (i) the distribution is the same for all firms. (ii) c_i is observed only by firm i; and (iii) firms and the regulator are risk-neutral. The value of $\mathcal{T}$ for the project beneficiaries, without considering the cost of the transmission line, is $\upsilon_s \geq c^+$; in other words, the project is always worthwhile. We also assume that the private value of the line is equal to the social value. Nevertheless, a dollar of profit left in the pocket of the transmission company has a social value of $\lambda \in [0, 1]$ — i.e. we allow for the surplus realized by the transmission company to be socially less valuable.[5] Note that when $\lambda = 1$ the social welfare function is utilitarian.

2.1.2. The allocation procedure

The regulator can choose between two procedures for building the line. The first, which we call "regulation", consists of choosing a firm and then bilaterally bargaining the toll π with it. The second case, which we refer to as "auction", consists of awarding the line to the firm that bids the lowest toll in a competitive auction.

2.1.3. The distribution of bargaining power

We assume that the regulator wants the toll to be as low as possible, subject to the constraint that at least one firm is willing to build the line. We also assume that all bargaining power is held

[4] Formally, the MC function is identical to the marginal cost curve facing a monopsonist — hence the notation.

[5] One reason may be that transmission companies are sometimes foreign firms. More important, higher transmission tolls will lead, ultimately, to higher average costs downstream and higher energy equilibrium prices. Then higher transmission rents come at the cost of downstream distortions.

by the regulator: in other words, the regulator can credibly make a "take-it-or-leave-it" offer to the firm. It follows that any eventual advantage of using an auction must come from moderating the information asymmetry that exists between the regulator and the regulated firm.

2.2. Regulation

Regulation consists of choosing a firm and fixing a toll. Assuming the regulator can make a credible take-it-or-leave-it offer to the current transmission firm, its problem is to choose $\pi \in [c^-, c^+]$ to maximize

$$F(\pi)[(\upsilon_s - \pi) + \lambda(\pi - E[c|c \leq \pi])],$$

i.e. the sum of expected beneficiary surplus and (adjusted) transmission company profits. The optimal toll, π^r, satisfies the first-order condition

$$f(\pi^r)(\upsilon_s - \pi^r) - (1 - \lambda)F(\pi^r) \geq 0,$$

from which it follows that

$$\pi^r = \begin{cases} \upsilon_s - (1-\lambda)\dfrac{F(\pi^b)}{f(\pi^b)}, & \text{if } \lambda \leq 1 - (\upsilon_s - c^+)f(c^+) \equiv \overline{\lambda}, \\ c^+ & \text{if } \lambda \geq 1 - (\upsilon_s - c^+)f(c^+) \equiv \overline{\lambda}. \end{cases}$$

Note that π^r is nondecreasing in the value of the line, υ_s, and in λ, the social value of a dollar of transmission firm's profits. Hereinafter, when needed, π^r (λ, υ_s) will denote the fact that the optimal regulated toll depends on λ and υ_s.

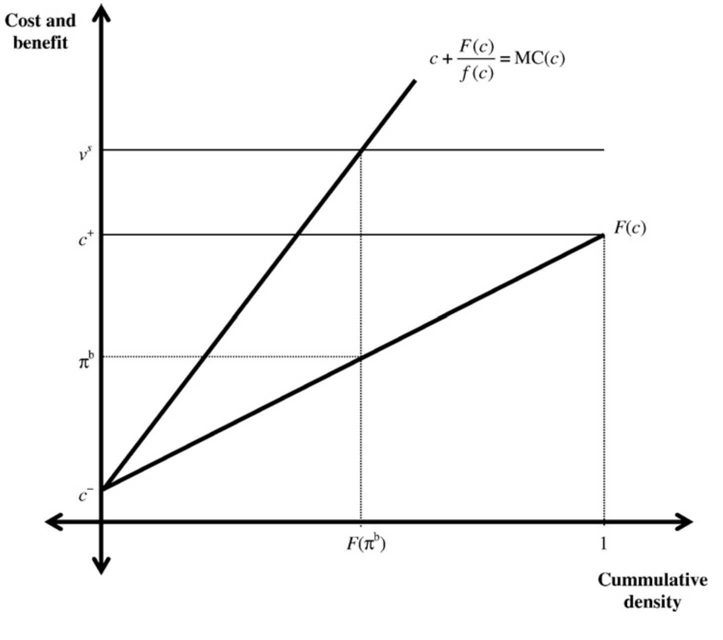

Fig. 2. Optimal regulation (λ=0).

To appreciate the economics underlying this result, it is helpful to look at Fig. 2, which, for simplicity has been drawn on the assumption that $\lambda = 0$ and $\upsilon_s < c^+ + \frac{F(c^+)}{f(c^+)}s$. Consider firstly a regulator who sets a toll equal to c^+. In this case, the probability of the line being built is 1, but the toll is high. Thus the firm will keep all the rent arising from the information asymmetry. If, on the other hand, the regulator sets a toll slightly lower than c^+, say $c^+ - \Delta c$, the likelihood of the line being built is equal to $F\,(c^+ - \Delta c) < 1$, but expected beneficiary surplus is

$$F(c^+ - \Delta c) \cdot (\upsilon_s - c^+ + \Delta c) > 0.$$

It is now easy to see that the regulatory trade-off consists of the following: as the toll is lowered (i.e. Δc rises), the conditional surplus increases, but the probability of the line being built falls. Where is the optimum?

Fig. 2 shows that the regulator should reason like a monopsonist facing a "supply" curve F and make the marginal cost $\mathrm{MC} \equiv c + \frac{F}{f}$ equal to the marginal benefit υ_s, because in that way $F \cdot (\upsilon_s - \pi)$ is maximized. More generally, if the regulator values a dollar of profits made by a transmission company in $\lambda \in [0, 1]$, then the relevant "marginal cost" is equal to $c + (1 - \lambda)\frac{F}{f}$, but the rule is identical. The point is that if the regulator does not value the profits of the transmission company very highly, it prefers to set a toll lower than c^+ to extract rents from the low-cost transmitter, even at the risk of the line not being built. This yields the following result:

Result 2.1. *When λ is sufficiently small, the regulator makes an offer that the firm will reject with probability greater than zero.*

Nonetheless, if value of the line is very high, or if the regulator values the transmission firm surplus with sufficient intensity (λ close to 1), then it will set a toll equal to c^+ to ensure that the line is built with probability 1. Thus:

Result 2.2. *If the regulator wants to guarantee the line being built, then it must allow the transmission firm to keep all the rent.*

In what follows it is important to note that regulation is equivalent to an auction in which there is only one bidder, and in which π^r represents its maximum acceptable bid. In this case the firm will bid π^b if $c \leq \pi^b$, and it will not participate if $c > \pi^b$. It is therefore natural to analyze what happens if the line is put out to tender and more firms are allowed to enter and compete for the right to build and operate it.

2.2.1. Remark

The reader who is familiar with regulation theory might wonder why not design a mechanism à Baron-Myerson (1982). The reason is that in practice the size of the line is determined by transmission needs. With "q" exogenous, the only regulatory instrument is toll, π, and it is not possible to simultaneously extract rents and guarantee provision.

2.2.2. Remark

In our model the regulator is informed about costs as good (or as bad) as any firm in the industry. An objection is that the real regulatory problem might not be to assess costs but to provide effort incentives to lower them. In other words, according to this view regulators can be expected to be good at measuring costs, even though they may end to be high because effort incentives are poor. In that case, the regulator could implement a contract à la Laffont–Tirole (1993) where costs are reimbursed and incentives provided by a transfer contingent on measured cost.

While regulators may be good auditors in developed countries, this is not so in most developing countries. In them, regulators often rely on information provided by the firm, which often is strategically manipulated. For example, Di Tella and Dyck (2008) study tariff reviews of Chilean distribution companies (a country with quite sophisticated regulatory institutions and practices) and find that costs increase above trend during years when a new price cap is set for the next four-year interval. They also examine the response of the stock market to cost announcements. Generally, costs that exceed cost expectations tend to depress returns to holding the firm's stock. But right before review periods high cost reports *increase* returns.

More generally, it seems fair to say that regulators in developing countries at most learn about the distribution of cost parameters during tariff reviews, but are not able to measure actual costs. And when regulators are neither able to observe costs ex post, not to give transfers to the firm, they are limited to set a price cap π (see Laffont (2005, pp. 52–53)). This coincides with regulatory regimes in many developing countries.

Having said this, we will show below that when $\lambda = 1$ (the regulator does not discount the surplus of the transmission company) an auction dominates regulation even when the regulator can perfectly observe costs ex post.

2.3. Auctions

2.3.1. Introduction

A competitive auction is a mechanism for choosing the firm to which the line will be awarded, and define the payment to be received for building and operating it. Although there are many types of auctions, we will work with an English auction in which the regulator starts by calling a toll equal to c^+ and progressively lowers it until just one firm remains that is willing to build the line. The line is then awarded at the toll at which the penultimate firm abandoned the auction.

2.3.2. An English auction dominates regulation

With an English auction the optimal strategy of transmission firm i is to maintain its offer to build the line until the toll reaches c_i, and withdraw as soon as the toll falls below that level. For if the firm withdraws earlier, it may lose the chance to be awarded the line with a toll that exceeds its cost, whereas if it withdraws later it runs the risk of building the line with a toll that does not cover cost. This means that the line will be awarded to the firm that can build it at the lowest cost, but the toll it receives will be equal to the second-lowest cost. Several results follow from this.

Result 2.3. *The line will always be built, and always by the most efficient firm.*

Result 2.4. *(a) The expected toll is equal to the expectation of the second-lowest-cost bidder; (b) the expected toll received by a firm whose cost is c_i if it wins the auction, is equal to the expectation of the second-lowest-cost bidder, conditional on c_i being the lowest.*

Result 2.5. *As the number of firms increases, the expected toll falls; i.e. π is decreasing in n.*

Result 2.5 follows immediately because the expected value of the second-lowest cost is decreasing in the number of participants in the auction. Hereinafter and when needed, we denote the toll that results from the auction by $\pi(n)$.

Two questions remain: which system produces a higher expected beneficiary surplus and which one yields higher social welfare.

It is not straightforward which yields a higher beneficiary surplus. To appreciate why not, let c^a be the cost of the current transmission firm, and c_2 the cost of the firm that joins the auction. As Fig. 3 shows, an auction yields higher beneficiary surplus when $c^a > \pi^r$ (with an auction, the line is built), and when $\max\{c^a, c_2\} < \pi^r$ (with an auction, the toll is lower). But if $c^a < \pi^r < c_2$, beneficiaries would be better off with regulation, because the auction yields a higher toll.

