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Integration and Separation with Costly Demand Information

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Abstract
We consider an industry characterized by a regulated natural monopoly in the upstream market and Cournot competition with demand uncertainty in the unregulated downstream market. The realization of demand cannot be observed by the regulator, whilst it can be privately observed at some cost by the upstream monopolist. Information acquisition is also unobservable. We study whether it is better to allow the monopolist to operate in the downstream market (integration) or instead to exclude it (separation). We show that asymmetric information on demand favours separation but unobservability of information acquisition favours integration.

Keywords: Information acquisition, liberalization and separation.

JEL Classification: D82, D83, L5

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1 Introduction

Over the last thirty years, different regulatory measures have been taken with regard to the vertical organization of network industries and in particular the downstream integration of input suppliers. On the one hand, for example, structural reforms during the 1980's and the 1990's led to a separation of the transmission grid from generation in the electricity industry (England and Wales), to a divestiture of transportation service and supply of gas in the gas industry, and to a structural separation of local network from long-distance market in the telecommunications industry (A&T in USA in 1982). On the other hand, the 1996 US Telecommunication Act, removed the restrictions that kept the Regional Bell Operating Companies out of the long-distance market, and in continental Europe dominant regulated firms have been left integrated.[1]

In the context of an upstream naturally monopolistic sector and a downstream unregulated sector, the economics literature has shown that downstream integration can alter the performance of the industry in two opposite ways. On the one hand, when the access price is greater than the marginal cost of the input, an integrated firm faces lower cost in the downstream market than its rivals. This generally yields a greater output in the downstream market and higher welfare than under separation. Downstream integration can also lead to a reduction in total fixed costs due to a lower number of suppliers entering the downstream market, to efficiency gains from economies of scope and to a better coordination between investments in the upstream and downstream markets (Vickers, 1995). On the other hand, downstream integration can make it difficult to create a level playing field in the downstream market because of the incentives of the integrated firm to increase the costs of its rivals. The firm may degrade the quality of the input to harm downstream competitors (Armstrong and Sappington, 2005) or it may exaggerate its cost in order to convince the regulator to set a higher access price (Vickers, 1995).

In the present paper we note that network industries are often characterized by volatile demand conditions and analyze whether downstream integration affects the incentives of firms to estimate demand conditions and adjust production accordingly. We then analyze how these

[1] This view is well summarized by the position of the UK regulator which states (Oftel 2001) *"an all encompassing prevention of vertical integration would be unjustified, since it may hamper innovation in new services, damage competition across different platform and hinder UK firms competiting in world market. Rather than precluding integration altogether, it is more appropriate to address any competition concerns through action by sectoral regulator".* See also see Cowan, (2001) for an in depth discussion.

information acquisition and transmission issues affect the desirability of integration.

Consider the electricity sector. As discussed by Borenstein (2002), the demand for electricity is almost completely insensitive to price fluctuations and difficult to forecast. One of the reasons is that weather conditions cause large unpredictable fluctuations particularly in the demand of residential consumers. The demand for electricity also varies with the level economic growth, the technological change and with the number and types of firms using electricity as an input for their production. Moreover, consumers of electricity are heterogeneous: there are consumers who require no interruption of service and consumers who are willing to accept interruptability. Demand forecasts thus require costly predictions over the level of industrial use of electricity and knowledge of the distribution of consumers' types.

The importance of accurate demand estimates in the electricity industry then stems from the need to reduce the risk of bankruptcy of the entire system and from universal service obligation (continuity of supply in time and space). As emphasized by Borenstein (2002), storage of electricity is very costly and capacity constraints on generation facilities cannot be breached for significant periods without risk. This implies that there are constraints on the amount of electricity that can be delivered at any point of time. Yet because of the properties of electricity transmission, an imbalance of supply and demand at any one location on an electricity grid can threaten the stability of the entire grid and disrupt delivery of the product.[2] The black-out in California in 2000 for example originated in a shortfall of supply due to an unexpected increase in demand (Newbery, 2002).

Another industry where accurate demand estimation is critical to good performance is telecommunications. Whilst twenty years ago the boundaries of the telecommunications industry were stable and well defined, now a rapidly changing technology has generated a supply of rapidly changing mix of services with a highly fluctuating demand for existing services. Demand information is then necessary to design a network compatible with the services offered and to make adequate investment in infrastructure modernization.

In this paper we show that downstream integration in network industries strengthens the incentives of firms to acquire valuable information on demand conditions and adjust their production and that this increases social welfare. We consider a stylized model with an

[2] Hence, when there is structural separation between generation of power and its distribution, even though the generating firms do not have a universal service obligation *per se*, the threat of break downs of the network puts the generating firms in a situation where they have a *de facto* obligation of continuous supply.

industry characterized by an upstream market which is a regulated natural monopoly and an unregulated downstream market with Cournot competition, homogenous products and demand uncertainty. The downstream demand is random and information on its realization is valuable to the regulator for the choice of the access price and it is valuable to the downstream firms for the choice of output. We compare the performance of two industrial structures: integration, where the upstream firm is integrated with a downstream firm, and separation, where the upstream firm does not operate in the downstream market.

We start by assuming that information on demand can only be acquired by the upstream monopolist. As benchmark we then consider the case where information on demand is costly but, once acquired, it becomes public information. In this benchmark, either integration or separation can be optimal, depending on the parameters but not on the problem of inducing information acquisition by the upstream firm. Instead, when information on demand is privately acquired, a novel difference between the two industrial structures emerges. When information acquisition is observable, compared to the benchmark, separation does better than integration. This is because of an 'informational externality' that arises when information on demand reaches the downstream firm through the public nature of the regulatory mechanism. When the upstream monopolist is allowed to produce in the downstream market, underreporting demand information induces a contraction in the rival's output and thus an increase in downstream profits. As a consequence a greater informative rent must be granted to the upstream firm under integration than under separation in order to induce truthful revelation.

This result is in line with previous literature on the effects of downstream integration in regulated industries. There informational problems call for separation because integration exacerbates the incentives of the upstream monopolist to exaggerate its own marginal cost. Our paper shows that this is true also when asymmetric information refers to demand rather than cost conditions.

However, when information acquisition is not observable by the regulator, as we think it is generally the case regulator-regulated firm relationships, the effect of information problems is reversed and, as we show, integration becomes more likely to be preferable to separation. This is because with separation information revelation by the upstream monopolist is cheap talk. The only way for the regulator to induce information acquisition by the firm is to let the firm operate also in the downstream market through vertical integration. Downstream integration makes the payoff of the upstream monopolist state-dependent thus creating value for information acquisition over the realized state.

In the second part of the paper we consider the possibility of information acquisition by the unregulated downstream firms. We obtain two main results. First, we show that incentives to acquire information remain stronger under integration than under separation because the value of information for a downstream firm under separation is lower than the value of information for the upstream monopolist under integration. This is due to incentive compatibility for truthful revelation of demand information. Since the regulatory mechanism is public, the information acquired by the upstream monopolist is automatically transmitted to its rival in the downstream market. To compensate the firm for the consequent loss in profits, the regulator must design an access price schedule that reflects demand changes in such a way as to reduce the correlation of firms' strategies in the downstream market. This in turn boosts the upstream monopolist's incentives to acquire information compared to an unregulated downstream firm.

Second, we show that information acquisition by a downstream firm is less valuable for social welfare than information acquisition by the upstream monopolist. This is because information acquired by the upstream monopolist is transmitted to the downstream firms via the regulation mechanism. Instead, information acquired by an unregulated downstream firm remains private. We conclude that the presence of costly but valuable information on demand in a network industry provides an argument in favour of downstream integration of the input supplier.

Beyond being related to the issue of vertical integration in regulated industries, our paper is also related to the literature on information acquisition on demand in unregulated industries. Hauk and Hurkens (2000) discuss information acquisition in Cournot markets and compare the case where information acquisition is observable by the rival and when it is not. Hurkens and Vulkan (2001) study the relationship between entry decisions and information gathering by potential entrants, whilst Dimitrova and Schlee (2003) analyze how potential entry affects the incentives of the incumbent monopolist to acquire information on demand. Our paper is also related to the literature on information acquisition by regulated firms under optimal regulation and under price cap regulation. See for example Cremer Khalil and Rochet, (1998) for the case of optimal regulation and Iossa and Stroffolini (2002) for the case of price cap regulation.

