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Abstract

I study the allocation of licenses to operate an oligopolistic market characterized by high demand uncertainty. The model is motivated by recent experiences of spectrum licensing for new telecommunication technologies. Demand is uncertain at the time of investment (roll-out). Firms rely on credit both to invest and to acquire the license. Under symmetry, and as a consequence of the possibility of default, firms' investment is decreasing in the debt inherited from the license assignment stage. We compare auctions and beauty contests. Auctions extract a higher license price, and then lower investment. From a planner's point of view, beauty contests dominate auctions when the revenue motive is unimportant and influence activities are not too wasteful.

Key words

Auctions, licenses, beauty contests, limited liability.

Resumen

En este artículo estudio la asignación de licencias para operar un mercado oligopolístico caracterizado por alta incertidumbre de demanda. El modelo es motivado por las experiencias recientes en asignación de licencias para uso de espectro radioeléctrico para su uso por las nuevas tecnologías de telecomunicaciones. La demanda es incierta en el momento de invertir (roll-out). Las empresas dependen del crédito tanto en el momento de invertir como en el momento de adquirir la licencia. Bajo simetría, y como consecuencia de la responsabilidad limitada de las empresas, la inversión de las empresas es decreciente en el volumen de deuda heredado de la fase de adquisición de licencia. Comparamos las subastas con los "concursos de belleza". Las subastas extraen un precio más alto por la licencia, y por lo tanto inducen una inversión menor. Desde un punto de vista de un planificador interesado en el excedente total, los "concursos de belleza" dominan a las acciones cuando el motivo de recaudación no es importante y las actividades de influencia no son un despilfarro.

Palabras clave

Subastas, licencias, concursos de belleza, responsabilidad.

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License Allocation and Performance in Telecommunications Markets

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C O N T E N T S

1. Introduction

A few years ago, Europe went through an exciting sequences of experiences in the allocation of licenses for UMTS or 3G telecom (see, for instance, Börgers and Dustmann, 2003, Jehiel and Moldovany, 2003, Klemperer, 2002, or van Damme, 2002). Different countries used different procedures and the results, particularly in terms of revenue, were extremely diverse. Some countries used auctions (UK, Germany, Italy, etc.), and some others used alternative, administrative procedures that are usually termed "beauty contests" (France, Spain, etc.). Much discussion has ensued as to particular aspects of design, especially auction design, in relation to issues like entry or collusion. Less has been said about the relative virtues of auctions and beauty contests. It seems that there is almost complete concensus in regarding beauty contests as inferior in terms of both efficiency, i.e., putting the licenses in the hands of the ablest, and revenue. This paper puts emphasis on a different sort of efficiency: the future behavior of firms in the final market.

It is almost a cliché to consider that any payment resulting from allocating the license will be considered as a sunk cost when firms choose their actions in the market. However, this requires that the conditions under which firms take decisions in the future are indeed unaffected by those payments. When all markets (capital and other) are perfect, this requirement may be satisfied. In the case of industries using new telecommunication technologies, we claim that this is not the case.

The sort of imperfection we consider in this paper is the uncertainty about the profitability of the market (demand and network roll-out costs). This occurred extensively when most of the licenses were allocated in Europe. This uncertainty, when coupled with limited liability, establishes a link between payments in exchange for licenses and future behavior in the market. Indeed, when firms have to resort to credit markets, uncertainty means that the interest rate is a function of both the size of new debt and the size of inherited debt. This is because the recovery rate in case the market turns out not to be viable is decreasing with total debt. Thus, at the time the firms take decisions about investment in establishing the network, the cost of capital will be larger the larger the debt inherited from acquiring the license.

In this paper we show that this results in a negative relationship between investment in network roll-out and license price. Thus, an allocation method that results in a higher price for the license also results in a lower investment in the market. We show that unless revenue motives are important, auctions will induce a level of investment below the socially efficient. Beauty contests, on the other hand, result in a higher level of investment. Thus, when beauty contests do not result in wasteful spending and revenue motives are not important, beauty contests may be superior to auctions.