We now use a result by Bulow and Klemperer (1996) to show that expected beneficiary surplus in an English auction with two firms is unambiguously higher. In other words, the expected loss borne by beneficiaries from occasions when an auction yields a higher toll than regulation (i.e. when $c^a < \pi^r < c_2$) is less than their gain in the rest of the cases.

Proposition 2.1 (Competition and beneficiary surplus). *Expected beneficiary surplus in an English auction in which the regulated firm a competes with one other firm, is greater than the expected beneficiary surplus when is regulated, that is*

$$\upsilon_s - E[\pi(2)] \geq F(\pi^r)(\upsilon_s - \pi^r)].$$

Proof. Lemma C.1 in Appendix C shows that when $\lambda = 0$ E_c^a $[\max\{\upsilon_s - \mathrm{MC}(c^a), 0\}]$ is the expected beneficiary surplus if the toll is regulated. On the other hand, it is E_{c,c_2}^a $[\max\{\upsilon_s - \mathrm{MC}(c^a), \upsilon_s - \mathrm{MC}(c_2)\}]$ with an English auction. For values of c^a such that $\upsilon_s \geq \mathrm{MC}(c^a)$, the expected surplus is clearly larger with an English auction (see Lemma C.2 in Appendix C). Now consider values of c^a such that $\upsilon_s < \mathrm{MC}(c^a)$. In this case we compare E_c^a $[\max\{\upsilon_s - \mathrm{MC}(c^a), 0\}] = 0$ with E_{c^a, c_2} $[\max\{\upsilon_s - \mathrm{MC}(c^a), \upsilon_s - \mathrm{MC}(c_2)\}]$ conditional on $\upsilon_s < \mathrm{MC}(c^a)$. But we know that E_{c_2} $[\mathrm{MC}(c_2)] = c+ \leq \upsilon_s$, so E_{c_2} $[\upsilon_s - \mathrm{MC}(c_2)] \geq 0$. Accordingly, $E_{c^a,\ c_2}$ $[\max\{\upsilon_s - \mathrm{MC}(c^a), \upsilon_s - \mathrm{MC}(c_2)\}] > 0$. Thus, beneficiaries obtain a higher surplus with an auction than with regulation

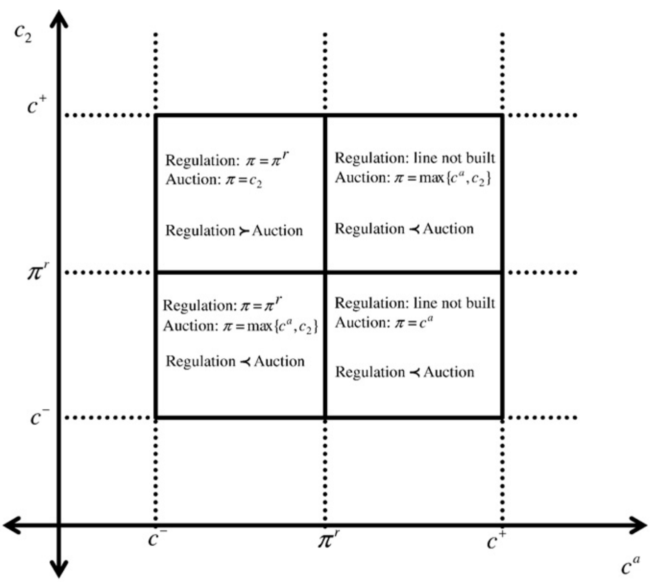

Fig. 3. Regulation and a two-bidder auction compared.

when $\lambda=0$. The proof is completed by noting that expected beneficiary surplus with regulation falls with λ. □

The next proposition shows that such an auction also yields higher social welfare than regulation.

Proposition 2.2 (Competition and social welfare). *For all* $\lambda\in[0,1]$ *expected social surplus in an English auction in which the regulated firm a competes with one other firm, is greater than the expected social surplus when the firm is regulated.*

Proof. Here we sketch the proof. In Proposition C.3 in Appendix C we provide the details. Note that social surplus with an English auction with two firms is

$$\upsilon_s - E[\pi(2)] - \lambda\big(E[\pi(2)] - E_{c^a,c_2}[\min\{c^a, c_2\}]\big).$$

On the other hand, social surplus with regulation is equal to

$$F(\pi^r)[\upsilon_s - \pi^r - \lambda(\pi^r - E[c|c\le\pi^r])]. \tag{2.1}$$

The claim is that

$$\upsilon_s - (1-\lambda)E[\pi(2)] - \lambda E_{c^a,c_2}[\min\{c^a, c_2\}] > F(\pi^r)[\upsilon_s - (1-\lambda)\pi^r - \lambda E[c|c\le\pi^r]].$$

The proposition is not straightforward, because firms' expected surplus is in general be greater with regulation. However, one can show that social surplus is greater with an auction if $\lambda=0$, $\lambda=1$ and $\lambda=\bar{\lambda}$. Moreover, social surplus with regulation (2.1) is increasing and convex in λ in the interval $[0, \bar{\lambda}]$; and increasing and linear in λ in the interval $[\bar{\lambda}, 1]$. Hence, social surplus with regulation must be smaller than with an auction for all λ in [0, 1]. □

Now an English auction with $n>2$ bidders must be even better: beneficiaries can expect a larger surplus, and expected costs fall further. Hence, we have established the following result:

Result 2.6. *An English auction with* $n\ge 2$ *dominates optimal regulation.*

The last result indicates that when $\lambda=1$, even a regulator who can measure costs ex post cannot beat an auction.

Proposition 2.3. *Assume* $\lambda=1$, *and that the regulator can measure costs ex post and fix* $\pi^r=c^a$. *Then expected social surplus with an English auction with two bidders dominates regulation.*

Proof. A regulator who can measure costs always builds the line and sets $\pi=c^a$. Hence, expected social surplus with regulation is

$$E[\upsilon_s - c^a + \lambda(c^a - c^a)] = \upsilon_s - E_{c^a}[c^a].$$

On the other hand, expected social surplus with an auction equals

$$\upsilon_s - E_{c^a,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}] + \lambda(E_{c^a,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}] - E_{c^a,c_2}[\min\{c^a, c_2\}]) = \upsilon_s - E_{c^a,c_2}[\min\{c^a, c_2\}],$$

if $\lambda=1$. □

2.3.3. Sealed-bid auctions

In Argentina, transmission lines are awarded in first-price sealed-bid auctions. In other words, firms place their toll bid in a sealed envelope, the line is awarded to the firm that submits the best bid, and the toll received by the successful bidder is equal to its own bid. It can be shown that the optimal bid submitted by a firm that is not a beneficiary, and whose cost is c, is equal to the expectation of the second-lowest-cost bidder, conditional on c being the lowest cost — precisely equal to the expected toll in an English auction. This gives the following result:

Result 2.7. *The expected toll in a first-price sealed-bid auction, in which the beneficiaries do not participate, is equal to the unconditional expectation of the second-lowest-cost bid, which is equivalent to that of an English auction.*

It is unnecessary to prove this result since it is a direct application of the well-known revenue-equivalence theorem (see, for example, Myerson (1981) or Klemperer (1999)). It follows that:

Corollary 2.4. *A sealed-bid transmission line auction dominates regulation.*

Strictly speaking, we have shown the corollary only in the case where beneficiaries do not participate in the auction. But, as we shall see presently, both the beneficiary's and social expected surpluses are even larger when beneficiaries are allowed to bid and build the line.

2.4. The role of the beneficiaries

At first sight one might think that beneficiary participation does not change the analysis of the previous subsection — if the beneficiaries' costs come from the same distribution, the function that relates the bid to its valuation in the auction should be the same as for the other firms. Nonetheless, we will now show that even in an English auction, and unlike the firms, the beneficiaries gain by submitting a bid that is below cost. By doing so, they obtain a toll that is even lower in expected value terms, and they can implement an optimal auction, given the alternative they have of building the line at cost c^b.

2.4.1. An English auction in which the beneficiaries participate

We start by considering an English auction involving only the beneficiaries and the current transmission firm. Clearly, the transmission firm bids c^a. On the other hand, if the beneficiaries know that their cost is c^b, they maximize their utility by bidding

$$\pi^b \equiv \arg\max_\pi \left\{F(\pi)(\upsilon_s - \pi) + [1 - F(\pi)]\left(\upsilon_s - c^b\right)\right\}.$$

The first-order condition for this problem satisfies

$$f\left(\pi^b\right)\left(c^b - \pi^b\right) - F\left(\pi^b\right) = 0,$$

from which it follows that

$$\pi^b = c^b - \frac{F\left(\pi^b\right)}{f\left(\pi^b\right)} \equiv \mathrm{MC}^{-1}\left(c^b\right). \tag{2.2}$$

Note that $\pi^b < c^b$, so sometimes the line is built by the beneficiaries despite being inefficient. Why is it that optimal bid is not simply c^b? For the beneficiaries, it is worth running the risk that the line is not built by another firm if its cost is slightly below c^b, in exchange for paying a lower toll when the other firms have costs that are substantially lower than c^b. In this sense they act very similarly to a regulator that can credibly commit to not building the line, but with several important differences.

Firstly, if the beneficiaries participate in the auction, the line is always built; secondly, the maximum toll π^b is independent of the value of the line υ_s, precisely because the beneficiaries will always build the line; thirdly, the maximum toll rises with c^b; lastly, when the beneficiaries participate they can implement the (privately) optimal auction contingent on cost, c^b.

In Lemma C.7 in Appendix C we show that in an English auction with n firms, the beneficiaries' optimal bid remains $\mathrm{MC}^{-1}(c^b)$. Accordingly, expression (2.2) is general:

Lemma 2.5. *In an English auction, the beneficiaries' optimal bid is $MC^{-1}(c^b)$ and does not depend on the number of firms participating in the auction.*

Proof. See Lemma C.7 in Appendix C. □

While beneficiaries clearly gain when they participate, the effect on social welfare is a priori ambiguous. On the one hand, beneficiaries make competition more intense and add one other cost draw to the sample, which is now of size $n+1$. But on the other hand, beneficiaries bid below costs and sometimes exclude more efficient transmission firms. The following proposition indicates that allowing beneficiaries to bid always increases social welfare:

Proposition 2.6. *An English auction with n firms and beneficiary participation yields higher expected social surplus than an English auction with n firms only. Consequently, an auction with beneficiary participation dominates regulation.*

Proof. See Proposition C.8 in Appendix C. □

2.4.2. The Argentine auction with beneficiaries participating

Recall that the Argentine system uses a first-price sealed-bid, auction. Generally speaking, firms will wish to bid higher than their cost, since that is the only way they can make a profit if they are awarded the line. But, how far above cost will the bid be?