The rest of the paper is organized as follows. In section 2 we set up the model. In section 3 we discuss the benchmark case where information acquisition is observable and acquired information can be made public at no additional cost. Section 4 analyzes the case where information acquisition is verifiable but the information is privately observed by the upstream monopolist. Section 5 considers the case of unobservable information acquisition, whilst section 6 studies the case of information acquisition by the affiliate. All proofs missing from the text are in an appendix

2 The model

We consider an industry characterized by an upstream regulated natural monopoly and a downstream unregulated market with Cournot competition, homogenous products and demand uncertainty. The production in the downstream market requires an essential input (e.g. an essential facility), produced in the upstream market. We compare two industrial structures: Integration (I) and separation (S). I indicates a situation where the upstream monopolist is allowed to produce, through a subsidiary, also in the downstream market while under S it is excluded. The number of firms in the downstream market is fixed and equal to two in both industrial structures; only one firm - in addition to the upstream monopolist - owns the technology required to produce the output. Thus the difference between the two industrial structures is solely that under separation the downstream firm that was subsidiary of the upstream monopolist is now an independent firm. This allows us to obtain sharp prediction and has no qualitative impact on our results.

The upstream market is regulated through a transfer given to the upstream monopolist and an access price paid to the upstream monopolist by the firm(s) in the downstream market for the utilization of the essential input. The technology used to produce the downstream output is the same under I and S and it only requires the essential input. Thus, the upstream monopolist's marginal cost of production of the final good is the marginal cost of the essential input, since the access price paid by its subsidiary is just an internal transfer, while for the rival the marginal cost of production of the final good is the access price. Therefore, there is a cost advantage either for the upstream monopolist or for the rival firm in the downstream market depending on whether the regulated access price is greater or lower than the marginal cost of production of the essential input. We assume that the upstream monopolist and its rival are equally efficient in the downstream market and normalize to zero both the marginal cost and the fixed cost of production.

The downstream market is characterized by a linear inverse demand function: $P(Q,\theta) = \theta - Q + \varepsilon$, where θ, with $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$, is a parameter of adverse selection; it has density function $f(\theta)$ and distribution function $F(\theta)$ satisfying the following assumption $\frac{\partial}{\partial\theta}(\frac{1-F(\theta)}{f(\theta)}) \leq 0$. $f(\theta)$ and $F(\theta)$ are common knowledge. ε is a random error with zero mean. The parameter θ can be interpreted either as the willingness to pay of consumers with preferences distributed according to $f(\theta)$ or as the level of market demand with realizations distributed according to $f(\theta)$. We denote by θ_0 and by σ^2 the mean value and the variance of the distribution of θ, respectively.

The realization of θ can be privately observed at some cost K by the upstream monopolist. In most of the paper we assume that information acquisition is prohibitively costly for the regulator and for the other firms. The regulator observes quantities and price but he cannot infer the true value of θ because of the noise ε. The informational advantage of the upstream monopolist stems from it being the incumbent firm. In Section 6, we relax this assumption and discuss the possibility that the downstream firm that was once a subsidiary of the upstream monopolist retains the technical expertise and know-how to acquire information on θ also at cost K.

The social value of information on demand stems from it serving to the determine the optimal access price and to adjust production in the downstream market. As explained in the introduction, information on demand can also be necessary to ensure continuation of service and minimize costly service disruptions. We model this effect in a reduced form and denote by u the social value of information in terms of lower risk of service disruptions. We refer to u as to 'service standards'.

Consider now the payoff of the firms, net of the information-acquisition cost. Under I, the profit function of the upstream monopolist is given by[3]

$$\Pi_I^M = (\theta - Q_I)q^M + a_I q^R + T_I \tag{1}$$

where $Q_I = q^M + q^R$ and q^M and q^R denote the quantity produced by the upstream monopolist and by the rival firm in the downstream market, respectively. T_I and a_I denote the transfer

[3]In the rest of this paper $\Pi(.)$ indicares the expected profit with respect to ε.

received by the regulator and the access price paid by the rival. The profit function of the rival is instead

$$\Pi_I^R = (\theta - Q_I - a_I)q^R \tag{2}$$

Under S, the profit function of the upstream monopolist is given by

$$\Pi_S^M = a_S Q_S + T_S \tag{3}$$

where $Q_S = 2q_S$ and q_S denotes the quantity produced by a downstream firm. T_S and a_S denote the transfer received by the regulator and the access price paid by the downstream firms. The profit of a downstream firm is

$$\Pi_S^D = (\theta - Q_S - a_S)q_S \tag{4}$$

The objective function of the regulator is given by the social value of the net consumer surplus plus the firms' profits. Let $S(\theta, Q)$ denote the gross consumer surplus, with $S'(\theta, Q) = P(\theta, Q)$ and $S''(\theta, Q) \leq 0$, and let $\lambda > 0$ denote the shadow cost of public funds due to the use of distorsive taxation to finance the transfer to the upstream monopolist. The objective function of the regulator under I, when there is information acquisition, can then be written as

$$W_I = S(\theta, Q_I) - P(\theta, Q_I)Q_I - (1+\lambda)T_I + \Pi_I^M + \Pi_I^R - K + u$$

Under S, when there is information acquisition, the regulator's objective function is

$$W_S = S(\theta, Q_S) - P(\theta, Q_S)Q_S - (1+\lambda)T_S + \Pi_S^M + 2\Pi_S^D - K + u$$

The timing of the game is the following. 1) Nature chooses θ; 2) the regulator offers the upstream monopolist the menu of contracts $\{a_I(\theta), T_I(\theta)\}$ under I and $\{a_S(\theta), T_S(\theta)\}$ under S; 3) the monopolist decides whether to acquire information on θ by investing K, and it observes θ if it does; 4) the monopolist decides whether to accept the contract offered by the regulator; the firms in the downstream market simultaneously choose their quantities; the transfer Th and the access price a_h $(h = I, S)$ are paid.

3 Costly Public Information

As benchmark we consider the case where information acquisition is observable and information can be made public at no additional cost. The optimal regulatory mechanism then induces the upstream monopolist to acquire information at cost K, then the information acquired is made public and used to adjust production in the downstream market. Under I, maximization of (1) w.r.t. q^M and of (2) w.r.t. q^R then yields the equilibrium variables in the downstream market as function of θ and a_I

$$q^M(\theta, a_I) = \frac{\theta + a_I}{3};\ q^R(\theta, a_I) = \frac{\theta - 2a_I}{3}; Q_I(\theta, a_I) = \frac{2\theta - a_I}{3}; P_I(\theta, a_I) = \frac{\theta + a_I}{3} \qquad (5)$$

Similarly, under S maximization of (**??**) w.r.t. q^S yields the equilibrium variables under Cournot competition in the downstream market as function of θ and a_S

$$q_S(\theta, a_S) = \frac{\theta - a_S}{3}; Q_S(\theta, a_S) = \frac{2\theta - 2a_S}{3}; P_S(\theta, a_S) = \frac{\theta + 2a_S}{3} \qquad (6)$$

Let $w_I(\theta, a_I) = S(\theta, Q_I) + \lambda P_I q^M + \lambda a_I q^R$ and $w_S(\theta, a_S) \equiv S(\theta, Q_S) + \lambda a_S Q_S$, we can rewrite the objective function of the regulator as

$$W_h(\theta, a_h, \Pi_h^M, K, u) = w_h(\theta, a_I) - \lambda \Pi_h^M - K + u \ \ \text{h=I,S} \qquad (7)$$

The regulator's problem then consists in setting, for each realization of θ, the couple $\left\{a_h(\theta), \Pi_h^M(\theta)\right\}$ that maximizes respectively W_h (given by 7) subject to the following two constraints

$$E\Pi_h^M(\theta) - K \geq 0, \qquad \text{h=I,S} \qquad \text{(IR-IA)}$$
$$\Pi_h^M(\theta) \geq 0 \text{ for all } \theta\epsilon \left[\underline{\theta}, \overline{\theta}\right] \qquad \text{h=I,S} \qquad \text{(IR)}$$

where $(IR - IA)$ ensures that the upstream monopolist finds it profitable to acquire information about θ; whilst (IR) ensures that the upstream monopolist accepts the regulatory contract once it has observed the realization of θ.[4] It is then immediate that, at the solution of the maximization problem the firm enjoys no rent in expectation (i.e. $E\Pi_h^M(\theta) = K$) and the optimal access prices under I and under S are respectively given by

$$a_I^*(\theta) = \frac{(5\lambda - 1)\theta}{1 + 10\lambda} \qquad (8)$$
$$a_S^*(\theta) = \frac{\theta\,(3\lambda - 1)}{2 + 6\lambda} \qquad (9)$$

with $a_h^*(\theta)$ increasing in λ. Under both I and S, the positive relationship between the access price and the shadow cost of public funds reflects a sort of Ramsey prices. On the one hand,

[4] We ignore the participation constraint of the rival, which can be shown to be always satisfied in equilibrium.

the higher a_h, the lower the transfer that needs to be paid to the upstream monopolist in order to ensure its participation. Ceteris paribus, this has a positive effect on welfare because it reduces distortionary taxation. On the other hand, the higher a_h, the lower the output in the downstream market (from 5). Ceteris paribus, this reduces welfare since production in the downstream market is suboptimal. Since the first effect is increasing in λ, whilst the second one is independent of λ, a more distortionary taxation (a greater value of λ) induces a higher level of the access price and a lower level of output. For sufficiently high λ, the first effect dominates: $a_h^*(\theta)$ is positive, i.e. higher than the marginal cost in the upstream market, and it is increasing in θ. For low λ, the second effect dominates: $a_h^*(\theta)$ is negative, i.e. lower than the marginal cost in the upstream market, and it is decreasing in θ.