Certainly, there are many caveats to the conclusions just mentioned. We conduct the analysis in an environment where firms are symmetric, so that we abstract from one of the most praised properties of auctions: the ability to identify the ablest firms. As the FCC\ put it in a filing to the US Supreme Court, "Under the auction mechanism, it is the winning bidder's willingness and ability to pay the most for the license that identifies it as the party that will best use the spectrum in the public interest" [1]. Accepting this statement, the ability to win a license is not so perfectly correlated to willingness to pay in beauty contests as it is in auctions. Thus, the aim of this paper is not to convince the reader that beauty contests are "always" superior to auctions, but rather pointing to one reason why we should not discard them as a reasonable alternative. Namely, a mechanism that extracts a high price as a reflection of licensees' willingness to pay may identify the ablest but it may also undermine their ability in the process.

We claim that our results illustrate part of what has happened in the development of 3G. For John Tennent, of Corporate Edge, the Telecom meltdown that followed the major wave of license allocation in Europe, was mainly caused by too high bid prices and the consequently high cost of debt required to finance these bids. "This prevented the telecom companies borrowing for their infraestructure and thus led to cost cutting programmes, the rest is history" [2].

There exists a literature on bidding under financial constraints, with or without the possibility of credit (for instance, Che and Gale, 1998 and 1996, Benoit and Khrisna, 2001, or Hyde and Vercammen, 2002) and limited liability (Zheng, 2001). The emphasis there is on how these (mainly exoge-

1. FCC v. NextWave Personal Communications, Inc., et al., Petition for a Writ Of Certiorari, No. 01-653 (S.Ct.), of 10/19/01; www.fcc.gov/ogc/briefs/nextwavepet.pdf.

2. Cited from Business Week Online, "Telecom Meltdown: Don't Blame Us, Say Forecasters", October 13, 2003.

nous) constraints affect behavior in the bidding game and on which auction designs are more appropriate. Here we point to the effects of bidding on future behavior in the market. In that sense, our model has no reduced form as either a private or a common value auction model. We model this investment and the final market competition similarly to Vives (1990). We add to his model credit market imperfections due to uncertainty and limited liability. The paper most closely related to this is Haan and Toolsema (2003). They also assume that firms borrow to finance their bids in a uncertain (cost) world with limited liability. The debt is assumed to affect firms' profits and behavior in the final market, because the decisions in that market (output, in our case) are taken before uncertainty is resolved. On the other hand, the market conditions are exogenous, since there is no investment stage in Haan and Toolsema (2003). The effects of these differences turn out to be dramatic. For instance, in their paper, prices are decreasing in the amount of debt, exactly the opposite of what we obtain. This is coupled with a higher probability of bankrupcy (which in their model is endogenous), and then welfare implications are more difficult to obtain. We will comment more on these differences later.

The rest of the paper is organized as follows. In Section 2 we present a simple model of oligopolistic competition preceeded by debt-financed license acquisition and investment under uncertainty. Section 3 solves the final market competitioin for given levels of investment, and once the uncertainty has resolved. We analyze investment decisions in Section 4. Section 5 establishes the efficiency benchmark by looking at the planner's solution. With all these elements, in Section 6 we compare the solutions under beauty contest auction. A section is deboted to discussing the results and some of the assumptions. Then some concluding remarks close the paper.

2. Model

N firms are potential holders of 2 licenses. Licenses are necessary to operate in a Cournot market characterized by the inverse demand function

$$p = a - b\ (q_i + q_j)$$

Firms have quadratic (variable) costs of operating in the market

$$C_i\ (q_i;\ w_i) = \frac{w_i}{2}\ q_i^2$$

that depend on the level of their investment in a physical asset, I_i: $w_i = w_i\ (I_i)$, with $w_i'(I_i) < 0$, and $w_i''\ (I_i) \geq 0$.

Once the two licenses are assigned (and after observing any price paid for them), firms simultaneously choose the level of their investment. At this point they do not know the value of the parameter a, which can take two values: low and high. With probability $1 - \alpha$, the parameter a takes the low value, which we assume as equal to 0. [3] We also assume that the liquidation value of the physical assets is lI_i, where l represents the salvage unit price of the equipment, and this is insufficient to repay the debt. For instance, this happens when, as we will assume, $l < m$, where m is the riskless price of capital. With probability α, demand will be high, so that repayment of investment (and license price) is feasible. To that effect, we assume that the high value of a (and also α) is high enough so that in the good realization if demand the (equilibrium) debt can be repaid.

We assume that firms do not have capital. Thus, they have to borrow from competitive banks both to make any payment associated to acquiring the license and to acquire the physical assets. Then firms borrow at possibly two points in time: at the time of acquiring the license and at the time of investing. As we have already mentioned, the unit cost of capital for banks is m. Finally, we assume all agents to be risk neutral.