Here again we can use the revenue-equivalence theorem, which enables us to deduce (see Appendix C) that the optimal bid of firm i is

$$E_{c_{-i},c^b}\left[\ \min\ \left[c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right]|c_i, c_i \leq \min\ \left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}\right].$$

In other words, when the cost of firm i is c_i, its bid is equal to the expected value of the second-lowest cost, conditional on c_i being the lowest — precisely equal to the expected toll received by firm i when its cost is c_i and it is awarded the line in an English auction.

On the other hand, it can be shown that for beneficiaries it is worth making the following bid:

$$E_{c_{-i},c^b}\left[\ \min\ \left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}|c_i = \mathrm{MC}^{-1}\left(\overline{c}^b\right)\leq \min\ \left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}\right].$$

As can be seen from Fig. 4, when beneficiaries have a cost of c^b, they should act as a firm whose cost is equal to $\mathrm{MC}^{-1}(c^b)$. This means that beneficiaries adapt their bid so that the line is awarded only to firms whose cost is at most $\mathrm{MC}^{-1}(c^b)$, exactly the same as in an English auction. The line is thus awarded in the same way as in an English auction:

Result 2.8. *When beneficiaries bid, the Argentine auction is equivalent to an English auction.*

Proof. See Lemma C.10 in Appendix C. □

2.5. Auctions vs. regulation

2.5.1. The benefits of competition

We can now use these results to compare auctions and regulation. Essentially, a competitive auction in which beneficiaries participate is superior to regulation for three reasons.

The first is obvious once the Bulow and Klemperer (1996) result is known: the auction introduces competition. This leads to a lower expected toll even if the regulator can credibly commit to not building the line, and to select a firm with lower expected costs.

Secondly, when $\lambda \geq \bar{\lambda}$, the auction eliminates the rents obtained by the regulated firm, because the regulator bears a cost if the line is not built. In one sense, the auction restores to the regulator the bargaining power given up through its inability to accept an announced project not being carried out.

Thirdly, participation by the beneficiaries makes competition even more intense.

2.5.2. A lower bound of the benefit of auctioning the line

Assume that in a given auction one observes (a) the winning bid, call it π^w; (b) the beneficiaries bid, π^b. Then the following follows:

Proposition 2.7. *π^b is a lower bound of the toll that would have been fixed by a regulator. Moreover, $\pi^b - \pi^w$ is a lower bound of the gain realized by auctioning instead of regulating.*

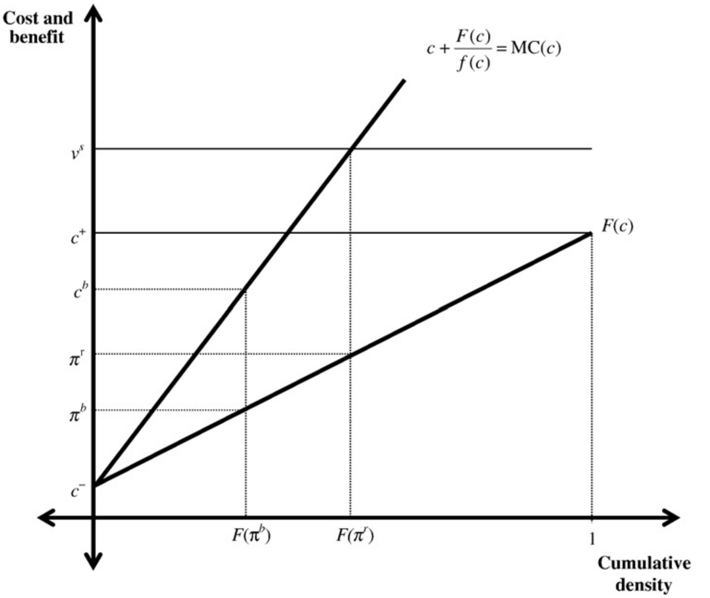

Fig. 4. Beneficiaries implement a (privately) optimal auction contingent on c^b.

Proof. Assume $\lambda=0$. We know that beneficiaries act in the auction as a bidder whose cost is $\mathrm{MC}^{-1}(c^b)$. Now if $c^b=c^+$, then

$$\pi^b(c^+) = \mathrm{MC}^{-1}(c^+),$$

no matter what type of auction is, because incentive compatibility implies that in any auction beneficiaries will give independent firm $\mathrm{MC}^{-1}(c^+)$ no rent and $\pi[\mathrm{MC}^{-1}(c^+)]=\mathrm{MC}^{-1}(c^+)$. Also, obviously $\pi^b(c^+)\geq\pi^b(c^b)$ for any auction. Now

$$\pi^r(0, \upsilon_s) = \max\left\{\mathrm{MC}^{-1}(\upsilon_s), c^+\right\} \geq \mathrm{MC}^{-1}(c^+) = \pi^b(c^+);$$

that the regulated toll is greater than $\mathrm{MC}^{-1}(c^+)$ follows from $\upsilon_s\geq c^+$; that $\mathrm{MC}^{-1}(c^+)\geq\mathrm{MC}^{-1}(c^b)$ follows from $c^+\geq c^b$.

Hence π^r $(0, \upsilon_s)\geq\pi^b(c^+)\geq\pi^b(c^b)$ and the beneficiaries' bid $\pi^b(c^b)$ is a lower bound of the regulated toll.

Also, if π^w is the winning bid,

$$\pi^r(0, \upsilon_s) - \pi^w \geq \pi^b\left(c^b\right) - \pi^w$$

and $\pi^b(c_b)-\pi^w$ is a lower bound of the gain of having auctioned the line. Last, note that π^r $(0, \upsilon_s)<\pi^r$ (λ, υ_s), which completes the proof. □

The economics of the result is very simple, and can be discussed with the help of Fig. 5. As we already know, when $\lambda=0$ the regulator sets her toll to exclude all firms with costs higher than $\mathrm{MC}^{-1}(\upsilon_s)$. At the same time, beneficiaries bid to exclude firms with costs higher than $\mathrm{MC}^{-1}(c^+)$, and $\mathrm{MC}^{-1}(c^+)<\mathrm{MC}^{-1}(\upsilon_s)$.

Note that because π^r $(\lambda, \upsilon_s)<c^+$ in general, one cannot use bid information to obtain a lower bound if only independent bidders participate in the auction. Thus, the participation of beneficiaries is key to estimate the gains obtained by auctioning a line from actual bidding.

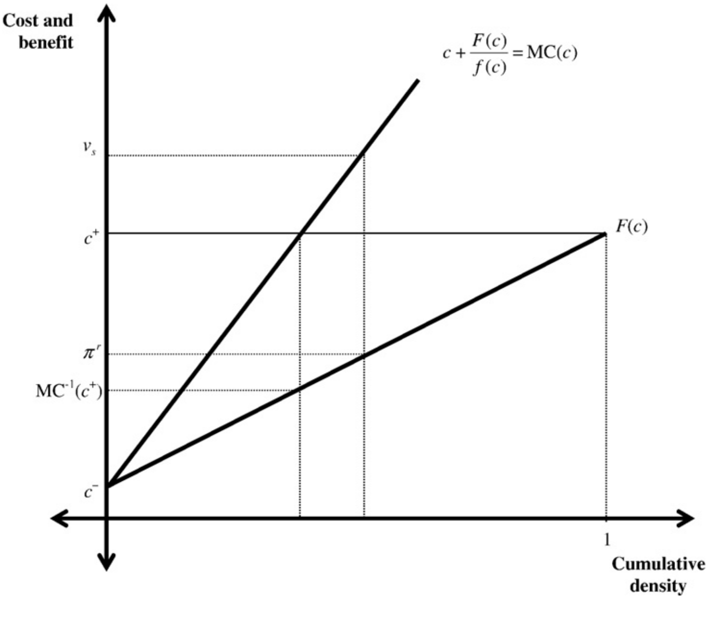

Fig. 5. A lower bound of the regulated toll.

3. Transmission in Argentina and the fourth Comahue line

In this section we briefly describe the Argentine mechanism for transmission system expansions.

3.1. The transmission expansion mechanism in Argentina

As Argentine transmission firms are not obliged to invest to accommodate increases in demand, four mechanisms have been established to decide on capacity expansions.[6] Two of these – expansions to improve quality, and minor extensions – are relevant to small projects.[7] The third, contracts between the parties, is used when there is only one beneficiary. Several international interconnection projects have been carried out under this modality, such as the Itá–Garabí line between Brazil and Argentina, and the Interandes line that interconnects Termoandes in Salta with the Chilean grid system. Fourthly, competitive bidding is used when expansions exceed a certain size.[8]

The procedure in the case of competitive bidding, which was followed in the fourth Comahue line expansion, consists of five steps:

- A requester group (generators, distributors or large customers) who want a new line to be built, request authorization to do so from the transmission firm to which they connect. The request describes the project and indicates either (i) a maximum annual fee, such that if nobody bids lower, the project is cancelled; or (ii) an annual toll at which the transmission firm undertakes to build the line under a build, operate and maintain (BOM) contract.
- The transmission firm passes the request to Argentina's national power regulator (ENRE), which studies the project and compares the net present value of the expected cost of supply without the project, against net present value with the project, including the new line's maintenance, operation and investment costs. It also sets the maximum annual fee.
- The wholesale electric power market management company (CAMESSA) identifies the line's beneficiaries, defined as all generators whose energy injections increase the flow of the line under normal operating conditions; and all distributors or large customers whose energy withdrawals increase the flow on the line under normal operating conditions. Each beneficiary's share is calculated using the "footprint" method, and this determines the number of votes the agent will have in the public hearing.
- ENRE calls a public hearing to obtain the views of parties affected by the project; and beneficiaries vote whether to accept or reject it. If the beneficiaries holding 30% of the votes oppose the project, it is rejected.
- If the project is approved in a public hearing, the requesting beneficiaries, who become the parties to the future BOM contract, call an international tender. The auction is awarded as follows: (i) if the maximum fee modality is chosen, the line is allocated to the bidder offering the lowest annual fee for 15 years, subject to a ceiling of the maximum fee. If there are no bids below the maximum fee, the auction is declared void and the process terminates; (ii) if the BOM contract modality is chosen, the line is awarded to the bidder offering the lowest fee, provided this is below 85% of the amount bid in the BOM contract. If the lowest bid is above

[6] For further details see, for example, Abdala and Chambouleyron (1999) or Chisari et al (2001) or ENRE (1997, chapter 3).

[7] For example, minor extensions are defined as projects costing no more than US$2 million (ENRE, 2001, p.57). According to ENRE (2001, chapter 3), between 1984 and 2001 the average value of a project contract between parties was US$5.8 million, whereas the average for minor extensions was US$730,000.