In light of the above analysis let $W_h^*(\theta, K, u)$ denote the maximum value function under costly public information and information acquisition, where $W_h^*(\theta, K, u) = w_h(\theta, a_h^*(\theta)) - (1 + \lambda)K + u$. The expected welfare from information acquisition under costly public information is then

$$EW_h^*(\theta, K, u) = Ew_h(\theta, a_h^*(\theta)) - (1 + \lambda)K \ + u \tag{10}$$

Instead, if information acquisition does not occur, the expected welfare is given by $Ew_h^*(\theta_0) = w_h^*(\theta_0)$, where $w_h^*(\theta_0) \equiv Ew_h^*(a_h^*(\theta_0), \theta)$, due to linear demand. Taking the difference between $EW_h^*(.)$ and $w_h^*(\theta_0)$ we obtain the following lemma.

Lemma 1 *Costly public information on demand is socially valuable for $K \leq K_h^*$, where $K_I^* = \frac{1+8\lambda+5\lambda^2}{2(1+\lambda)(1+10\lambda)}\sigma^2 + \frac{u}{(1+\lambda)}$ and $K_S^* = \frac{(1+\lambda)}{2(1+3\lambda)(1+\lambda)}\sigma^2 + \frac{u}{(1+\lambda)}$*

Under both I and S, public information on demand θ is socially valuable because social welfare maximization calls for a different access price for any given θ and profit maximization calls for quantities under Cournot competition to vary with θ. Clearly the social value of information also increases with service standards u.

We can now compare the two industry structures.

Proposition 1 *Under costly public information, there exists a level of λ, denoted by $\lambda^* > 0$, such that (i) $W_S^*(\theta, K, u) \gtreqless W_I^*(\theta, K, u)$ and $w_S^*(\theta_0) \gtreqless w_I^*(\theta_0)$ for $\lambda \lesseqgtr \lambda^*$; (ii) $K_S^*(\lambda, u) \gtreqless K_I^*(\lambda, u)$ for $\lambda \lesseqgtr \lambda^*$. That is for $\lambda \geq \lambda^*$, under I expected welfare and the value of information are at least as high than under S. The opposite statement holds for $\lambda < \lambda^*$.*

Under both I and S, the regulator uses the access price to reduce the need for distortionary taxation and to affect the behaviour of the firms in the downstream market. When λ is high, reducing the level of distortionary taxation is particularly important and thus the social value of the revenue obtained by the upstream monopolist in downstream market under I is high. This effect favours I. When λ is low, reducing the level of distortionary taxation is less important and the main concern of the regulator becomes to increase production in the downstream market. This calls for a low access price and it favours S.

4 Observable information acquisition with private information

In this section we consider the case where information acquisition is observable but the information is privately observed by the upstream monopolist. In this case, the regulator can demand the upstream monopolist to incur cost K to acquire information and use a direct truthful regulatory mechanism of the form: $\{a_h(\theta), \Pi_h^M(\theta)\}$, with $h = I, S$. We assume that the regulatory mechanism is public information and so is the report $\widehat{\theta}$ made by the monopolist. This is realistic, given the lack of control on the activities of regulators if we assumed otherwise.[5]

4.1 Integration

Under I, consider the game played in the downstream market. Given the demand parameter announced by the upstream monopolist $\widehat{\theta}$ and the access price set by the regulator, $a_I(\widehat{\theta})$, the upstream monopolist chooses q^M to maximize

$$\Pi_I^M(\theta, \widehat{\theta}) = (\theta - q^M - q^R)q^M + a_I(\widehat{\theta})q^R + T_I(\widehat{\theta}) \tag{11}$$

whilst the rival chooses q^R so as to maximize

$$\Pi_I^R(\widehat{\theta}) = (\widehat{\theta} - q^M - q^R - a_I(\widehat{\theta}))q^R$$

Since in equilibrium $\widehat{\theta} = \theta$, the rival learns the realization of demand from the report of the monopolist and uses it to set its own output. Thus, there is an informational externality: the information that the upstream monopolist acquires becomes public through the

[5] It is also possible to show that if $\widehat{\theta}$ were confidential information, under plausible assumptions ensuring strict monotonicity, its value could be easily inferred from the value of $a_h(\widehat{\theta})$.

regulatory mechanism; this affects the strategy of the rival and, through this, the payoff of the monopolistic firm.

From the above two equations we obtain the equilibrium quantities produced in the downstream market for any given level of $\widehat{\theta}$ and $a_I(\widehat{\theta})$

$$q^M(\theta,\widehat{\theta}) = \frac{3\theta - \widehat{\theta} + 2a_I(\widehat{\theta})}{6};\ q^R(\widehat{\theta}) = \frac{\widehat{\theta} - 2a_I(\widehat{\theta})}{3} \tag{12}$$

By substituting for these equilibrium quantities in the profit function of the upstream monopolist, given by (11), and using standard techniques, we obtain the following two incentive compatibility conditions for truth-telling

$$\begin{aligned} IC1 \quad &: \quad \frac{\partial \Pi_I^M(\theta)}{\partial \theta} = q^M(\theta, \widehat{\theta} = \theta) = \frac{\theta + a_I(\theta)}{3} > 0 \\ IC2 \quad &: \quad \frac{\partial^2 \Pi_I^M(\theta)}{\partial \theta \partial \widehat{\theta}} = \frac{\partial a_I(\theta)}{\partial \theta} > \frac{1}{2} \end{aligned}$$

From ($IC1$) we note that the firm has incentives to underreport the realization of θ. How strong these incentives are depends on the rival's reaction in the unregulated market which in turns depends on whether the rival is informed or not. Suppose for a moment that also the rival is informed and sets its output on the basis of the true realization of θ. In this case, the profit function of the incumbent from reporting $\widehat{\theta}$ would be

$$\Pi_L^M(\theta,\widehat{\theta}) = (\theta - q^M(\theta,\widehat{\theta}) - q^R(\theta,\widehat{\theta}))q^M(\theta,\widehat{\theta}) + a_L(\widehat{\theta})q^R(\theta,\widehat{\theta}) + T_L(\widehat{\theta})$$

with $q^M(\theta,\widehat{\theta}) = \frac{\theta + a(\widehat{\theta})}{3}$ and $q^R(\theta,\widehat{\theta}) = \frac{\theta - 2a(\widehat{\theta})}{3}$, and we would have

$$\frac{\partial \Pi_L^M(\theta,\widehat{\theta})}{\partial \theta} = q^M(\theta,\widehat{\theta}) - \frac{\partial q^R}{\partial \theta}\left(q^M(\theta,\widehat{\theta}) - a(\widehat{\theta})\right) = \frac{2\theta + 5a(\widehat{\theta})}{9}$$

Thus when also the rival is informed, the gain from underreporting θ is as follows. First, the higher θ the greater the profit that the upstream monopolist can obtain in the downstream market for any given level of output produced by the rival. This effect is positive and given by $q^M(\theta,\widehat{\theta})$. Second, the higher θ the greater the output of the rival in the downstream market, which in turn generates two effects: it reduces the profits of the upstream monopolist in the downstream market ($-\frac{\partial q^R}{\partial \theta} q^M(\theta,\widehat{\theta})$), which is the standard result under Cournot competition with homogeneous products, and on the other hand it increases the access revenues due to greater output by the rival $\frac{\partial q^R}{\partial \theta} a(\widehat{\theta})$. The sum of these two effects is negative, but is more than compensated by the first effect described above. Overall, the firm gains from underreporting θ.

Now consider the case studied in this paper where the rival is uninformed and chooses its output on the basis of $\widehat{\theta}$, the level of demand reported by the upstream monopolist. An informational externality affects the incumbent's incentives to underreport θ.[6] Since the output of the rival depends on $\widehat{\theta}$ and not on θ, the terms $-\frac{\partial q^R}{\partial \theta} q^M(\theta, \widehat{\theta})$ and $\frac{\partial q^R}{\partial \theta} a(\widehat{\theta})$ (whose sum is negative) disappear and only the positive term $q^M(\theta, \widehat{\theta})$ remains. The incentives to underreport demand are strengthened by the fact that by underreporting θ the upstream monopolist can now induce the rival to reduce output; overall the informative externality leads to a greater informative rent.