3. Consequently, we assume that the license is worthless in this case.

3. Final market competition

DEFINE $D(w_i, w_j) = (b + w_i)(b + w_j) + b(2b + w_i + w_j)$. Given the investment decisions by both firms, and in case the parameter a takes the high value, firm i maximizes market profits

$$\pi_i^m = P(q_i + q_j)\, q_i - C_i(q_i; w_i)$$

by setting

$$q_i = a\frac{(b + w_j)}{D(w_i, w_j)} \tag{3.1}$$

and then the price is

$$p_i = a\frac{(b + w_j)(b + w_i)}{D(w_i, w_j)}$$

which implies market profits equal to

$$\pi_i^m = (b + \frac{w_i}{2})(q_i)^2 \tag{3.2}$$

Final market profits are increasing in the level of physical assets, I_i. That is, they are decreasing in w_i. Indeed

$$\frac{\partial \pi_i^m}{\partial w_i} = \frac{1}{2}(q_i)^2 + 2(b + \frac{w_i}{2})\, q_i \frac{\partial q_i}{\partial w_i}$$

and

$$\frac{\partial q_i}{\partial w_i} = -\, q_i \frac{(2b + w_j)}{D(w_i, w_j)}$$

so that

$$\frac{\partial \pi_i^m}{\partial w_i} = -\,(q_i)^2\left(\frac{1}{2} + \frac{b^2}{D\,(w_i,\,w_j)}\right) < 0$$

On the other hand, final market profits are decreasing in the level of physical assets of the rival firm, I_j (that is, increasing in w_j):

$$\frac{\partial \pi_i^m}{\partial w_j} = (2b + w_i)\;q_i\,\frac{\partial q_i}{\partial w_j}$$

and

$$\frac{\partial q_i}{\partial w_j} = q_j\,\frac{b}{D\,(w_i,\,w_j)}$$

so that

$$\frac{\partial \pi_i^m}{\partial w_j} = q_i\,q_j\,\frac{b\,(2b + w_i)}{D\,(w_i,\,w_j)} > 0$$

Also, notice that when $w_j = w = w$, so that $q_i = q_j = q$,

$$\frac{\partial \pi_i^m}{\partial w_j} + \frac{\partial \pi_i^m}{\partial w_i} = -q^2\,\frac{(b + w)^2}{2D\,(w,\,w)} < 0$$

so that an increase in symmetric levels of investment increases the final market profits of both firms.

Finally, investment in physical assets by the two firms are strategic substitutes, at least for not too disimilar investment levels. Indeed, for $q_i = q_j$ (i.e., for $w_i = w_j$), $\frac{\partial^2 \pi_i^m}{\partial w_i\,\partial wj} < 0$

4. Investment in physical assets

WHEN firms take investment decisions, they hold a debt (as a consequence of license acquisition) of B_i. At this time, firms (and banks) know α, but not the realization of the demand. That is, they are still uncertain about whether the demand in the final market will be high or low. As we have already mentioned, we assume that $l < m$, so that the liquidation value of the physical assets is not enough to repay the debt in the bad state of the world. For instance, $l(I_i) < mI_i$. Banks take that into account, so that if the firm borrows I_i the interest $r\,(I_i; B_i)$ that banks charge satisfies the zero profit condition for banks, i.e.,

$$m = \alpha r\,(I_i; B_i) + (1-\alpha)\,\frac{lI_i}{I_i + B_i}$$

under the assumption that in case of failure, the liquidation value is shared proportionally by all claimants. That is, the unit cost of funds for the firm is

$$r\,(I_i; B_i) = \frac{m}{\alpha} - \frac{1-\alpha}{\alpha}\,\frac{lI_i}{I_i + B_i} \tag{4.1}$$

Notice that this unit cost is increasing in B_i and decreasing in I_i. Then, given the level of debt B_i, firm i solves

$$Max_{I_i}\,\pi_i = \alpha\,[\pi_i^m - r\,(I_i; B_i)\,I_i - r\,(B_i)\,B_i]$$

where $r\,(B_i)$ is the rate charged by banks on the debt B_i, constant at this stage. The first order condition of this problem is

$$\left[-(q_i)^2\left(\frac{1}{2} + \frac{b^2}{D\,(w_i, w_j)}\right)\right]\frac{dw_i}{dI_i} -$$

$$\left[\frac{m}{\alpha} - \frac{(1-\alpha)\,l}{\alpha}\left(1 - \frac{B_i^2}{(I_i + B_i)^2}\right)\right] = 0 \tag{4.2}$$