[8] We describe the expansion mechanisms in greater detail in Appendix B.

85%, the firm that offered the BOM contract and the firm submitting the best bid have the right to improve their offers. The line is allocated to the lowest final bid.

Once the line is built, the owner charges the beneficiaries the agreed fee for 15 years, after which it charges the remuneration established for the other installations.

3.2. The fourth Comahue line

The Comahue–Buenos Aires corridor expansion project, known as the fourth line, was motivated by the installation of 1700 MW of hydro-capacity in the Comahue area in the north of the Argentine Patagonia, following electric power sector privatization in 1993. For that reason, various studies were begun and others, which had been halted during the deep crisis Argentina suffered at the end of 1980s, where resumed. The projects studied aimed to maximize transmissible power on the three existing lines, maintain or improve the safety of the grid system, and increase the transmission capacity of the corridor through new investments.

To optimize the existing system, a set of reinforcements for existing lines was designed, and improvements were made to electric power control and stabilization elements. This equipment was installed gradually, and when the fourth line came into operation in 1999 the capacity of the Comahue–Buenos Aires corridor was 3300 MW.

Taking the 3300 MW as a base, there were several expansion alternatives. Studies showed that the most advantageous one was to build a 500 kV line of alternating current, about 1300 km long, starting in Piedra del Águila and interconnecting to the system at the Choele Choel, Bahía Blanca, Olavarría and Abasto substations. This alternative followed the route studied nearly 10 years earlier by the Hidronor firm, and made it possible to transmit up to 4600 MW during peak demand periods, without having to dissipate a load even in the event of the worst possible simple failure.[9] At other times, the system was stable even in the face of double failures transmitting 4550 MW, equivalent to 55% of the demand of the Argentine grid system.

3.2.1. Rejection and new request

The chronology of the auction is shown in Table 1. The first request to build the fourth line was lodged on 2 September 1994 by the firms Hidroeléctrica El Chocón S.A. and Hidroeléctrica Alicurá S.A., which at the time represented slightly over 30% of beneficiaries (see Table 1 for a chronology of the process that lead to the auction and Table 2 for a list of beneficiaries and their participations).[10] Turbine Power Co. S.A. later joined the group on 24 November. The expansion was requested under the competitive tender modality for construction, operation and maintenance (a BOM contract), with a fee of US$54.6 million per year for the first three and a half years and US$61.4 million for the remainder of the period (excluding VAT). Tenesa expressed interested in becoming an independent transmission firm.

On 17 February 1995, the request was considered in a public hearing and was opposed by Hidroeléctrica Piedra del Águila, Hidroeléctrica Cerros Colorados and Central Térmica Alto Valle. The opposition group managed to veto the project because between them they represented 34.18% of the votes. Subsequently, Capex and Central Neuquén also rejected the project, thereby raising the level of opposition to over 50%, and ENRE finally rejected the request on 28 March 1995. Although these

[9] This was achieved thanks to disconnection adapted to failure on the order of 960 MW.

[10] Although the percentages indicated in this table correspond to the second request, the values are very similar to those of the first.

Table 1
Chronology of the auction

Date	Event
09/02/1994	Generators group agrees to request expansion of the Comahue–Buenos Aires line.
02/17/1995	Public hearing.
03/28/1995	Request is rejected.
05/07/1996	Generators group agrees to request a new expansion of the Comahue–Buenos Aires line.
05/20/1996	GEEAC asks ENRE to evaluate the line expansion.
May to September	ENRE studies the project.
	ENRE convenes a public hearing (ENRE resolutions 441/96 and 525/96
09/03/1996	Requesters and Transener reach agreement
09/25/1996	Public hearing
10/24/1996	Certificate of convenience and necessity issued for the expansion.
	ENRE resolution 613/96, minute 285.
05/22/1997	Auction called
10/27/1997	Auction held
11/12/1997	Award
	ENRE resolution 1028/97, minute 367.

firms thought the line needed to be expanded, they considered the fee proposed for the BOM contract to be too high, and apparently did not believe the auction would result in a substantially lower one.

The rejection was followed by just over a year of negotiations between the beneficiaries that had requested the expansion in 1994 and those who opposed it, during which time several aspects of the regulations were altered to allow new types of tender. The defect of an auction involving a BOM contract is that it gives a sort of first option to the transmission company that accompanies the request, since it will win the auction if no better bid is forthcoming. If this option proposes a toll that is too high, as some of the beneficiaries believed, the losers of the auction are forced to finance the project. Accordingly, a maximum fee option was introduced, whereby in the absence of a lower bid the line is not built. In addition, permission was given to use accumulated congestion funds (the so-called SALEX account) as an advance on toll payments. As a result the release of such funds was brought forward, which under the previous regulations could only have been used after payment of the first fee installment.

In May 1996, the Comahue area electric power generators group (GEEAC) presented a new expansion request.[11] This time the project consisted of a 500 kV line connecting the Piedra del Águila and Abasto transformer stations, passing through the installations at Choele Choel, Bahía Blanca and Olavarría; in other words, the same project that had been rejected in the previous hearing. The difference was that this time the requesters accounted for 82.14% of the votes, thereby exceeding the 70% limit needed to avoid a veto. The request set the maximum fee at US$43,666,667 plus VAT, to be paid for 15 years. The remuneration for the independent transmission firm that won the auction to build the project was completed with US$80 million to be received during the construction phase, drawn from the subaccount containing surpluses arising from transmission capacity constraints (SALEX). These values were based on the fact that SALEX had sufficient funds at that time to ensure that at least the amount requested as an advance would be available at the time of starting the construction.[12]

[11] GEEAC consisted of Capex, Central Térmica Alto Valle, Hidroeléctrica Cerros Colorados, Hidroeléctrica Piedra del Águila, Hidroeléctrica Alicurá, Hidroeléctrica El Chocón, Turbine Power Co., and Central Puerto.

[12] In practice, between the date of the request and the start of construction work in 1997, funds continued to accumulate in the account because of transmission constraints. As a result, an amount far in excess of the US$80 million requested was ultimately available, and this was used to pay the fee for the first two years.

Table 2
Beneficiaries

Name of firm	% fee payment
Capex	8.81
Central Puerto	7.22
Central Térmica Alto Valle	1.43
Central Térmica Filo Morado	0.92
Edelap	0.58
Edenor	0.11
Ederesa	0.02
Edesur	1.49
Ente Ejecutivo Presa Casa de Piedra	0.96
Eseba Distribución	3.98
Eseba Generación	5.51
Hidroeléctrica Alicurá	13.94
Hidroeléctrica Cerros Colorados	4.86
Hidroeléctrica El Chocón	16.31
Hidroeléctrica Piedra del Águila	27.42
Pichi Picún Leufú	4.29
Turbine Power Co.	2.15

At this point it is worth explaining how the maximum fee was calculated by the requesters. To do so, they simulated the financial results of an independent transmission firm whose aim was to build, operate and maintain this fourth line over a 30-year horizon. This exercise provided the value of the proposed maximum fee, which gave an internal rate of return of 12.55% (real) for shareholders of the future transmission firm.

3.2.2. The battle between transmission firms

As the new request reflected broad consensus among the beneficiaries, and the maximum fee proposed with the advance of funds from the SALEX account were attractive values, the process was expected to surge ahead; but in practice this did not happen.

Starting with the request (May 1996), and given the certainty that the project would materialize, Transener started to play a major role in the process. Usually, the existing transmission firm plays at least the following roles in an expansion project:

- *Counterparty*: As concession holder of the electric power transmission public service, linked to the expansion project, it has to give an opinion on relevant technical aspects of the project.
- *Operator*: As operator of the existing system, it must continue to operate and maintain existing facilities to which the new project will be connected — a role that regulation did not clearly define at the time of the request.
- *Issuer of technical license*: The existing transmission firm issues the technical license governing the conditions for building, operation and maintenance of the new installations.
- *Supervisor*: As supervisor it is responsible for overseeing the new works at all stages of construction and operation.
- *Competitor*: In this role it is a potential bidder in the auction to choose the new independent transmission firm.

The initial negotiations between GEEAC and Transener addressed the technical aspects of the project. Transener acted in its counterparty role and had to define the relevant technical aspects.

As seen in ENRE Resolution 613/96, after about three months the parties notified ENRE (1996) on 3 September that they had agreed on the points that were in dispute. This enabled ENRE to call a public hearing which was finally held on 25 September that year.

As expected, the only dissenting voice in that hearing was Eseba Generación, which claimed its geographic position would prevent it from benefiting in proportion to its share of the payments. This argument was rejected by ENRE. Nonetheless, the most interesting aspect of the hearing was the conflict of faced by Transener, particularly concerning its roles as operator, issuer of the technical license and potential bidder.

One of the potential independent transmission firms (Litsa–Cartelone) claimed that the procedure should ensure that only firms that were in equal conditions would compete, without creating *de facto or de jure* advantages that placed one or more of the potential bidders in a privileged situation. According to Litsa–Cartelone, this would be achieved by excluding parties that had conflicts of interest — specifically in this case Transener.

The concerns raised by Litsa–Cartelone were partly justified. In particular, one would expect Transener to try to impose discriminatory technical conditions exceeding those established in the transmission services concession contract, in order to increase its rivals' costs. Justifiably, Litsa–Cartelone argued that these technical conditions ought not to differ from those imposed by licenses already granted, unless objective and verifiable circumstances so justified. Nonetheless, it was clear that Litsa–Cartelone also wanted to exclude Transener simply to eliminate a competitor.

On 24 October 1996, ENRE approved the expansion request and the maximum fee proposed by the requesters (Resolution 613/96), and proceeded to issue the certificate of convenience and necessity (CCN). It also authorized an appropriation of funds to the project from the SALEX account. At that time, the second round of negotiations between GEEAC and Transener began, in which the latter this time acted as technical license issuer. Given Transener's interest in participating in the auction, it is hardly surprising that it tried to insist that it should itself be responsible for maintaining the equipment relating to the new line to be installed in the existing substations. This left competitors in the uncomfortable situation of having to choose between building new equipment to be connected – a cost that Transener as the transmission firm did not have to incur – or else use the existing equipment and contract the service. The problem with this second alternative was that the regulations at the time said nothing about how fees should be set, and Transener was interpreting it as an unregulated service. GEEAC realized that if Transener was left free to set these fees, it would reduce competition in the auction process. Although GEEAC wanted the largest number of bidders, it came to the conclusion that the way to achieve this was by excluding Transener from the auction process. As a result, the negotiations lasted considerably longer than on the previous occasion, and only in March 1997 (six months after approval) did ENRE issue Resolution 227, stating that the operation and maintenance of existing substations affected by the fourth line project would be carried out by Transener, provided they were "consistent with the guidelines of the reference project" (understood to mean the project approved in the request), and defining the charges associated with those services. Then, on 19 May 1997, ENRE convened a hearing of the parties in which it was agreed that Transener could participate in the auction, but which included an alternative project that would enable the independent transmission firm itself to carry out the operation and maintenance of all project components.[13] By virtue of

[13] The bidding documents allowed for three contracting alternatives: (i) total coincidence with the reference project, i.e. direct connection to existing substations; (ii) connection by extending bars and sectionizers, with installations adjacent to those already existing, and provided by the contractor; (iii) connection with extension of bars with switches in installations provided by the contractor, adjacent to those already existing.