Consider now the optimal mechanism. Let $E\Pi_I^M(\theta, a_I(\theta))$ denote the expected rent of the upstream monopolist for given access price and let μ be the non-negative multiplier associated with information acquisition constraint $(IR - IA)$, the following lemma obtains.

Lemma 2 *Let $\widehat{K}_I^0 \equiv E\Pi_I^M(\theta, \widehat{a}_I(\theta, \mu = 0))$ and $\widehat{K}_I^1 \equiv E\Pi_I^M(\theta, \widehat{a}_I(\theta, \mu = \lambda))$ with $\widehat{K}_I^1 > \widehat{K}_I^0$ Under observable information acquisition, the optimal access price schedule with integration is given by*

$$\widehat{a}_I(\theta, \mu) \equiv \frac{\theta(5\lambda - 1) - 3(\lambda - \mu(K))\frac{1-F(\theta)}{f(\theta)}}{1 + 10\lambda} \tag{13}$$

where (i) for $K \leq \widehat{K}_I^0$, $\mu(K) = 0$; (ii) for $K \in (\widehat{K}_I^0, \widehat{K}_I^1)$, $\mu(K) \in (0, \lambda)$ solves $E\Pi_I^M(\theta, \widehat{a}_I(\theta, \mu)) = K$;with $\mu'(K) \geq 0$; and (iii) for $K \geq \widehat{K}_I^1$, $\mu(K) = \lambda$.

The intuition is as follows. When K is low (i.e. $K < \widehat{K}_I^0$), the expected rent - evaluated at $a_I^*(\theta)$ - is greater than K. Thus the $(IR - IA)$ constraint is slacking and we are in a standard adverse selection problem. To reduce this rent, which has a social cost of λ, the regulator introduces a downward distortion in the access-price schedule with respect to the perfect information allocation (8) for all $\theta < \overline{\theta}$. This leads to $\widehat{a}_I(\theta, \mu = 0)$. As K raises, eventually it reaches a level, $\widehat{K}_I^0$, where the expected rent, evaluated at $\widehat{a}_I(\theta, \mu = 0)$, is equal to K. From this value of K onwards, the $(IR - IA)$ constraint starts to be binding. Thus there is

[6] This informational externality of regulation is highlighted also by Calzolari and Scarpa (2006) who consider a multiutility firm active both in a regulated and in an unregulated market, with private information about economies of scope.

no longer a need to minimize the informative rent, and in fact, the firm needs to receive an additional transfer to help it cover the cost of acquiring information. The distortion in the access price is gradually reduced, and as K reaches the value $\widehat{K}_I^1$, the access price schedule returns to its full information level, $a_I^*(\theta)$. For even higher K, the firm is compensated for the information acquisition cost with an increase in the monetary transfer.[7]

Let $\widehat{W}_I(\theta, K, u)$ denote the maximum value function under observable information acquisition when there is information acquisition and $E\widehat{W}_I(\theta, K, u)$ its expectation. If instead there is no information acquisition, the maximum value function is given by $w_I^*(\theta_0)$. We denote by $\widehat{K}_I^*$ the level of K such that for $K \geq \widehat{K}_I^*$ information acquisition is suboptimal. Since $E\widehat{W}_I(.) \leq EW_I^*(.)$, we have $\widehat{K}_I^* \leq K_I^*$.

Now consider how the unobservability of θ affects the performance of regulation. Let $\widehat{\Delta}^I(.) \equiv \max\{EW_I^*(\theta, K, u), w_I^*(\theta_0)\} - \max\{E\widehat{W}_I(\theta, K, u), w_I^*(\theta_0)\}$ and without loss of generality consider the case where $\widehat{K}_I^1 \leq K_I^*$. The following lemma is then obtained.

Lemma 3 *(i)* $\widehat{\Delta}^I(K) > 0$; *with* $\frac{\partial \widehat{\Delta}^I(K)}{\partial K} = \mu(K) - \lambda < 0$ *for all* $K < \widehat{K}_I^1$; *(ii)* $\widehat{\Delta}^I(K) = 0$ *for* $K \geq \widehat{K}_I^1$. *That is, asymmetric information reduces expected welfare under integration for all* $K < \widehat{K}_I^1$, *whilst it has no effects for* $K \geq \widehat{K}_I^1$.

Lemma 3 is easily understood in light of the fact that for $K < \widehat{K}_I^1$ information acquisition is optimal but it is costly in terms of expected rent due to asymmetric information. For $K > \widehat{K}_I^1$, the rent is insufficient to cover information acquisition cost. The IC constraint $(IC1)$ starts to slack, whilst the $(IR - IA)$ starts to bind as under costly public information leading to $EW_I^*(\theta, K, u) = E\widehat{W}_I(\theta, K, u)$. It also follows from this that $\widehat{K}_I^* = K_I^*$ and that $\widehat{\Delta}^I$ is independent of u.

4.2 Separation

Following the same reasoning as under I, consider the game played in the downstream market when the value of demand parameter announced by the upstream monopolist is $\widehat{\theta}$. Anticipating that in equilibrium $\widehat{\theta} = \theta$, a downstream firm chooses q_S so as to maximize

$$\Pi_S^D(\widehat{\theta}) = (\widehat{\theta} - 2q_S - a_S(\widehat{\theta}))q_S$$

[7] Second order conditions are satisfied and the constraint $IC2$ is satisfied provided that

$$-\frac{3}{2} + 5\lambda - 3(\lambda - \mu)\frac{\partial}{\partial \theta}(\frac{1 - F(\theta)}{f(\theta)}) \geq 0$$

yielding $q_S(\widehat{\theta}) = \frac{\widehat{\theta} - a_S(\widehat{\theta})}{3}$ and profit for the upstream monopolist equal to

$$\Pi_S^M(\widehat{\theta}) = a_S(\widehat{\theta}) 2 q_S(\widehat{\theta}) + T_S(\widehat{\theta}) \tag{14}$$

It follows that $\frac{\partial \Pi_S^M(\theta)}{\partial \theta} = 0$, which implies that the upstream monopolist has no incentives to misreport the value of θ and therefore the optimal mechanism is the same as under costly public information. Intuitively, under S the profits of the upstream monopolist are equal to the access revenues which only depend on the quantities produced by the downstream firms. These quantities are in turn independent of θ : since the downstream firms are ignorant, their output decisions are taken on the basis of the reported realization of θ and not of its true realization. It follows that the profits of the upstream monopolist are independent of the true realization of θ. This explains why the informational externality generated by the regulatory mechanism, as under I, works, contrary to I, in favour of truthful reporting of θ. Indeed if the downstream firms were informed, by underreporting θ the incumbent could gain the greater access revenues corresponding to the true realization of θ. In particular, if the downstream firms were informed, we would have

$$\Pi_S^M(\theta, \widehat{\theta}) = a(\widehat{\theta}) Q(\theta, \widehat{\theta}) + T_S(\widehat{\theta})$$

with $Q(\theta, \widehat{\theta}) = \frac{2\theta - 2a(\widehat{\theta})}{3}$ and

$$\frac{\partial \Pi_S^M(\theta, \widehat{\theta})}{\partial \theta} = a(\widehat{\theta}) \frac{\partial Q}{\partial \theta} > 0 \tag{15}$$

That is, with informed downstream firms, it would be more costly for the regulator to extract information about demand from the upstream monopolist because the firm would have incentives to underreport θ in order to raise its access revenues.

Let $E\widehat{W}_S(\theta, K, u)$ denote the expected maximum value function under S when there is information acquisition and information acquisition is observable. We have

$$E\widehat{W}_S(\theta, K, u) = EW_S^*(\theta, K, u) \tag{16}$$

For $K > \widehat{K}_S^*$ there is no information acquisition and the maximum value function is given by $w_S^*(\theta_0)$, and it follows from (16) that $\widehat{K}_S^* = K_S^*$. Let $\widehat{\Delta}^S(.) = \max\{EW_S^*(\theta, K, u), w_S^*(\theta_0)\} - \max\{E\widehat{W}_S(\theta, K, u), w_S^*(\theta_0)\}$ in light of (16) we obtain the following lemma.

Lemma 4 $\widehat{\Delta}^S = 0$ *for all* K *and* u. *That is, under separation, asymmetric information has no effect on welfare.*

Under observable information acquisition, asymmetric information has no effect on the efficiency of the regulatory mechanism since the monopolist has no incentives to misreport the level of demand; the optimal access price is then given by (9), and the $(IR-IA)$ constraints is binding for all $K>0$.

4.3 Comparison

From Lemmas 3 and 4 we have seen that for all $K<\widehat{K}_I^1$ asymmetric information creates a distortion in the optimal mechanism under I but not under S, whilst for all $K\geq\widehat{K}_I^1$ under both I and S there is no distortion. The Proposition below is then obtained.