We notice that

$$\frac{dI_i}{dB_i} = \frac{\frac{(1\text{-}\alpha)\, l}{\alpha} \frac{2I_iB_i}{(I_i + B_i)^3}}{\frac{\partial^2 \pi_i}{\partial I_i^2}}$$

The denominator of this expression is negative, at the optimal (interior) choice of investment. The numerator is positive. Then, we conclude

Lemma 1: $\frac{dI_i}{dB_i} < 0$

That is, the larger the payment firms make for their licenses, the lower their investment. This lemma shows the basic conflict between the two goals of public revenue and incentives to invest. Remember that $\frac{\partial^2 \pi_i^m}{\partial w_i \partial wj} < 0$. Thus, we conclude that $\frac{dI_i}{dB_j} > 0$. In other words, the larger the debt held by the rival firm, the larger the firm's willingness to invest.

In the next section we will also need to know what happens with the levels of investment when the levels of debt of both firms increase symmetrically. Notice that the respective levels of investment will also change symmetrically. That is, $dI_i = dI_j$. Thus, we are interested in $\frac{dI_i}{dB_i}\Big|_{B_i=B_j}$, where again, from equation (4.2),

$$\frac{dI_i}{dB}\Bigg|_{B_i=B_j=B} = \frac{\frac{(1-\alpha)\, l}{\alpha} \frac{2I_i B_i}{(I_i+B_i)^3}}{\frac{\partial^2 \pi_i}{\partial I_i^2} + \frac{\partial^2 \pi_i^m}{\partial w_i \partial w_j} \frac{dw_i}{dI_i} \frac{dw_j}{dI_j}}$$

The new term in the denominator is also negative. Thus, we conclude that

Lemma 2: $\frac{dI_i}{dB_i}\Big|_{B_i=B_j=B} < 0$

5. The planner's solution

WE consider what would be an optimal market solution, from a planner's point of view, under the constraint that two firms at most operate in the market, and the planner cannot control the behavior of the firms in the market. Let λ represent the shadow price of public funds. This is the value the planner places on an euro in revenues from assigning licenses. We will consider only symmetric market structures [4].

From Lemma 2, the planner can control the firms' choices of investment by simply controlling the level of debt (i.e. the relationship between B and I is invertible). Thus, let $B(I)$ be the level of debt (per firm) that corresponds to a level of investment (per firm) I. Given I, and therefore w, output in the final market will be given by equation (3.1). Then, denoting by $Q(w)$ total output for (symmetric) w, the planner's problem is

$$Max_I\, \alpha\left(\int_0^{Q(w)} (a-bx)\,dx - 2\frac{w}{2}\left[\frac{Q(w)}{2}\right]^2\right) + (1-\alpha)\,l\,(2I) - m(2I) + 2\lambda B(I)$$

the solution to which satisfies

$$-q_i^2\left[\frac{1}{2}+\frac{b}{w+3b}\right]\frac{dw}{dI} - \frac{m-(1-\alpha)\,l}{\alpha} + \frac{\lambda B'(I)}{\alpha} = 0 \qquad (5.1)$$

Let us compare equation (5.1) with (4.2). If $B = 0$, and in a symmetric equilibrium, (4.2) becomes

4. Recall that the final market is characterized by decreasing returns to scale, that $w''(I) > 0$, and that competition is more intense when firms are symmetric. Thus our restriction is without loss of generality if for a fixed amout B of total debt, the maximum total investment I is attained when the firms share the burden of B symmetrically.

$$-q_i^2\left[\frac{1}{2}+\frac{b}{w+3b}\,\frac{b}{b+w}\right]\frac{dw}{dI}-\frac{m-(1-\alpha)\,l}{\alpha}=0 \qquad (5.2)$$

Evaluated at the solution to (5.1), the left hand side of (5.2) is equal to

$$q_i^2\,\frac{b}{w+3b}\left(\frac{w}{b+w}\right)\frac{dw}{dI}-\frac{\lambda B'\ (I)}{\alpha}$$

The second order conditions for maximization of profits requires that the left hand side of (5.2) is decreasing in I_i. Under global convexity, we can then obtain some conclusions:

Remark 1: If the planner does not care about revenue ($\lambda = 0$), the level of investment in the private solution is lower than the level of investment in the second best solution even when $B = 0$. In this case, simply giving away the licenses is the best policy for the planner. When revenue is an important enough goal (λ large), then the optimal price of the license is $B > 0$.