Options (i) and (ii), meant that Transener would operate and maintain the existing substations, unlike variant (iii) which allowed the successful bidder to maintain and operate the installations.

this agreement, on 22 May ENRE issued Resolution 525/97, approving the bidding documents submitted by GEEAC.

This was not the end of the process, however, because Litsa–Cartelone again attempted to exclude Transener, this time by challenging its right to participation in a petition to ENRE. It argued that Transener would enjoy tax advantages if it did not set up a firm of exclusive purpose to participate in the auction, and that, in any event, it was technically inconvenient and even impossible for two different operators to coexist. On 6 August 1997, however, ENRE rejected the petition (Resolution 742/97).

As can be seen, there was a struggle at this stage between Transener and the potential entrants. On the one hand, Transener tried to include rules that raised its competitors' costs, while on the other hand, the potential entrants tried to exclude Transener and thereby reduce competition in the auction. Ultimately the dispute was resolved in the most favorable way for the auction process, by allowing participation by all actors, with the regulations being adapted and complemented for this purpose.

The final part of this process, and perhaps the least well known, concerns what happened at the end of the auction, when Transener and the entrants had exhausted all regulatory avenues for getting their arguments included in the bidding procedure. As the auction involved technical prequalification prior to opening the envelopes containing the economic bids, Transener filed arguments to disqualify one of the technical alternatives presented by Litsa–Cartelone, and this had to be resolved by GEEAC.[14] In the end, none of the alternatives was disqualified, and the outcome was the successful result described below.

3.3. The outcome: auctions vs. regulation once again

Fig. 6 shows the bids submitted in the auction. The line was awarded to Transener with a toll of US$24.52 million, but the range of bids was wide, with a maximum of US$39.47 million bid by Atalaya Energy, the consortium formed by the project beneficiaries. Nonetheless, competition was tight: the Líneas de Transmisión del Comahue consortium submitted bids that were scarcely higher than the winning bid itself.

Proposition 2.7 says that the difference between Atalaya's and the winner's bid is a conservative estimate of the benefit of auctioning the line instead of regulating tolls. Thus:

Result 3.1. *If in Argentina the line had been regulated optimally, the toll would have been at least 61% higher (US$39.47 million compared to US$24.52 million).*

In practice, once a project has been approved it is unlikely that a regulator can turn back. In that case, the regulated toll would have been equal to c^+. Although it cannot be estimated with the information obtained from the auction, the toll would clearly have been at least as high as the US $39.47 million bid by the beneficiary consortium. Accordingly, Result 3.1 is a conservative estimate of how much more would have been paid for the transmission line if Transener had been legally appointed as a monopoly to build the line, and its toll had been regulated.

3.4. Who decides whether a line should be built?

Once it has been decided to hold the auction, it could be argued that the Argentine mechanism allows for the lowest possible expected tolls, given that information is asymmetric.

[14] A number of GEEAC members formed an independent transmission firm of their own to participate in the auction, for which reason they abstained from participating in bid prequalification.

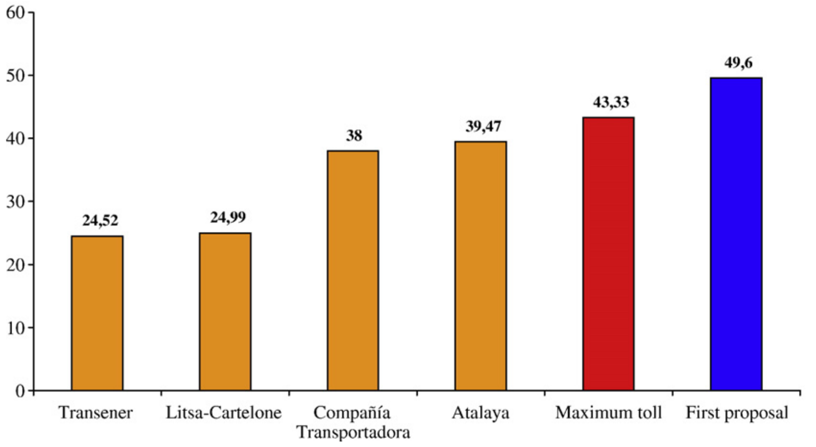

Fig. 6. The outcome of the auction (annual toll in US$ millions).

Nonetheless, one of the defects of the transmission expansion mechanism in Argentina is the veto right available to 30% of beneficiaries.[15] As seen above, although the fourth Comahue line was first proposed in 1994, its construction was only approved in August 1997.

It has long been realized that under the Argentine voting mechanism, not all socially desirable projects are necessarily carried out; and also that, on the contrary, socially unprofitable projects are sometimes approved (see Chisari et al. (2001)). Nonetheless, it seems implausible, to say the least, to argue that the delay in constructing the fourth line was a result of the generators' attempts to block a socially profitable project that imposed private losses on them. On the contrary, the sequence of events described above suggests that the mechanism made it possible for the line to be built for much less than would have been the case if the procedure had been different.

To start with, the first postponement following the veto by a number of generating firms can be explained by the fact that the initial project was expensive. This can be seen not only from the difference between the fee proposed by the BOM contract and that which emerged from the auction (just under US$60 million compared to US$25 million); the same conclusion holds when comparing the BOM contract proposed with the highest bid in the second request.

A simple comparison can be made between the present value of tolls to be paid by beneficiaries under the fee proposed in the BOM contract (first request), with the maximum fee plus the advance of SALEX funds in the second request. In calculating present values we used a 10% discount rate[16]; the exercise shows that the implicit cost in the BOM contract fee was US$370.1 million, compared to US$346.5 million with the maximum fee — i.e. the second request envisaged a project that was US $23.6 million or 6.3% cheaper. The fact that nearly all generators approved the second project, but not the first one, at least suggests that the threshold that made the project socially profitable was of this order of magnitude. Unless the private benefit of those voting in favor of the first hearing had been very large, is at least plausible to claim that the first proposal might not have been socially profitable. Of course, if we consider the final value that resulted from the auction, we conclude that the definitive project turned out to be US$144 million cheaper, or 40% less expensive in present

[15] An additional defect, discussed by Chisari et al (2001) is that not all beneficiary parties vote in the project.

[16] This assumes a two-year construction period and the following timetable for paying the US$80 million advance proposed by GEEAC over the two years: 15.5% in the first semester; 70.7% in the second; 3.8% in the third, and 10% in the fourth semester.

value terms. These magnitudes are significant and suggest that the delay was socially desirable; they also show that it is convenient for the parties that will pay for the line to be the ones who finally decide whether or not it gets built.

Lastly, as we saw above, once the line had been approved, subsequent postponements were mainly the result of attempts by the transmission firms to influence the rules so as to make the auction less competitive. But this delay was also worthwhile, because the rules that ultimately emerged allowed beneficiaries to participate in the auction along with the existing transmission firm, but forced Transener to grant nondiscriminatory access to its facilities.

4. Concluding remarks

In this paper we argue that auctioning transmission lines is far better than directly regulating them. Auctions dominate regulation in general. Moreover, when the social welfare function depends only on social costs and benefits, but not on who receives rents, an auction dominates regulation even when the regulator can perfectly audit costs ex post. Last, one can expect substantially lower tolls when lines are auctioned. Our premise is that regulation is like a one-firm auction, and there are substantial gains to be realized from competition and beneficiary participation.

The last observation concerns the procedure that is followed in Argentina to decide whether to build a line. In Argentina the decision is delegated to beneficiaries, and so the system is more or less fully “unregulated”. In Chile, by contrast, recent changes to the electricity law mandate the auctioning of new transmission lines in ways that closely follow Argentina’s, but delegate expansion decisions to an independent committee which centrally decides which lines are to be built. Our point here is that nothing prevents auctions from being used even in a centrally planned transmission system. The decision on whether to build a line can be almost fully separated from the decision of how to set its toll.

Appendix A. The Argentine transmission system and its remuneration

A.1. Description

Argentina’s high-voltage energy transport system (Sistema de Transporte de Energía en Alta Tensión) consists of transmission installations for voltages of 220 kV and above, and includes compensation, transformation, maneuver, control and communications equipment, together with some 9700 km of power lines. Transener is the system’s leading transmission firm by far, with lines totaling around 8800 km.

The firm responsible for operating the system receives around US$33 million per year for doing so. This amount, which is referred to as remuneration for transmission capacity, is established every five years by Argentina’s electric power regulator (ENRE) to cover operating costs. Remuneration for transmission capacity is divided into three components: variable remuneration, which corresponds to transmission losses valued at the cost of energy and power; the connection charge, which corresponds to income for operating and maintaining the equipment needed to connect users to the system; and a complementary charge, which, when added to the previous categories, completes the annual remuneration approved every five years. Parties responsible for paying each of the three charges – known as transmission system users – consist firstly of generators, co-generators and self-generators in their generating functions; and secondly of distributors and large users, as customers. A distinctive characteristic of the Argentine system is that the remuneration of existing lines when the industry was privatized in the early 1990s did not include investment costs.

The variable remuneration component is paid by the different users, based on the energy they inject into and withdraw from the system. This is implicit in the price differences between nodes due to energy and power losses. To set the connection charge, an amount for installation is defined, and this is paid by users connected to each node of the system, prorating the power they inject or withdraw at the corresponding node. Lastly, the complementary charge is allocated to each user by identifying the footprints of each node of the system.[17]

Next we briefly describe the way in which each of the charges is calculated, and the mechanisms used to identify areas of influence.

A.2. Remuneration of the transmission system

Variable remuneration. When energy and power are transmitted, part of it is lost. As total losses are proportional to the square of the power transmitted, marginal losses are greater than average losses. Thus, if node prices are adjusted to cover marginal losses, an agent that buys at exporting node a, paying the marginal price, and then withdraws and sells at an importing node b, at the marginal price in that node, will end up with a positive difference. In Argentina this difference is referred to as the variable remuneration, and it is kept by the transmission firm.