Proposition 2 *(i)* $\widehat{\Delta}_I(K)-\widehat{\Delta}_S>0$ *and* $\frac{\partial(\widehat{\Delta}^I(K)-\widehat{\Delta}^S)}{\partial K}=\mu(K)-\lambda<0$ *for* $K<\widehat{K}_I^1$*, where* $\mu(K)$ *is defined in Lemma 2. (ii)* $\widehat{\Delta}_I(K)-\widehat{\Delta}_S=0$ *for* $K\geq\widehat{K}_I^1$*. That is, when information acquisition is costly but observable, asymmetric information on demand generates a bias in favour of separation for all* $K<\widehat{K}_I^1$*, whilst it has no effect on the welfare comparison between Integration and separation for all* $K\geq\widehat{K}_I^1$*. The bias in favour of separation over the range* $K<\widehat{K}_I^1$ *decreases with* K*.*

5 Unobservable information acquisition

In this section we consider the case where information acquisition is unobservable.

5.1 Integration

Consider the case of I, when the regulator induces through the choice of the regulatory mechanism the upstream monopolist to acquire information. In this case, an additional constraint needs to be added to the regulator's maximization program (PL-1) compared to the case where information acquisition is observable. This is the incentive compatibility constraint on information acquisition, $(IC-IA)$, which ensures that, under the optimal mechanism, the upstream monopolist prefers to incur K to become informed about the realization of θ rather than remain uninformed.

In this context, it is easy to show that with linear demand function an uninformed upstream monopolist would choose the contract corresponding to the mean of the distribution of θ : $\{a(\theta_0), T(\theta_0)\}$. By using equations $(IC1)$ and (20), the $(IC - IA)$ is then given by

$$E\Pi_I^M(\theta) - \Pi_I^M(\theta_0) = \int_{\underline{\theta}}^{\overline{\theta}} \frac{\theta + a_I(\theta)}{3}(1 - F(\theta) - \Upsilon_{\theta<\theta_0})d\theta \geq K \qquad \text{(IC-IA)}$$

where Υ is a dummy variable with $\Upsilon = 1$ if $\theta < \theta_0$ and $\Upsilon = 0$ if $\theta \geq \theta_0$. Let ν denote the non-negative multiplier of the $(IC - IA)$, the regulator's problem is then

$$\max_{a_I(\theta), \Pi_I^M(\theta)} \int_{\underline{\theta}}^{\overline{\theta}} W_I(\theta, a_I(\theta), \Pi_I^M(\theta), K, u)dF(\theta)$$
$$s.t. : (IR - IA),\ (IR), (IC1), (IC2), (IC - IA)$$

We obtain the following Lemma.

Lemma 5 *Let* $\widetilde{K}_I = \frac{1}{6}(1 + \frac{\partial \widehat{a}_I(\theta, \mu=0)}{\partial \theta})\sigma^2 < K_I^0$. *Under unobservable information acquisition, the optimal access price schedule with* I *is given by*

$$\widetilde{a}_I(\theta, \nu) = \begin{cases} \frac{\theta(5\lambda - 1) - 3(\lambda - \nu(K))\frac{1-F(\theta)}{f(\theta)}}{1+10\lambda} & \text{for} \quad \theta > \theta_0 \\ \frac{\theta(5\lambda-1) - 3\left(\lambda \frac{1-F(\theta)}{f(\theta)} + \nu(K)\frac{F(\theta)}{f(\theta)}\right)}{1+10\lambda} & \text{for} \quad \theta < \theta_0 \end{cases} \qquad (17)$$

where (i) $\nu(K) = 0$ *for* $K \leq \widetilde{K}_I$, *(ii)* $\nu(K) \in (0, \lambda]$ *and solves*

$$E\Pi_I^M(\theta, \nu) - \Pi_I^M(\theta_0) = K \qquad (18)$$

with $\nu'(K) > 0$ *and* $v(K) \geq \mu(K)$,*for* $K > \widetilde{K}_I$.

Information is valuable to the upstream monopolist since it yields an informative rent. For $K \leq \widetilde{K}_I$ this informative rent is sufficient to induce information acquisition and the optimal mechanism remains the same as under observable information acquisition. Instead, when $K > \widetilde{K}_I$, the optimal mechanism needs to be modified. Recall constraint (IC-IA). Depending on whether θ is greater or smaller than θ_0 an increase in $a_I(.)$ has one or two (opposing) effects on the value of information. An increase in $a_I(.)$ increases $E\Pi_I^M(\theta)$ by $(1 - F(\theta))$ and eases the information constraint, but for $\theta \in (\underline{\theta}\ , \theta_0)$ a unit increase in $a_I(.)$ increase also $\Pi_I^M(\theta_0)$ by a unit and makes the information constraint tighter. Therefore $\widetilde{a}_I(\theta)$ is higher than $\widehat{a}_I(\theta)$ for large values of θ and smaller for low θ which implies a discontinuity at θ_0.

Let $\widetilde{W}_I(\theta, K, u)$ denote the maximum value function under unobservable information acquisition when information acquisition is induced, and let $E\widetilde{W}_I(.)$ denote its expectation. From Lemma 5, we have that $E\widetilde{W}_I(.)$ is decreasing in K and there exists a $\widetilde{K}_I^*(u)$ such that for $K \leq \widetilde{K}_I^*(u)$ there is information acquisition and $E\widetilde{W}_I(.)$ is obtained, whilst for $K > \widetilde{K}_I^*(u)$ there is no information acquisition and the maximum value function is given by $Ew_I^*(\theta_0) = w_I^*(\theta_0)$, where it is immediate that $\widetilde{K}_I^*(u)$ is increasing in u and that $\widetilde{K}_I^*(u) \leq \widehat{K}_I^*(u)$.

Let $\widetilde{\Delta}_I(.) = \max\{E\widehat{W}_I(.), w_I^*(\theta_0)\} - \max\{E\widetilde{W}_I(.), w_I^*(\theta_0)\}$, that is $\widetilde{\Delta}_I$ denotes the welfare difference under I between the case where information acquisition is observable and the case where it is not observable.

Lemma 6 *Under unobservable information acquisition, (i)* $\widetilde{\Delta}_I = 0$ *for* $K \leq \widetilde{K}_I$; *(ii)* $\widetilde{\Delta}_I(K, u) > 0$, *with* $\frac{\partial \widetilde{\Delta}_I(K,u)}{\partial K} = \nu(K) - \mu(K)$, $\frac{\partial \widetilde{\Delta}_I(K,u)}{\partial u} \geq 0$ *for* $K \in (\widetilde{K}_I, K_I^*(u)]$, *(iii)* $\widetilde{\Delta}_I(K) = 0$ *for* $K > K_I^*(u)$.

Intuitively, when K is low (case (i) in the Lemma), the unobservability of information acquisition does not induce any welfare loss since the firm has incentives to acquire information in order to gain the informational rent. However, as K increases (case (ii)) inducing information becomes costly. The $(IC - IA)$ constraint starts to bind and the regulator starts to distort the mechanism in order to provide the firm with incentives to acquire information. When K increases even further (case (iii)) information acquisition becomes so costly that it is preferable for welfare not to induce it.

5.2 Separation

Consider the value of information for the upstream monopolist under S. Recall that $\frac{\partial \Pi_S^M}{\partial \theta} = 0$, which as we have seen implies that there is no gain for the upstream monopolist from misrreporting the value of the demand parameter. Whilst this is a positive result for the regulator when information acquisition is observable, it becomes problematic when information acquisition is not observable, as the lemma below emphasizes.

Lemma 7 *Under unobservable information acqisition the upstream monopolist never acquires information under separation.*

Intuitively, since the monopolist cannot extract any informative rent from acquiring information under S, it will have no incentives to invest K in order to learn the value of θ, or to put it differently, since the monopolist does not produce in the downstream market, information revelation is a cheap talk game. It follows from the above lemma that the optimal regulatory mechanism will be given by $\{a_S^*(\theta_0), \Pi_S^*(\theta_0)\}$, leading to an expected welfare of $E\widetilde{W}_S(\theta, K, u) = w_S^*(\theta_0)$. Then, letting $\widetilde{\Delta}_S(.) = \max\{E\widehat{W}_S(.), w_S^*(\theta_0)\} - \max\{E\widetilde{W}_S(.), w_S^*(\theta_0)\}$, we obtain the lemma below.

Lemma 8 *(i)* $\widetilde{\Delta}_S(K, u) > 0$, *for all* $K \leq K_S^*(u)$, *with* $\frac{\partial \widetilde{\Delta}_S(K)}{\partial K} = -(1+\lambda)$, $\frac{\partial \widetilde{\Delta}_S(K,u)}{\partial u} > 0$, *ii)* $\widetilde{\Delta}_S = 0$ *for all* $K > K_S^*(u)$.

Since there is no information acquisition under S, a welfare loss due to the unobservability of information acquisition will arise whenever information acquisition is socially desirable, i.e. whenever $K \leq K_S^*$.