6. Auctions and beauty contests

CONSIDER first one of the most common auction formats: sealed, pay-your bid auction. The two highest bidders each win a license, and the winners pay their own bids. Firms face a schedule $r_A(B)$, where the subscript A stands for auction, and decide how much to bid B. Since licenses are a necessary condition to obtain a positive profit, firms are willing to bid up to the point where their profits are zero [5]. In pure strategies, we conjecture that symmetric firms will bid up to that point. That is, we conjecture a sort of Bertrand equilibrium in symmetric price competition with complete information. Then, given $r(B)$, a necessary condition for pure strategies, symmetric equilibrium of this form is

$$\pi_i^m(w, w) - r(I; B^*)\mathrm{I} - r_A(B^*)B^* = 0 \qquad (6.1)$$

where $r(I; B)$ is given by (4.1), I is given by (4.2), and w is the cost levels corresponding to these (symmetric) investment levels. What equation (6.1) defines is the bid at which, conditional on winning a license, the firm breaks even in case the realization of demand is favorable (in any other case the profit for the firm is zero anyway). A second necessary condition is that the left hand side of (6.1) is negative for $B_i > B^*$. Otherwise a firm could borrow more and bid accordingly. This deviation would guarantee a license and positive profits when the state of the world is favorable. However, this second condition is guaranteed,

Lemma 3: Given conjectured bid B by all other firms, the left hand side of (6.1) is decreasing in B_i.

5. Beyond this point, banks would not be willing to lend.

Proof: The derivative of this term, using the envelope theorem, reduces to

$$\frac{\partial \pi_i^m}{\partial w_j} w_j' \frac{dI_j}{dB_i} - \frac{\partial r(I; B_i)}{\partial B_i} I - [r_A'(B_i) B_i + r_A(B_i)] \qquad (6.2).$$

Now, for (competitive) equilibrium in the credit market, $r_A(B)$ satisfies

$$r_A(B_i) = \frac{m}{\alpha} - \frac{1-\alpha}{\alpha} \frac{lI_i}{I_i + B_i}.$$

Here I_i is the level of investment that the bank can expect from the firm after bidding B_i for the license and obtaining one. The bank conjectures that the bid of the rival firms is B, so that for any bid below B it expects its own customer firm not to win a license. For any $B_i > B$ the slope of $r_A(B)$ is:

$$r_A'(B) = -\frac{1-\alpha}{\alpha} \frac{l}{(I_i + B)^2} \left[-I_i + B \frac{dI_i}{dB} \right]$$

The value of $\frac{dI_i}{dB}$, from Lemma 1, is negative. Therefore, we conclude that $r_A'(B) > 0$. Thus, the three terms in (6.2) are negative, since $\frac{\partial r(I; B_i)}{\partial B_i} < 0$, $\frac{\partial \pi_i^m}{\partial w_j} > 0$, $w_j' < 0$, and $\frac{dI_j}{dB_i} > 0$. QED

Thus, equation (6.1) is necessary and sufficient for a symmetric equilibrium in the auction of licenses. Moreover, conditions that guarantee that this equation has only one solution are not hard to find.

A.1. $w(I)$ is log convex, and $b < \frac{1}{2\sqrt{2}}$.

Lemma 4: Under A.1, the symmetric equilibrium in pure strategies when licenses are auctioned is unique.

Proof: Notice that equation (6.1) is necessary for a pure strategy, symmetric equilibrium. Indeed, if the left hand side was positive, a firm can increase its profits by increasing its bid an arbitrarily small amount. If it was negative, the bank would not be willing to lend that much.