A little more formally, if we let C_v be the variable remuneration, this is equal to

$$C_v = p_b E_b - p_a E_a \tag{A.1}$$

where E_b is the energy arriving at node b, E_a is the energy leaving node a, p_b is the price at node b, and p_a is the price at node a. Clearly, $E_b < E_a$ because part of the energy transmitted is lost. (Expressions for power are similar, and we omit them for brevity). Nonetheless, if the difference $p_b - p_a$ is equal to the marginal loss, then $\frac{p_b}{p_a} > \frac{E_a}{E_b}$, because the marginal losses are greater than average losses. Accordingly, $C_v = p_b E_b - p_a E_a > 0$.

In practice, the Argentine price system is uni-nodal, and marginal losses are recognized as node factors. A market node is defined (Ezeiza, in the outskirts of Buenos Aires) where the market price p^{me} is established. Prices at each of the system nodes are proportional to the market price according to node factors that reflect marginal losses under normal operating conditions. Thus, expression (A.1) can be rewritten as:

$$C_v = (f_b E_b - f_a E_a) \times p^{me}, \tag{A.2}$$

where f_i is the node factor of node i. In our example, $p_b - p_a = p^{me} f_b - p^{me} f_a$.

It is interesting to discuss how the Argentine regulations treat income variables when a line transmitting to the market becomes congested. In that case, the exporter node price a becomes de-linked from the rest of the market, in the sense that the difference $p_b - p_a$ is greater than that explained by marginal losses, $p^{me} f_b - p^{me} f_a$ — in other words, the price at node a is less than the price at the importer node b, minus energy losses. This is why the price is determined through

[17] The area of influence, or footprint, of a transmission system user is defined as the set of lines and other network installations that are directly or indirectly affected by an injection or withdrawal of power in the node where the user is installed. A line or installation is considered affected when its power flow increases as a result of an increase in power injected or withdrawn in the node where the user is installed.

the equilibrium of local supply and demand when the node becomes de-linked from the rest of the market. The maximum capacity of the line is only an additional demand in exporter node a or an additional injection in importer node b, but does not determine the margin.

Thus, when the line becomes congested, the income of an agent that could buy at price p_a at the exporter node a, and then sell at the importer node b, would be:

$$C_{\mathrm{v}}^{c}=\left(f_b E_b-\frac{p_a}{p^{\mathrm{me}}}E_a\right)\times p^{\mathrm{me}}.$$

Nonetheless, the Argentine regulations require the variable income of the transmission firm to remain equal to (A.2). The difference

$$C_{\mathrm{v}}^{c}-C_{\mathrm{v}}=E_a\cdot p^{\mathrm{me}}\left(f_a\frac{p_a}{p^{\mathrm{me}}}\right)$$

is known as congestion rent or variable revenue.

What happens to the congestion rent? Clearly, if remuneration by the existing system does not include investments and, as we shall see below, system expansions are not directly assigned to the firm that operates the congested lines, the rent cannot remain in the hands of the operator. The question is whether or not it is paid to the users that cause the congestion. The answer is no, because it is not directly allocated to either of them. This revenue is accumulated in a special account, managed by the wholesale market management operator (CAMESSA), whose funds are used only to make investments in congested corridors and are allocated as described below.

The connection charge. Every five years an hourly charge is set for connection to each type of equipment — transformers, lines and switches. The charge at each node is distributed between the users that are connected, according to their pro-rated share of the maximum total power at the point of connection. Maximum power demanded is used in the case of consumers, and nominal power in the case of generators. This charge is applied to the hours for which the equipment is really available, with penalties deducted for non-availability.

The complementary charge and areas of influence. This charge ensures that the operator receives all of the remuneration for transmission capacity, and is equal to the difference between the latter and the revenue obtained from the variable remuneration. Each user is charged according to its prorate share of each line within its respective footprint.

In Argentina the law defines the Ezeiza node as the only point of reference for determining the use made of the transmission system by the various users. Broadly speaking, installations whose energy flows are in the direction of Ezeiza are paid by energy injections at the point of origin (generators), whereas installations whose energy flows are directed away from Ezeiza towards consumption, are paid by distributors or customers. It is worth mentioning that this use concept for each line is economically correct, and the only debatable point is the fact that the market node is fixed by fiat.

Power flows are estimated for a set of typical system operating states t. Then, at each node k, unit increments of power generated or demanded are applied individually, compensated by a variation in the Ezeiza node, which thus acts as the swing bus. The footprint of node k will therefore be the set of lines in which the power flow increased. If we define $\Delta(i, k, t)$ as the variation of the power flow on line i given a unit variation $\Delta(k)$ in power generated or demanded at node k under operating state t, the area of influence of node k consists of lines i

such that $\Delta(i, k, t) > 0$ given the unit increase of power generated or demanded by node k. Let A_i be the set of nodes such that line i forms part of their area of influence.

Once this exercise has been done for each node and operating state, the pro-rata share of node k in line i under state t is determined. Let

$$P^{\max}(i,k,t) = \frac{\Delta(i,k,t)}{\Delta(k)} \times P^{\max}(k),$$

where P (k) is the maximum power generated or consumed at node k. And let

$$P_{\text{total}}^{\max}(i,t) = \sum_{j \in \mathcal{A}_i} P^{\max}(i,j,t).$$

The so-called node k share factor in the use of line i under operating state t is therefore

$$\lambda(i,k,t) = \frac{P^{\max}(i,k,t)}{P_{\text{total}}^{\max}(i,t)}.$$

The share of node k in line i is distributed among users connected to the node either directly, or else indirectly through subtransmission facilities that do not belong to the transmission firm. The share factor of a user located at node k is equal to the fraction of total power for which the user is responsible (power dispatched in the case of generators, or demanded in the case of distributors or large customers).

Appendix B. Mechanisms for expanding the transmission system

In this appendix we provide a more detailed description of the mechanisms used to expand the Argentine transmission system.

Expansions in Argentina are carried out by "independent transmission firms" — the owners of transmission lines and installations that are made available to the transmission system operator under conditions established in the technical license.[18] Independent transmission firms are not agents of the wholesale electric power market (MEM).

There are two regulatory frameworks for power transmission. As mentioned above, in the case of existing installations users only pay maintenance and operation costs, but not investment costs. Although this is not a necessary condition, it has enabled the Argentine system to develop a different regulatory framework for expansions, which it was decided to carry out on a competitive basis, applying the principle of replacing regulation by competition for the field, as originally proposed by Chadwick (1859) and later popularized by Demsetz (1968). The principle behind this idea when applied to electric power transmission is that although economies of scale exist, they are largely exhausted at the level of each project. Accordingly, the existing firm does not necessarily have lower costs in the case of new projects, even though the average cost of each project falls as its size increases.

Below we describe the mechanisms included in the Argentine regulations for expanding transition installations.

[18] The system operator collects the remuneration of the entire transmission system on a monthly basis, and then transfers the fraction corresponding to the independent transmission installations.

B.1. Expansion modalities

Expansions of transmission capacity through contracts between the parties. When one or more market agents (generators, distributors or large customers) need to expand the capacity of the transmission system, they can enter into a build, operate and maintain (BOM) contract with the operator or an independent transmission firm.

To enter into a BOM contract, an expansion request must be presented to the operator, who in turn notifies ENRE. The regulator holds a public hearing and authorizes the project if there is no justified opposition. This authorization enables the operator to issue the corresponding technical license.[19] Once this has been done, expansions are remunerated in the same way as existing installations.

Expansions of transmission capacity through competitive tender. A market agent or group of agents can also ask the operator of the system to which they wish to connect, for authorization to carry out an expansion through public tender. The request may be made in two modalities:

- An offer of a BOM contract, from a transmission firm or a party interested in becoming an independent transmission firm, for a constant annual fee to be paid by project users over a 15-year period.
- A maximum annual fee proposal to be paid for 15 years by project users, accompanied by a technical bid and an economic evaluation demonstrating, to the satisfaction of ENRE, the economic feasibility of the expansion remunerated with the proposed fee.

The request can only be filed if the sum total of the requesters' line use share factors is at least 30%. This information must be ratified by CAMESSA, which at the request of the transmission firm calculates the participation factors and the proportion in which each agent should share in the pro-rated amortization costs. Once this has been accomplished, the transmission firm applies to ENRE for the certificate of convenience and necessity (CCN).

At that time, ENRE evaluates the requests. The decision criterion is that the present value of the total cost of investment, operation and maintenance of the electric power system, including the modifications arising from the expansion being requested, should be less than the present value of the total cost of operation and maintenance of the modifications, including in such operating costs the value of energy not supplied. ENRE then publishes the request, together with the proposed amortization period, the annual maximum fee and the agents that will pay for the expansion in the proportions determined by CAMESSA, and holds a public hearing.

The public hearing may reveal opposition to the request, which if it represents more than a 30% share of line payments, obliges ENRE to reject the request without further ado. If this situation does not arise, but there is justified opposition in the judgment of ENRE, the latter may seek the opinion of independent consultants and resolve the issue directly. If there is no opposition, however, ENRE approves the expansion request, the amortization period, the

[19] The technical license contains the technical conditions for construction, operation and maintenance to be complied with to connect the equipment to the system; it must also specify the necessary technical requirements to ensure the required quality of service, the operator's supervision faculty, the sanctions regime for non-compliance, and additional services to be provided. These conditions may not exceed those established in the concession contract with the operator that issues the license.

annual fee, the beneficiaries and their shares in the fee payment, and issues the CCN for the expansion, thereby authorizing the transmission firm to define the terms of the technical license needed for its execution.

Once ENRE authorization has been obtained, the requester or requester group, which now becomes the contract principal, must hold a competitive auction for the construction, operation and maintenance of the expansion proposed in its request. Depending on the modality used in the request, the following types of auction are possible:

- Request with BOM contract offer.
  - (i) The bidder that proposed the project can compete in the auction.
  - (ii) If nobody bids a lower fee than that quoted in the request evaluated by ENRE, the principal is authorized to enter into the BOM contract with the independent transmission firm whose bid accompanied the request, for the approved annual fee.
  - (iii) In the event that there are annual fee bids between 85% and 100% of the fee contained in the request, the bidders satisfying this condition and the transmission firm or independent transmission firm that accompanied the offer will be entitled to improve their bids, and the contract will be awarded on the basis of lowest annual fee.
  - (iv) If there are bids below 85% of the annual fee contained in the request, the contract will be awarded directly to the lowest bidder.
- Request with maximum annual fee bid
  - (i) If bids are presented that are lower than the annual maximum fee included in the expansion request, ENRE shall directly authorize the principal to sign a BOM contract with the auction winner.
  - (ii) If there are no bids with annual fees below the maximum included in the expansion request, ENRE l declare the auction void, automatically revoking the CCN already issued.