5.3 Comparison

We now study how the unobservability of information acquisition affects the performance of the two regimes, I and S, compared to a situation where information acquisition is observable by the regulator. The proposition below summarizes our main result.

Proposition 3 *(i) If* $\lambda \leq \lambda^*$, *unobservability of information acquisition creates a bias in favour of Integration (i.e.,* $\widetilde{\Delta}_I(K, u) \leq \widetilde{\Delta}_S(K, u)$*) and this bias is non-increasing in* K; *(ii) If* $\lambda > \lambda^*$, *there exists a level of* K, *denoted by* $K^*(u)$, *where* $K^* \in (\widetilde{K}_I, \widetilde{K}_I^*)$ *such that for* $K \leq K^*(u)$ *unobservability of information acquisition creates a bias in favour of Integration (i.e.,* $\widetilde{\Delta}_I(K, u) \leq \widetilde{\Delta}_S(K, u)$*) and this bias is non-increasing in* K. *For* $K > K^*(u)$ *unobservability of information acquisition creates a bias in favour of separation (i.e.,* $\widetilde{\Delta}_I(K, u) \geq \widetilde{\Delta}_S(K, u)$*) and this bias is non-decreasing in* K *for* $K \leq K_S^*(u)$.

The above proposition follows from a combination of two effects. First, as we have seen in the previous section, it is easier to induce information acquisition under I than under S. Ceteris paribus this creates a bias in favour of I. Intuitively, inducing information acquisition is easier under I than under S because information on θ is more valuable to the firm when it can use this information also to choose output in the product market (as under I) than when it cannot (as under S). This result is close to Iossa and Legros (2004) who have shown that property rights can help to increase incentives to acquire information. Second, the value of information acquisition depends on λ. If $\lambda \leq \lambda^*$ information acquisition is more valuable under S than under I (since $K_S^* \geq K_I^*$, and $\widehat{K}_S^* \geq \widehat{K}_I^*$) and thus more is lost from lack of information under S compared to I. These two effects go in the same direction and explain point (i). Instead, if $\lambda > \lambda^*$, information acquisition is more valuable under I than under S (since $K_S^* < K_I^*$) and the two effects go in opposite direction. Then, for low K information acquisition is valuable under both I and S and a bias arises in favour of I. For high K the opposite is true. This explains point (ii).

Before concluding this section consider the effect of an increase in the social value of information, as captured by an increase in u. From Lemmas 6 and 8, we obtain.

Corollary 1 *The greater is u the more unobservability of information acquisition is likely to generate a bias in favour of Integration.*

Intuitively, an increase in the social value of information (u) increases the welfare loss due to the unobservability of information acquisition both under I and under S ($\widetilde{\Delta}_I$ and $\widetilde{\Delta}_S$ are non-decreasing in u). However, since under S the regulatory mechanism does not provide any incentives to acquire information, an increase in the social value of information increases the welfare loss ($\frac{\widetilde{\Delta}_S}{\partial u} > 0$) whatever the cost information acquisition (K). Instead, under I,an increase in the social value of information does not affect the welfare loss due to the unobservable information acquisition for all values of K where the regulatory mechanism induces information acquisition ($\frac{\widetilde{\Delta}_I}{\partial u} = 0$ for low level of K, i.e. $K \leq \widetilde{K}_I^* \in [\widetilde{K}_I, K_I^*)$).

6 Information acquisition by the affiliate

Until now we have assumed that the upstream monopolist is the only firm that, at cost K, can acquire information on the realization of θ. However, if we take into account that one of the two downstream firms was an affiliate of the upstream monopolist before the separation, it seems possible that also this firm will have the technology and the know-how to acquire information on θ. In this section we allow for this possibility. We let the cost of information acquisition for the downstream firm be K and we assume again that information acquisition is unobservable. Contrary to the upstream monopolist, the downstream firm is unregulated and thus the information it acquires will not be transmitted to its rival neither will it be used to set the access price.

Under unobservable information acquisition, the optimal mechanism is the same as when the downstream firm cannot acquire information, and it is given by $\{a_S(\theta_0), \Pi_S^M(\theta_0)\}$. This is because the total output is linear in a_S and the regulator does not know θ at the time of choosing the regulatory mechanism.

In light of this, consider the incentives of the downstream firm to acquire information. It is easy to show that $q_S^N(\theta_0, a_S) = \frac{\theta_0 - a_S}{3}$ is the quantity produced by an uninformed firm when also the rival is uninformed, whilst $q_S(\theta, \theta_0, a_S) = \frac{\theta}{2} - \frac{\theta_0}{6} - \frac{a_S}{3}$ is the quantity produced the downstream firm when it acquires information and the rival is uninformed.

Denoting by $\Pi_S^D(\theta, \theta_0, a_S)$ the maximum value function of the downstream firm when it acquires information and the rival is uninformed and by $\Pi_S^D(\theta_0, a_S)$ the expected profit of the firm when it does not acquire information, we obtain the value of information for the downstream firm

$$E\Pi_S^D(\theta, \theta_0, a_S) - \Pi_S^D(\theta_0, a_S) = \frac{\partial^2 \Pi_S^D(\theta, \theta_0, a_S)}{\partial^2 \theta} \frac{\sigma^2}{2} = \frac{\sigma^2}{4} \tag{19}$$

which leads us to the following Proposition.

Proposition 4 *The incentives to acquire information of the affiliate under Separation are lower than the incentives to acquire information of the upstream monopolist under Integration; the affiliate acquiring information on* θ *for all* $K \leq \widetilde{K}_S$, *where* $\widetilde{K}_S = \frac{\sigma^2}{4} < \widetilde{K}_I$.

Since the downstream firm is not regulated, its information cannot be used to set the access price which will therefore be set on the basis of the expected value of θ. Further, the access price cannot be used as an instrument to increase the firm's incentives to acquire information. The value of information for the downstream firm is then given only by the profitability of adjusting its output level to the realized level of demand. For $K \leq \widetilde{K}_S$, this effect induces information acquisition. However, $\widetilde{K}_S < \widetilde{K}_I$, defined in Lemma 5 the value of information for the downstream firm under S is smaller than the value of information for the upstream monopolist under I. This is a consequence of the fact that the upstream monopolist is regulated and the regulatory mechanism is public knowledge whilst the downstream firm is not regulated.

In particular, information acquired by the upstream monopolist is revealed to its rival through the regulatory mechanism. This generates two opposite effects. First, the rival adjusts its output to the realized value of demand: the greater is θ, the greater is the rival's output. This first effect increases the correlation of firms' strategies and thus reduces the upstream monopolist's gain from acquiring information.

However, the second effect works in an opposite direction and more than compensate the first one. Incentive compatibility requires that the access price be an increasing function of θ. Thus a greater θ reduces the rival's output via the increase in the access price and this lowers the correlation of firms' strategies and raises the upstream monopolist's gain from acquiring information. Rewriting $(IC2)$ as

$$\frac{\partial^2 \Pi_I^M(\theta)}{\partial\theta\partial\widehat{\theta}} = -\frac{1}{2}\frac{\partial q^R(\theta)}{\partial\theta} = -\frac{1}{6}\left(1 - 2\frac{\partial a_I(\theta)}{\partial\theta}\right) > 0$$
$$with\ \frac{\partial a_I(\theta)}{\partial\theta} > \frac{1}{2} \iff \frac{\partial q^R(\theta)}{\partial\theta} < 0$$

we see that incentive compatibility calls for the sensitivity of the regulated access price to be high enough to make the rival's quantity decrease with θ. In other words, the access price structure must reflect demand changes in such as way as to reduce the correlation of firms' strategies in the downstream market. This in order to compensate the firm for the loss in profits due to the transmission of information generated by the public nature of the regulatory mechanism. As a result, $\widetilde{K}_S < \widetilde{K}_I$: a regulated upstream monopolist has stronger incentives to acquire information than an unregulated downstream firm[8].

The role played by the public nature of the regulatory mechanism explains why the above result stands in contrast with the case of information sharing about a common value in an unregulated Cournot market.[9] In that context knowledge by a rival firm of its own profit function leads to higher correlation of strategies and thus reduces the incumbent's profit so that there is no incentive for a firm to transmit information about demand parameter to the rival.

[8] The value of information for either firm is proportional to the sensitivity of output to θ, and the output of the informed upstream monopolist under I is more sensitive to θ than the output of the informed downstream firm under S.In particular, let $q^i = \frac{\theta - q^R}{2}$ be the output chosen under Cournot competition by the firm who acquires information, with $i = M$ under I and $i = D$ under S, and with $q^R = \frac{\theta - 2a(\theta)}{3}$ denoting the output of the rival. Then the sensitivity of output of the upstream monopolist firm with respect to θ is given by: $\frac{1}{2}\left(1 - \frac{\partial q^R}{\partial \theta}\right)$, whilst the sensitivity of output of the downstream is $\frac{1}{2}$, since information is not passed onto the rival.