Now, computing the derivative of the right hand side of (6.1) with respect to the symmetric level of B, and applying the envelope theorem from the optimal choice of I, we obtain

$$\frac{\partial \pi_i^m}{\partial w_j} w_j' \frac{dI_i}{dB_i}\bigg|_{B_i=B_j} - \frac{\partial r(I;B)I}{\partial B} - \frac{\partial r_A(B)B}{\partial B}.$$

Applying the envelope theorem again, we can write this as

$$\frac{\partial \pi_i^m / \partial w_j}{\partial \pi_j^m / \partial w_j} \frac{dI_i}{dB_i}\bigg|_{B_i=B_j} \frac{\partial r(I;B)I}{\partial I} - \frac{\partial r(I;B)I}{\partial B} - \frac{\partial r_A(B)B}{\partial B}$$

Now, $\left|\frac{\partial \pi_i^m / \partial w_j}{\partial \pi_j^m / \partial w_j}\right| < 1$. Also, $\left|\frac{dI_i}{dB_i}\bigg|_{B_i=B_j}\right| < 1$, under assumption A.1. Indeed,

$$\frac{\partial^2 \pi_i}{\partial I_i^2} + \frac{\partial^2 \pi_i^m}{\partial w_i \partial w_j} w_i' w_j' = \frac{\partial^2 \pi_i^m}{\partial w_i^2} \left(w_i'\right)^2 + \frac{\partial \pi_i^m}{\partial w_i} w_i'' + \frac{\partial^2 \pi_i^m}{\partial w_i \partial w_j} w_i' w_j'$$

$$-\frac{(1-\alpha)\ l}{\alpha} \frac{2I_iB_i}{(I_i+B_i)^3}$$

When $b < \frac{1}{2\sqrt{2}}$, $\frac{\partial^2 \pi_i^m}{\partial w_i^2} + \frac{\partial \pi_i^m}{\partial w_i}\frac{1}{w} + \frac{\partial^2 \pi_i^m}{\partial w_i \partial w_j}$ is negative. Together with log convexity of w, this implies that

$$\frac{\partial^2 \pi_i^m}{\partial w_i^2} \left(w_i'\right)^2 + \frac{\partial \pi_i^m}{\partial w_i} w_i'' + \frac{\partial^2 \pi_i^m}{\partial w_i \partial w_j} w_i' w_j' < 0$$

Thus, the denomiator in the expression of $\frac{\partial I_i}{dB_i}\bigg|_{B_i=B_j}$ is larger than the numerator, in absolute value. Then, the derivative of the right hand side of (6.1) with respect to B is smaller than

$$\frac{\partial r(I;B)I}{\partial I} - \frac{\partial r(I;B)I}{\partial B} - \frac{\partial r_A(B)B}{\partial B}$$

$$= \frac{m}{\alpha} - \frac{1-\alpha}{\alpha} l \left[\frac{2I}{I+B}\right] - r_A(B) - r_A'(B)B$$

$$= -\frac{1-\alpha}{\alpha} l \left[\frac{I}{I+B}\right] - r_A'(B)B < 0.$$

Thus, the right hand side (6.1) is decreasing. QED

Notice that A.1 is far from being necessary for uniqueness of symmetric equilibrium in the auction. Nevertheless, we choose to make this assumption in order to simplify the analysis.

We now turn to an alternative to auctioning: beauty contests. Many actual mechanisms fall into this category (see Dykstra and van der Windt, 2004). We choose to model a beauty contest as a lottery where the odds of different parties are proportional to the efforts (expenditure) of these parties in what we term influence activity [6]. This may be an unfair characterization, yet it is one that embodies the worst attributes that economists often critizise in them. We also claim that it portrays the main characteristic of a process that usually takes some time to conclude, during which firms are spending resources (assesment, development, etc.) with an uncertain outcome.

Thus, let S_i be the expenditure of firm i in these activities. Firm i wins a license with probability $\frac{2S_i}{\sum_j S_j}$. Investment decisions are still given by equation (4.2), with only substituting S_i for B_i. In this case, however, zero profits is not an equilibrium condition. In fact, firms choose their expenditure in influence activity so as to maximize

$$\alpha \frac{2S_i}{\sum_j S_j} \left[\pi_i^m (w, w) - r(I; S_i) I - r_{BC}(S_i) S_i\right],$$

where, since now the break-even condition for a bank is

$$m = \frac{2S_i}{\sum_j S_j} \left[\alpha r_{BC}(S_i) + (1-\alpha) \frac{lI_i}{I_i + S_i}\right]$$

satisfies that

$$r_{BC}(S_i) = \frac{\sum_j S_j}{2S_i} \frac{m}{\alpha} - \frac{1-\alpha}{\alpha} \frac{lI_i}{I_i + S_i}$$

Notice the difference between $r_{BC}(S)$ and $r_A(B)$. For the same (and symmetric) level of expenditure associated to acquiring the license ($S = B$), $r_{BC}(S) > r_A(B)$. Also, $r'_{BC}(S) < r'_A$.