Extension of installations. These are expansions or adaptations of existing transformer stations owned by an operator or an independent transmission firm, which do not form part of an expansion reaching beyond the transformer station.

In such case, a transmission firm wishing to expand its installations must submit a budget for the civil works and an annual fee proposal, together with the request for a certificate of convenience and necessity. ENRE will process the request if it considers that the technical, economic, reliability, safety, and transmission capacity studies submitted by the requester justify the expansion; and it accepts the operating and maintenance costs declared by the requester. These may not exceed regulated values for the existing installations. Once this has been satisfied, ENRE authorizes the requester to convene an auction process.

In expansions requested by the operator or the independent transmission firm that owns the station, the inspection of the civil works will be carried out by the owner of the station for the fee quoted by it, provided this is duly justified and supported in an adequate declaration of costs, to the satisfaction of ENRE, with supervision charges included in this amount. If none of the bids received for engineering, supply and assembly are better than the fee budgeted by the requester that owns the station, ENRE will declare the auction void, thereby automatically revoking the CCN previously issued.

The SALEX account. Regardless of the modality adopted, requesters may ask for a transfer of funds from a subaccount containing surpluses arising from transmission capacity constraints on a given expansion, which can be drawn on for advance payment of the construction of the expansion works.

B.2. Remuneration of expansions

Amortization and exploitation. The remuneration of expansions carried out through BOM contracts should follow the same guidelines that regulate expansions under the public auction procedure, namely:

- during the amortization period, monthly remuneration equal to 1/12 of the approved annual fee.
- during the exploitation period, which starts once the amortization period has concluded, the monthly remuneration is what results from the remuneration regime applicable to the transmission firm's existing installations, as discussed in the previous appendix.

During the amortization period, the revenue indicated is obtained through variable transmission tolls plus the complementary charge until the fee is completed; and it is distributed between users according to their share factors, following the procedure described in the previous appendix.

Payments from the independent transmission firm to the operator. The independent transmission firm that wins an auction must build, operate and maintain the expansion under the operator's supervision. For supervising and operating the line, the operator will receive the following payments:

- During the construction period, a supervision charge equivalent to 3% of the total value of the civil works, payable in equal monthly installments matching the number of months stipulated for its construction.
- During the operation period, a charge for supervision. During the expansion amortization period, this charge is equal to 4% of the remuneration applicable to the installation if it formed part of existing facilities. During the exploitation period, this charge is equal to 2.5% of the remuneration for carrying out the activity covered by the technical license.

B.3. Financial transmission rights

At the start of this decade, the above-mentioned procedures were complemented by allowing stakeholders (market agents or otherwise) that were not payers of an expansion, to participate in its financing by acquiring financial transmission rights in proportion to the extent to which they finance the cost of the civil works. The term "financial transmission rights" means the right to receive charges for congestion and losses as defined in Appendix A.

Appendix C. Proofs

In this appendix we provide formal proofs for a number of lemmas quoted in the text.

C.1. Auctions vs. regulation

Lemma C.1. *Let $\lambda = 0$. If regulation is optimal then expected beneficiary surplus is*

$$E_c[\max\{\upsilon_s - \mathrm{MC}(c), 0\}].$$

Proof. Note that optimal regulation is equivalent to a mechanism P: $[c^-, c^+]\to[0, 1]$ such that

$$P(c) = \begin{cases} 1, & \text{if } c \le \pi^r(0, \upsilon_s), \\ 0, & \text{if } c > \pi^r(0, \upsilon_s), \end{cases}$$

with π^r that satisfies

$$\upsilon_s = \pi^r + \frac{F(\pi^r)}{f(\pi^r)} = \mathrm{MC}(\pi^r)$$

(in the rest of the proof we will use π^r to mean π^r $(0, \upsilon_s)$). As shown in Fig. 1, an elementary relation in price theory implies that

$$F(\pi)\cdot\pi = \int_{c^-}^{\pi} \mathrm{MC}(c)f(c)dc.$$

Accordingly, the expected surplus from regulation is

$$F[\pi^r]\cdot(\upsilon_s - \pi^r) = \int_{c^-}^{c^+} [\upsilon_s - \mathrm{MC}(c)]f(c)P(c)dc = E_c[\ \max\ \{\upsilon_s - \mathrm{MC}(c), 0\}]. \qquad \square$$

Lemma C.2. *Expected beneficiary surplus in an English auction in which two firms compete is*

$$E_{c^a,c_2}[\ \max\ \{\upsilon_s - \mathrm{MC}(c^a), \upsilon_s - \mathrm{MC}(c_2)\}].$$

Proof. In an English auction, the line is awarded to the bidder that has the lowest cost, but it receives the highest cost as its toll. Accordingly, wherever $c^a \ge c_2$ the toll collected is equal to

$$F(c^a)\cdot c^a = \int_{c^-}^{c^a} \mathrm{MC}(c_2)f(c_2)dc_2;$$

and equal to

$$F(c_2)\cdot c_2 = \int_{c^-}^{c_2} \mathrm{MC}(c^a)f(c^a)dc^a$$

wherever $c_2 > c^a$. Accordingly, expected beneficiary surplus is

$$\upsilon_s - \int_{c^-}^{c^+} f(c^a)\int_{c^-}^{c_2} \mathrm{MC}(c_2)f(c_2)dc_2 - \int_{c^-}^{c^+} f(c_2)\int_{c^-}^{c_2} \mathrm{MC}(c^a)f(c^a)dc^a.$$

But, by hypothesis, the marginal cost function is increasing in c. So, expected beneficiary surplus can be rewritten as

$$\begin{aligned} &\upsilon_s - \int_{c^-}^{c^+} f(c^a)\int_{c^-}^{c^a} \min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}f(c_2)dc_2 \\ &- \int_{c^-}^{c^+} f(c_2)\int_{c^-}^{c_2} \min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}f(c^a)dc^a \\ &= \upsilon_s - \int_{c^-}^{c^+}\int_{c^-}^{c^a} \min\ \{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}f(c^a)f(c_2)dc^a dc_2 \\ &= \upsilon_s - E_{c^a,c_2}[\ \min\ \{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}] = E_{c^a,c_2}[\ \max\ \{\upsilon_s - \mathrm{MC}(c^a), \upsilon_s - \mathrm{MC}(c_2)\}]. \square \end{aligned}$$

Proposition C.3 (Competition and social welfare). *Expected social surplus in an English auction in which the regulated firm a competes with one other firm, is greater than the expected social surplus when the firm is regulated.*

Proof. To begin, note that social surplus with an auction with two firms is

$$W^A \equiv \upsilon_s - E_{c^a,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}] \\ + \lambda\left(E_{c^a,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}] - E_{c^a,c_2}[\min\{c^a, c_2\}]\right).$$

On the other hand, social surplus with regulation is equal to

$$W^r \equiv F\left(\pi^R\right)\left[\upsilon_s - \pi^R + \lambda\left(\pi^R - E_{c^a}\left[c^a | c^a \le \pi^R\right]\right)\right].$$

The claim is that

$$\upsilon_s - E[\pi(2)] + \lambda\left(E[\pi(2)] - E_{c^a,c_2}[c^a, c_2]\right) \ge F(\pi^r)(\upsilon_s - \pi^r)] + \lambda\left(\pi^r - E_{c^a}\left[c^a | c^a \le \pi^R\right]\right).$$

We prove it in two steps.

Step 1. Let $\lambda = 0$. Then $W^A = \upsilon_s - E^a_{c,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}]$ and $W^r =_F (\pi^R)\,[\upsilon_s - \pi^R]$. But we already know that expected beneficiary surplus is higher with an auction than with regulation. Hence $W^r < W^A$ when $\lambda = 0$.

Next let $\lambda = \lambda^{-}$. Then $\pi^r = c^+$ and $F(\pi^r) = 1$. Social surplus with an English auction is

$$\upsilon_s - \left(1 - \overline{\lambda}\right)E_{c^a,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}] - \overline{\lambda}E_{c^a,c_2}[\min\{c^a, c_2\}].$$

Regulation, on the other hand, yields surplus

$$\upsilon_s - \left(1 - \overline{\lambda}\right)c^+ - \overline{\lambda}E_{c^a}[c^a].$$

But $c^+ > E^a_{c,c_2}[\min\{\mathrm{MC}(c^a), \mathrm{MC}(c_2)\}]$ and $E_{c^a}[c^a] > E_{c^a,c_2}[\min\{c^a, c_2\}]$. Hence $W^r < W^A$ when $\lambda = \overline{\lambda}$.

Finally, let $\lambda = 1$. Then $W^A \equiv \upsilon_s - E^a_{c,c_2}[\min\{c^a, c_2\}]$ and (because $\pi^r = c^+$ and $F(c^+) = 1$), $W^r \equiv \upsilon_s - E^a_c[c^a]$. Hence $W^r < W^A$ when $\lambda = 1$.

Step 2. Now note social surplus with an auction is linear and increasing in λ. At the same time, the envelope theorem implies that

$$\frac{\partial W^r}{\partial \lambda} = \begin{cases} \pi^r - E[c^a | c^a \le \pi^r] & \text{if } \lambda \le \overline{\lambda}; \\ c^+ + E_{c^a}[c^a] & \text{if } \lambda \le \overline{\lambda} \end{cases}$$

and

$$\frac{\partial^2 W^r}{\partial \lambda^2} = \begin{cases} F(\pi^r)\dfrac{d\pi^r}{d\lambda} > 0 & \text{if } \lambda \le \overline{\lambda}; \\ 0 & \text{if } \lambda \le \overline{\lambda}. \end{cases}$$

Hence, social surplus with regulation is convex in λ in the interval $[0, \overline{\lambda}]$ and linear in the interval $[\overline{\lambda}, 1]$. It follows that W^r cannot cut W^A, otherwise it could not be that $W^r < W^A$ at 0, $\overline{\lambda}$ and 1. This completes the proof. □

C.2. *Auctions with beneficiary participation*

Definition C.4. Let $c \equiv [c^a, c_2,.., c_n]$, $\mathbf{A} \equiv \min\{\text{MC}(c^a),..., \text{MC}(c_n)\}$ and $\mathbf{B} \equiv \min\{\text{MC}(c^a),..., \text{MC}(c_n), c^b\}$.