[9] See Raith (1996) for a general model.

More importantly, the result of Proposition 4 implies that unobservability of information acquisition creates a bias in favour of Integration also when the affiliate can acquire information. Not only does the affiliate have weaker incentives to acquire information than an upstream monopolist but also, when the affiliate acquires information it does so privately. No socially valuable information transmission to either the rival or the regulator takes place. We summarize this result in the following corollary.

Corollary 2 *Unobservability of informaiton acquistion creates a bias in favour of Integration also when the affiliate can acquire information.*

7 Conclusions

In this paper we have studied the desirability of allowing an upstream monopolist to operate in the downstream market (integration) rather than to exclude it (separation), in the presence of costly demand information. We have shown that asymmetric information on demand favours separation but unobservability of information acquisition favours integration. We have also shown that the greater the value of information about demand the more integration is likely to be preferable to separation. Thus integration may be preferable in industries such as telecommunication and electricity where demand is uncertain and lack of information on demand can generate very costly service disruptions. The case for integration based on the issue of demand information is instead weaker in industries where the value of information on demand is smaller.

We have focused on the case where the number of firms is the same under both integration and separation. An extension of our analysis could be to study how the cost of acquiring that technology may affect entry decisions.

8 Appendix

Proof of Lemma 1. Under I, information acquisition is optimal if $Ew_I^*(\theta) - w_I^*(\theta_0) + u \geq (1+\lambda)\,K$. By using Taylor expansion we can rewrite

$$Ew_I^*(\theta) - w_I^*(\theta_0) = \frac{\partial^2 w_I(\theta)}{\partial^2\theta}\frac{\sigma^2}{2} = \frac{1+8\lambda+5\lambda^2}{2(1+10\lambda)}\sigma^2$$

leading to K_I^*.The same procedure proves K_S^*■

Proof of Proposition 1. (i) First note that $W_S^*(\theta,\lambda,u,K) = W_I^*(\theta,\lambda,u,K)$ at $\lambda = 0$, and $\frac{dW_I^*(\theta,\lambda,u)}{d\lambda}\Big|_{\lambda=0} = -\theta^2$, $\frac{dW_S^*(\theta,\lambda,u)}{d\lambda}\Big|_{\lambda=0} = -\frac{\theta}{2}^2$ which implies $W_S^*(\theta,\lambda,u) > W_I^*(\theta,\lambda,u)$ in a neighborhood of $\lambda = 0$. Tedious calculations then give $\frac{d^2W_I^*(\theta,\lambda,u)}{d\lambda^2} - \frac{d^2W_S^*(\theta,\lambda,u)}{d\lambda^2} = b$, where b is a positive constant, which implies that there exists a $\lambda^* > 0$, independent of θ, such that $W_S^*(\theta,\lambda,u) < W_I^*(\theta,\lambda,u)$ for all $\lambda > \lambda^*$, and vice versa. (ii). From (i) $EW_S^*(\theta,\lambda,u) - w_S^*(\theta_0,\lambda) = EW_I^*(\theta,\lambda,u) - w_I^*(\theta_0,\lambda)$ at $\lambda = 0$ and $\lambda = \lambda^*$, i.e. $K_S^*(\lambda,u) = K_I^*(\lambda,u)$ at $\lambda = 0, \lambda = \lambda^*$. Furthermore from the definition of $K_S^*(\lambda,u)$ and $K_I^*(\lambda,u)$ it easy to show that they are continuous non-increasing functions of λ with $\left|\frac{\partial K_S^*(\lambda,u)}{\partial\lambda}\right| < \left|\frac{\partial K_I^*(\lambda,u)}{\partial\lambda}\right|$ at $\lambda = 0$ and $\left|\frac{\partial K_S^*(\lambda,u)}{\partial\lambda}\right| > \left|\frac{\partial K_I^*(\lambda,u)}{\partial\lambda}\right|$ at $\lambda = \lambda^*$; so the result follows.■

Proof of Lemma 2 Using standard techniques, from $(IC1)$, we obtain the expected rent of the upstream monopolist

$$E\Pi_I^M(\theta, a_I(\theta)) = \Pi_I^M(\underline{\theta}) + \int_{\underline{\theta}}^{\overline{\theta}} \frac{\theta + a_I(\theta)}{3}\frac{1-F(\theta)}{f(\theta)}dF(\theta) \tag{20}$$

The regulator's problem is then to determine, for each θ, the couple $(\widehat{a}_I(\theta), \widehat{\Pi}_I^M(\theta))$ which solves the following maximization problem (referred to as PL-1)

$$\max_{a_I(\theta),\Pi_I^M(\theta)} \int_{\underline{\theta}}^{\overline{\theta}} W_I(\theta, a_I(\theta), \Pi_I^M(\theta), K, u)dF(\theta) \tag{PL-1}$$

$$s.t.:(IR-IA),(IR),(IC1)(IC2) \tag{21}$$

where in $(IR - IA)$, the expected rent is given by (20). Since the objective function of program (PL-1) is strictly concave and the constraint $(IR - IA)$ is linear in a_I and in K, the problem is convex with an unique solution. Neglecting for the moment constraint $(IC2)$, maximization of the the Lagrangian of program (PL-1) w.r.t. a yields

$$-(1+10\lambda)\widehat{a}_I(.) - \theta + 5\lambda\theta - 3(\lambda-\mu)\frac{1-F(\theta)}{f(\theta)} = 0$$

where the SOC and constraint $(IC2)$ are satisfied provided that $-\frac{3}{2}+5\lambda-3(\lambda-\mu)\frac{\partial}{\partial\theta}(\frac{1-F(\theta)}{f(\theta)}) \geq 0$. Now, consider the case where $(IR-IA)$ is not binding and $\mu=0$. Substituting for $a_I = \widehat{a}_I(\theta, \mu=0)$ in (20) we obtain $\widehat{K}_I^0$. Thus, $\mu=0$ is the solution for $K \leq \widehat{K}_I^0$. Substituting for $a_I = \widehat{a}_I(\theta, \mu=\lambda)$ in the same equation, we obtain $\widehat{K}_I^1$.

(i)Since $W_I()$ is strictly concave and the $(IR-IA)$ constraint is linear in a_I and in K, it follows that its value function, $E\widehat{W}_I$, is concave in K and $\mu(K) = -\frac{\partial E\widehat{W}_I(.)}{\partial K} - 1$. Given the concavity of $E\widehat{W}_I$, $\mu(K)$ is a non-decreasing function of K; for $K \leq \widehat{K}_I^0, E\widehat{W}_I(.)$ is linear in K and $\mu(K)=0$. (ii)To see that $\mu \leq \lambda$, consider an increase dK in K; a (suboptimal) feasible response by the regulator that would maintain all the constraints satisfied would be to increase all the transfers by dK and to keep the same access price schedule This would decrease its payoff by $(1+\lambda)dK$. Therefore we have $E\widehat{W}_I(\theta, K+dK, u) \geq E\widehat{W}_I(\theta, K, u) - (1+\lambda)dK$ and so $\frac{\partial E\widehat{W}_I(.)}{\partial K} \geq -(1+\lambda)$.(iii)Since, for $K \geq \widehat{K}_I^1, \widehat{a}_I(\widetilde{\theta}, \mu=\lambda) = a_I^*(\theta)$ we have $E\widehat{W}_I(\theta, u) = EW_I^*(\theta, u)$■

Proof of Lemma 3. In light of Lemma 2 we have

$$E\widehat{W}_I(\theta, K, u) = w_I(\theta, \widehat{a}_I(\theta, \mu(K))) - \left(\lambda E\Pi_I^M(\theta, \widehat{a}_I(\theta, \mu(K)) + K\right) + u \tag{22}$$

$$\text{with } \frac{\partial E\widehat{W}_I(\theta, K)}{\partial K} = -\left(1+\mu(K)\right)$$

Now note that $\widehat{\Delta}^I(K) > 0$ for $K \to 0$, since $E\Pi_I^M(\theta, \widehat{a}_I(\theta, \mu=0)) > K$ and $EW_I(\theta, \widehat{a}_I(\theta, \mu=0), u) < EW_I(\theta, a_I^*(\theta), u)$ from $a_I^*(\theta) = \arg\max EW_I(\theta, a_I(\theta), u)$ and $a_I^*(\theta) \neq \widehat{a}_I(\theta, \mu=0)$. From (10), (22) and Lemma 2, we then have $\frac{\partial \widehat{\Delta}^I(K)}{\partial K} = -\lambda + \mu(K) \leq 0$. For $K \geq \widehat{K}_I^1$, $EW_I(\theta, \widehat{a}_I(\theta, \mu=\lambda), u) = EW_I(\theta, a_I^*(\theta), u)$, since $\widehat{a}_I(\widetilde{\theta}, \mu=\lambda) = a_I^*(\theta)$.■