In a symmetric equilibrium, firms maximize profits when all parties, banks and firms, conjecture the right expenditures in influence activities.

6. This is another difference with Haan and Toolsema (2003). They model beauty contests as fixing the price of licenses at zero. They also consider posted prices.

The first difference between beauty contests and auctions appears in the profits of the firms.

Proposition 1: *In a symmetric, pure strategy equilibrium, firms' profits are positive when licenses are assigned through a beauty contest and zero when they are assigned through an auction.*

Proof: The first order conditions for maximization of profits in a beauty contest, under equilibrium conjectures is

$$\left(\frac{\partial \pi_i^m}{\partial w_j} w_j \frac{dI_j}{dB_i} - \frac{\partial r(I;\, S)}{\partial B_i} I - [r'_{BC}(S)S + r_{BC}(S)]\right)\frac{2}{N} +$$

$$[\pi_i^m - r(I;\, S)I - r_{BC}(S)S]\ \frac{2(N-1)}{N^2\,\mathrm{S}} = 0.$$

Similarly to the case of auctions (equation (6.2)), the first term in the left hand side above is negative. Indeed, although we cannot gurantee that $r'_{BC} \geq 0$, one can check that, if $r(I;\, S) > 0$ (a condition for interior solution), then $\frac{\partial r(I;\, S)}{\partial B_i} I + [r'_{BC}(S)S + r_{BC}(S)] > 0$. On the other hand, $\frac{\partial \pi_i^m}{\partial w_j} w'_j \frac{dI_j}{dB_i} < 0$ just as in the case of auction. But if the first term is negative, we have to conclude that

$$\pi_i^m - r(I;\, S)I - r_{BC}(S)S > 0,$$

as we wanted to show. QED

This is in contrast with the results in Haan and Toolsema (2003). There firms obtain positive profits when licenses are assigned through auctions. The reason is credit rationing. In their model, uncertainty is not resolved before market competition. Thus, increasing the nominal interest rate (debt burden) induces firms to take a more aggresive stance in the market and then lowers the gross profits of firms. If uncertainty was resolved before firms had to decide on market variables, then the debt burden would be a sunk cost at this point. Thus an equilibrium with positive profits and probability of winning the auction less than one for a firm could not exist, even if bankrupcy was endogenous, as in their model.

We are also interested in how the two licencing mechanisms compare as to firms' incentives to invest. Given Lemma 2, this amounts to comparing firms' equilibrium levels of debt. That is , to compare B with S in equilibrium. As one could expect, $B > S$.

Proposition 2: *The level of investment by firms is lower when the licenses are assigned through auction than when they are assigned through a beauty contest.*

Proof: Notice that for $B = S$, in a symmetric equilibrium, firms' profits in a beauty contest are negative whenever they are negative in an auction. Indeed, firms' profits in a beauty contest are

$$\frac{2S_i}{\sum_j S_j}\left[\pi_i^m(w, w) - r(I; S_i)I - r_{BC}(S_i)S_i\right]$$

$$= \frac{2}{N}\left[\pi_i^m(w, w) - r(I; S)I - r_A(S)S\right] - \frac{2}{N}\left[r_{BC}(S)S - r_A(S)\right]S$$

Now, $r_{BC}(S) - r_A(S) > 0$, and the first term in the right hand side is ($\frac{2}{N}$ times) the profit of a firm in an auction when all firms hold a debt of S. Thus, if this profit is negative, then the left hand side, the profit of a firm in a beauty contest when all firms spend S in influence activities, is negative too. Now, if B is the equilibrium bid (level of debt) in the auction, then the profit of firms when they hold any level of debt higher than that is negative. Since, from Proposition 1 the equilibrium profit in a beauty contest is positive, we conclude that S is indeed lower than B. Then, from Lemma 2, Proposition 2 follows. QED

7. Discussion

A direct corollary of Proposition 2 is that market outcomes, that is, all that happens after licenses are assigned, are more efficient following beauty contests than following auctions. Certainly, this result is subject to several caveats. One of the important assumptions for the conclusion is that firms are symmetric. That is, the assignment mechanism does not play any role in selecting the most effective firms as users of the licenses (providers of the service). This is probably unrealistic. When firms are heterogeneous, the results above should be understood as a drawback of assignment mechanisms that use (license) price competition as a device to elicit information about the effectiveness of firms. Beauty contests (of the type analyzed above) will always result in a positive probability that a less effective firm happens to be selected as a license holder. Auctions, on the other hand, are better at putting licenses in the right hands. However, competitive bidding attains that goal by relying on the fact that firms that are more able to generate (and extract) surplus in the final market are more willing to pay, and will pay more, for a license. The point made in the previous section is that higher prices for licenses may undermine the ability of (all) firms to generate that surplus.