Lemma C.5. *If the beneficiaries can build the line at a cost $c^b \in [c^-, c^+]$, and implement an optimal auction, their expected surplus is*

$$\upsilon_s - E_{c,c^b}[\mathbf{B}].$$

Proof. Conditional on the beneficiaries' cost being c^b, and for a direct allocation incentive-compatible mechanism p: $[c^-, c^+]^n \times [c^-, c^+] \rightarrow [0, 1]^n$, such that the firm whose cost is c^+ receives zero surplus in expected value terms, and with $\sum_i p_i(c) \in [0, 1]$ for all c and $p_i(c)$ nonincreasing in c_i (given incentives compatibility), then the beneficiaries' expected surplus can be written as

$$\left(\upsilon_s - c^b\right) + \sum_{i=a}^{n} \int_{c^-}^{c^+} \cdots \int_{c^-}^{c^+} \left[c^b - \text{MC}_i(c_i)\right] p_i(\text{c}) f(c^a) \ldots f(c_n) dc^a \ldots dc_n$$

(this is a direct application of Lemma 3 in Bulow and Klemperer (1996)). From this expression it is easy to see that the optimal allocation rule contingent on the beneficiaries' cost being c^b is:

- Award the line to i with probability 1, if

$$\text{MC}_i(c_i) = \min\ \{\text{MC}(c^a), \text{MC}(c_2), \ldots, \text{MC}(c_n)\} \le c^b.$$

- Award the line to the beneficiaries if

$$\min\ \{\text{MC}(c^a), \text{MC}(c_2), \ldots, \text{MC}(c_n)\} > c^b.$$

With this allocation rule the beneficiaries' expected surplus, conditional on their cost being c^b, is

$$\begin{aligned}&\left(\upsilon_s - c^b\right) + \sum_{i=a}^{n} \int_{c^-}^{c^+} \cdots \int_{c^-}^{c^+} \left[c^b - \text{MC}_i(c_i)\right] p_i(\text{c}) f(c^a) \ldots f(c_n) dc^a \ldots dc_n \\ &= \left(\upsilon_s - c^b\right) - E_c\left[\mathbf{B}|c^b\right].\end{aligned}$$

Lastly, the unconditional expected value of the surplus is

$$\begin{aligned}&\int_{c^-}^{c^+} \left\{ \left(\upsilon_s - c^b\right) + \sum_{i=a}^{n} \int_{c^-}^{c^+} \cdots \int_{c^-}^{c^+} \left[c^b - \text{MC}_i(c_i)\right] p_i(\text{c}) f(c^a) \ldots f(c_n) dc^a \ldots dc_n \right\} f\left(c^b\right) dc^b \\ &= \upsilon_s - \int_{c^-}^{c^+} E_\text{c}\left[\mathbf{B}|c^b\right] f\left(c^b\right) dc^b \upsilon_s - E_{\text{c},c^b}[\mathbf{B}].\end{aligned}$$ □

Lemma C.6. *In the (privately) optimal mechanism, the probability with which i builds the line if it cost is c_i is*

$$\widehat{p}_i(c_i) \equiv \mathcal{F}(c_i)[1 - F[\text{MC}(c_i)]].$$

with $F(c_i) \equiv [1 - F(c_i)]^n$.

Proof. For i to be assigned the construction of the line the following must occur simultaneously: (i) the marginal cost of the $n-1$ remaining firms must be greater; (ii) the marginal cost of i must be no greater than c^b. The function MC is increasing throughout its range; accordingly, the probability of i having the lowest marginal cost is equal to the probability of its having the lowest cost, which is equal to $F(c_i)$. For the same reason, the probability that $\mathrm{MC}(c_i) \leq c^b$ is $1-F[\mathrm{MC}(c_i)]$, which competes the proof. □

Note that in the optimal mechanism the probability of the line being assigned to i depends only on the distribution of costs, F, and not on the particular features of the mechanism. This is a simple consequence of the fact that the optimal mechanism is efficient, in the sense that when it awards the line to a firm it always chooses the lowest-cost firm.

Lemma C.7. *An English auction such that the beneficiaries bid $\pi(c^b)=MC^{-1}(c^b)$ is (privately) optimal.*

Proof. Given the revenue-equivalence theorem, this lemma can be proved by showing that in an English auction where the beneficiaries bid $\pi(c^b)=\mathrm{MC}^{-1}(c^b)$, (i) the probability of the line being awarded to firm i given that its cost is c_i is $\tilde{p}_i(c_i)$; (ii) the expected surplus of the firm whose cost is c^+ is zero. (i) follows from the fact that in an English auction such as that proposed, a firm is awarded the line only if its cost is the lowest of the n firms and its marginal cost no greater than c^b. (ii) follows by noting that a firm whose cost is c^+ is awarded the line with probability 0. □

Proposition C.8. *An English auction with n firms and beneficiary participation yields higher expected social surplus than an English auction with n firms only.*

Proof. Let $p \equiv \mathrm{prob}\ \{\mathbf{A} \leq c^b\}$, that is p is the probability that a firm wins the auction and builds the line when beneficiaries bid in the auction.

With beneficiary participation, social surplus is

$$\begin{aligned} &\upsilon_s - (1-\lambda)E_{c,c^b}[\mathbf{B}] \\ &\quad - \lambda\left(pE_{c,c^b}\left[\min\{c^a,\ldots,c_n\}|\mathbf{A}\leq c^b\right] + (1-p)E\left[c^b|\mathbf{A}\leq c^b\right]\right) \\ &\quad = \upsilon_s - (1-\lambda)E_{c,c^b}[\mathbf{B}] - \lambda\left(pE_{c,c^b}\left[\min\{c^a,\ldots,c_n\}|\mathbf{A}\leq c^b\right] + (1-p)E[c]\right), \end{aligned} \tag{C.1}$$

where we have used the fact that $E[c^b \mid \mathbf{A} \leq c^b] = E[c]$. Note that the parenthesis shows the expected cost when beneficiaries participate in the auction.

On the other hand, social surplus with an English auction with n firms only is equal toa

$$\upsilon_s - (1-\lambda)E_c[\mathbf{A}] - \lambda E_c(\min\{c^a,\ldots,c_n\}). \tag{C.2}$$

We will now rewrite (C.2) to facilitate the comparison with (C.1). Note first that

$$E_c[\mathbf{A}] \equiv E_{c,c^b}[\mathbf{B}] + (1-p)\left(E_{c,c^b}\left[\mathbf{A}|\mathbf{A}>c^b\right] - E[c]\right),$$

with $E_{c,c^b}\ [\mathbf{A} \mid \mathbf{A} \leq c^b - E[c] > 0$ because $E_c\ [\mathbf{A}] > E_{c,c^b}\ [\mathbf{B}]$. Next, note that

$$E_c[\min\{c^a,\ldots,c_n\}] \equiv (1-p)E_{c,c^b}\left[\min\{c^a,\ldots,c_n\}|\mathbf{A}>c^b\right] + pE_{c,c^b}\left[\min\{c^a,\ldots,c_n\}|\mathbf{A}\leq c^b\right].$$

Thus, social surplus with an English auction with n firms only (expression (C.2)) can be rewritten as

$$\begin{aligned} &\upsilon_s - (1-\lambda)\left[E_{c,c^b}[\mathbf{B}] + (1-p)\left(E_{c,c^b}\left[\mathbf{A}|\mathbf{A}>c^b\right] - E_{c,c^b}\left[c^b|\mathbf{A}>c^b\right]\right)\right] \\ &\quad - \lambda\left[(1-p)E_{c,c^b}\left[\min\{c^a,\ldots,c_n\}|\mathbf{A}>c^b\right] + pE_{c,c^b}\left[\min\{c^a,\ldots c_n\}|\mathbf{A}\leq c^b\right]\right]. \end{aligned} \tag{C.3}$$

Now subtract (C.3) from (C.1), social surplus with beneficiary participation. This yields

$$(1-\lambda)(1-p)\left(E_{c,c^b}\left[\mathbf{A}|\mathbf{A}>c^b\right]-E[c]\right)+\lambda(1-p)\left[E_{c,c^b}\left[\min\{c^a,\ldots,c_n\}|\mathbf{A}>c^b\right]-E[c]\right].$$

We know that the first term is strictly positive. To sign the second term, note that $\mathbf{A}>c^b$ implies that $\min\{c^a,\ldots,c_n\}\geq\pi^b\geq c^-$. Hence $E_{c,c^b}[\min\{c^a,\ldots,c_n\}\mid\mathbf{A}>c^b]>E[c]$. □

Lemma C.9. *In a (privately) optimal English auction the expected toll received by firm i when its cost is c_i, conditional on the line being awarded to it, is*

$$E_{c_{-i},c^b}\left[\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}|c_i,c_i\leq\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}\right],$$

with $c_{-i}\equiv(c^a,c_2,\ldots,c_{i-1},c_{i-1},\ldots,c_n)$.

Proof. In an optimal English auction the lowest bid wins and receives a toll equal to the second-lowest bid. For each firm it is worthwhile bidding a toll equal to cost; for the beneficiary, on the other hand, it is worthwhile offering $\mathrm{MC}^{-1}(c^b)$. Accordingly, i is awarded the line only if $c_i\leq\min\{c_{-i},\mathrm{MC}^{-1}(c^b)\}$ and it pays the expectation of the second-lowest bidder. □

Lemma C.10. *A first-price sealed-bid auction, in which the beneficiaries' bid is*

$$E_{c_{-i},c^b}\left[\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}|c_i=\mathrm{MC}^{-1}\left(c^b\right),c_i\leq\min\left\{c_{-i}\right\}\right]$$

when their valuation is c^b, is (privately) optimal.

Proof. Assume that when the cost of firm i is c_i its bid is equal to

$$E_{c_{-i},c^b}\left[\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}|c_i,c_i\leq\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}\right],$$

— its expected toll in an optimal English auction conditional on i being awarded the line — and this strategy is followed by each of the n firms. In this case, if the line is awarded to a firm, it will be the lowest-cost firm — the toll offered by i is decreasing in c_i. Moreover, if the beneficiaries' cost is c^b, then the minimum toll (i.e. the beneficiaries' bid)

$$E_{c_{-i},c^b}\left[\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}|c_i=\mathrm{MC}^{-1}\left(c^b\right)\leq\min\left\{c_{-i},\mathrm{MC}^{-1}\left(c^b\right)\right\}\right] \quad (\text{C.4})$$

is exactly equal to the bid submitted by the highest cost firm that could be awarded the line in an optimal English auction when the beneficiaries' cost was c^b.

Accordingly, the probability of the line being awarded to firm i, given that its cost is c_i, is $\hat{p}_i(c_i)$. Furthermore, the probability of the line being awarded to a firm whose cost is c^+ is 0, so its expected surplus is zero. Accordingly, the first-price sealed-bid auction such that the beneficiaries' bid is (C.4) replicates the award of the optimal auction.

Lastly, the fact that the combination of strategies examined is a Bayesian equilibrium means that the result is equivalent to an optimal direct incentive-compatible mechanism. □

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