Proof of Lemma 5. Constraint $(IC-IA)$ implies that the constraint $(IR-IA)$ is automatically satisfied and therefore it can be neglected. Neglecting for the moment the constraint $(IC2)$, the Lagrangian of the maximization problem becomes

$$\int_{\underline{\theta}}^{\overline{\theta}} (S(\theta, Q_I(\theta, a_I)) + \lambda P(\theta, a_I)q^M(\theta, a_I) + \lambda a_I q^R(\theta, a_I) + u$$
$$-\lambda q^M(\theta, a_I)\frac{1-F(\theta)}{f(\theta)} + \nu q^M(\theta, a_I)\frac{1-F(\theta)-\Upsilon_{\theta<\theta_0}}{f(\theta)} - (\nu+1)K)dF(\theta)$$

Since the function is strictly concave and the constraint $(IC-IA)$ is linear in a_I and in K, the problem is convex with an unique solution. Maximization w.r.t. a yields

$$-(1+10\lambda)\widetilde{a}_I(.) - \theta + 5\lambda\theta - 3\lambda\frac{1-F(\theta)}{f(\theta)} + 3\nu\frac{1-F(\theta)-\Upsilon_{\theta<\theta_0}}{f(\theta)} = 0$$

where SOC and constraint $(IC2)$ are satisfied provided that $-\frac{3}{2}+5\lambda-3\lambda\frac{\partial}{\partial\theta}(\frac{1-F(\theta)}{f(\theta)})+3\nu\frac{\partial}{\partial\theta}(\frac{1-F(\theta)-\Upsilon_{\theta<\theta_0}}{f(\theta)})\geq 0$.

(i) Now, let us take the case where the $(IC-IA)$ is slacking at the solution to the maximization program, and thus $\nu(K)=0$. From the $(IR-IA)$ and the $(IC-IA)$ it follows that $(IR–IA)$ cannot be binding. Thus when $\nu(K)=0$, we have $\mu=0$, and we obtain that for all $K\leq\widetilde{K}_I$, where $\widetilde{K}_I=E\widehat{\Pi}_I^M(\theta,\mu=0)-\widehat{\Pi}_I^M(\theta_0,\mu=0)=\frac{\partial^2\Pi_I^M(\theta,\mu)}{\partial^2\theta}\frac{\sigma^2}{2}=\frac{1}{6}(1+\frac{\partial\widehat{a}_I(\theta,\mu=0)}{\partial\theta})\sigma^2$, the optimal mechanism is the same as under observable information. Comparing $\widetilde{K}_I$ with $\widehat{K}_I^0$ from Lemma 2, we have $\widetilde{K}_I<\widehat{K}_I^0$. Instead for $K>\widetilde{K}_I$ the $(IC-IA)$ constraint is binding and the $(IR-IA)$ can be neglected.

(ii) Following the same reasoning as in the proof of Lemma 2, we have $\nu(K)\leq\lambda$.We now show that $\mu(K)\leq\nu(K)$.for all $K>\widetilde{K}_I$ Suppose by contradiction that there exists a $K>\widetilde{K}_I$, denoted by K_0, such that $\mu(K_0)>\nu(K_0)$. Then since $\nu(K)>\mu(K)=0$ for $K\leq\widehat{K}_I^0$, $\mu'(K),\nu'(K)\geq 0$ and $\mu''(K),\nu''(K)=0$ for all K, it follows that $\mu(K)\geq\nu(K)$ for all $K\geq K_0$, and that the level of K such that $\mu(K)=\lambda$, is smaller than the level of K such that $\nu(K)=\lambda$. Take therefore a K where $\nu(K)<\lambda$ and $\mu(K)=\lambda$. From $(IR-IA)$, substituting for $\widehat{a}_I$ $(\mu=\lambda)$ we have

$$\int_{\underline{\theta}}^{\overline{\theta}}\frac{\theta+\frac{\theta(5\lambda-1)}{1+10\lambda}}{3}(1-F(\theta))d(\theta)=K,$$

whilst from $(ICL-IA)$, substituting for $\widetilde{a}_I$ $(\nu<\lambda)$

$$\int_{\underline{\theta}}^{\theta_0}-F(\theta)\frac{\theta+\frac{\theta(5\lambda-1)-3\left(\lambda\frac{1-F(\theta)}{f(\theta)}+\nu(K)\frac{F(\theta)}{f(\theta)}\right)}{1+10\lambda}}{3}d\theta+\int_{\theta_0}^{\overline{\theta}}\frac{\theta+\frac{\theta(5\lambda-1)-3(\lambda-\nu(K))\frac{1-F(\theta)}{f(\theta)}}{1+10\lambda}}{3}(1-F(\theta))d\theta=K$$

and it is immediate that the LHS of the $(IR-IA)$ is greater than the LHS of $(IC-IA)$ implying that it cannot be that they are both binding for that level of K ■

Proof of Lemma 6. The maximum value function is given by

$$\begin{aligned}E\widetilde{W}_I(\theta,K,u) &= Ew_I(\theta,\widetilde{a}_I(\theta,\nu(K))-\lambda E\Pi_I^M(\theta,\widetilde{a}_I(\theta,\nu(K))-K+u\\ &\text{with}\frac{\partial E\widetilde{W}_I(\theta,K,u)}{\partial K}=-(1+\nu(K))\end{aligned}$$

and from Lemmas 2 and 5 we have: $E\widehat{W}_I(.)=E\widetilde{W}_I(.)$ for $K\leq\widetilde{K}_I$ and $\widetilde{K}_I^*\in(\widetilde{K}_I,K_I^*)$. For $K\in(\widetilde{K}_I,\widetilde{K}_I^*)$, $\frac{\partial E\widehat{W}_I(.)}{\partial K}-\frac{\partial E\widetilde{W}_I(.)}{\partial K}=-\mu(K)+\nu(K)$, where $\mu(K)=0$ for all $K\leq\widehat{K}_I^0$,

$\mu(K), \nu(K) \leq \lambda$ and $\mu(K) \leq \nu(K)$ for all K. Since $\mu(K) = \lambda$ for all $K \geq \widehat{K}_I^1$, then the level of K such that $\nu(K) = \lambda$ is a $K \in (\widetilde{K}_I, \widehat{K}_I^1]$. From this we have

$$\frac{\partial \widetilde{\Delta}_I}{\partial K} = \begin{cases} \nu(K) > 0 & \text{for} \quad K \in (\widetilde{K}_I, \widehat{K}_I^0] \\ -\mu(K) + \nu(K) > 0 & \text{for} \quad K \in (\widehat{K}_I^0, \widehat{K}_I^1) \\ -\lambda + \lambda = 0 & \text{for} \quad K \in \left[\widehat{K}_I^1, \widetilde{K}_I^*\right) \\ -1 - \lambda & \text{for} \quad K \in \left[\widetilde{K}_I^*, K_I^*\right] \end{cases}$$

if $\widetilde{K}_I^* > \widehat{K}_I^1$. The remaining cases are qualitatively similar. From the definition of $\widetilde{\Delta}_I$, $\frac{\partial \widetilde{\Delta}_I}{\partial u} = 0$ for $K \in (\widetilde{K}_I, \widetilde{K}_I^*(u)]$ and $\frac{\partial \widetilde{\Delta}_I}{\partial u} = 1$ for $K \in (\widetilde{K}_I^*(u), K_I^*(u)]$.■

Proof of Proposition 3 (i) From Proposition 1 $\lambda \leq \lambda^*$ implies $K_S^*(u) \geq K_I^*(u)$. Then from Lemmas 6 and 8 we have: $\widetilde{\Delta}_I(K,u) - \widetilde{\Delta}_S(K,u) = -\widetilde{\Delta}_S(K,u) < 0$ for all $K \leq \widetilde{K}_I$ and for $K \in (K_I^*(u), K_S^*(u))$, whilst $\widetilde{\Delta}_I(K,u) - \widetilde{\Delta}_S(K,u) = 0$ for $K \geq K_S^*(u)$. Then, since the functions $\widetilde{\Delta}_I(K,u)$ and $\widetilde{\Delta}_S(K,u)$ are continuous and $\frac{\partial}{\partial K}(\widetilde{\Delta}_I(K,u) - \widetilde{\Delta}_S(K,u))$ is non-negative for all $K \in (\widetilde{K}_I, K_I^*(u))$, therefore $\widetilde{\Delta}_I(K(u)) - \widetilde{\Delta}_S(K(u)) < 0$ for all K. (ii) Similar reasoning proves the result when $K_S^*(u) < K_I^*(u)$. ■

Proof of Proposition 4. It follows from (19).

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