A second caveat has to do with revenue and waste. Indeed, in addition to outcomes in the final market, auctions and beauty contests may differ dramatically in what occurs at the moment of allocating licenses. In this respect, comparing auctions and beauty contests requires understanding what is the nature of influence activities and the expenditures that we denoted by *S*. Indeed, when licenses are auctioned, firms' payments are transfers to the seller (government). However, in the sort of beauty contests that we are considering, these payments may be of a different nature. In one extreme, one can think of the government organizing lotteries, so that influence activity simply means buying more tickets of that lottery [7]. In the other extreme,

7. Dykstra and van der Windt (2004) distinguish between lotteries and beauty contests. Beauty contests would rather range from posted prices mechanisms to multidimensional auctions.

firms' payments would be pure waste, unproductive expenses aimed only at convincing the official to award the license to the firm. In general, we would expect that a fraction of the influence activity expenditure translates into government revenues (or is spent in ways that the goverment values). Thus, a payment S of a firm would translate into a revenue δS for the government and waste $(1 - \delta) S$. Those revenues for the government are valued at λ. Thus, when revenue motives are not important, $\lambda = 0$, comparing auctions with beauty contests from the point of view of the government means comparing a social waste of $N(1 - \delta)\ S$ with the market efficiency gains of higher investment. When $\lambda > 0$, we should also consider total revenue. One first question is whether NS is larger or lower than $2B$. Che and Gale (1996) have shown that all-pay auctions with financially constrained bidders result in higher revenues for the seller than first price auctions. The possibility of hitting the constraint is lower in the former, and then this breaks revenue equivalence in its favor. We should expect something similar in our model. On the one hand, the fact that the cost of credit is increasing in the volume is a (endogenous) generalization of financial constraints. On the other hand, all-pay auctions share with the beauty contest analyzed here the fact that non-winners do have to pay their bids. It is easy to check that in equilibrium $\frac{2}{N}\, r_{BC} < r_A$. That is, for the same total expenditure in license acquisition $(2B = NS)$, we would have $S\, r_{BC} < B\, r_A$. The interest rate is the measure of financial constraints in our model. Then we conclude that firms are more "financially constrained" in a pay your bid auction than in a beauty contest, just as they are more so in a first-price auction than in an all-pay auction, in the model by Che and Gale. Additionally, in our model firms invest more under beauty contests, and as we mentioned above higher investment (as a proportion of total credit) lowers the interest rate.

Does this result in higher revenues for the seller? The answer is not clear. Indeed, part of the surplus created by lower credit constraints and then higher investment is appropriated by the firms (they obtain positive profits). Therefore, we cannot generally conclude that firms' total spending is higher under beauty contest.

There is one simplifying assumption in our model that we should Comment on. We have asumed that the probability of default $(1 - \alpha)$ is exogenous. In particular, it is independent of license payments. When licenses fetch prices as high as in th UK or Germany, this may not be the case.

Considering the posibilty of endogenous default means introducing a higher slope of the interest rate with respect to the volume of credit. Thus, this only contributes to making mechanisms that fetch high prices, like auctions, less attractive from a social point of view, by reinforcing precisely the points we have made in this paper.

8. Concluding remarks

WE have analyzed a simple model of an oligopolistic market with investment and uncertain demand. We have claimed that this is a model that fits telecommunication markets using new technologies, and have analyzed how the licensing mechanisms affect the outcome in these markets. In particular, we have emphasized the relationship between license prices and the price of credit. Due to this relationship, higher license prices result in lower investment and less market efficiency in the final market.

There are interesting issues that fall beyond the scope of this paper. One of these questions has to do with designing licensing mechanisms free from excessive pricing that still guarantee that licenses end up in the right hands, when firms are asymmetric. When firms have private information about their asymmetric characteristics, this latter goal is not trivial. Resale is not an answer, because of asymmetric information. Yet, using willingness to bid as a signal of potential performance may, as we have been arguing in this paper, affect incentives to invest. We hope that the present paper induces this and similar lines of research.

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