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ABSTRACT

Regulating a Multi-Utility Firm*

We study the regulation of a utility firm which is active in a competitive unregulated sector as well. If the firm jointly operates its activities in the two markets, it enjoys economies of scope, whose size is the firm's private information and is unknown to the regulator and the rival firms. We jointly characterize the unregulated market outcome (with price and quantity competition) and also optimal regulation. Accounting for the several effects of regulation on the unregulated market, we show the existence of an informational externality, in that regulation provides useful information to the rival firms. Although joint operation of multi-utility's activities generates scope economies, it also brings about private information to the multi-utility, so that regulation is less efficient and also the unregulated market may be negatively affected. Nevertheless, we show that letting the multi-utility integrate productions is (socially) desirable, unless joint production is instead characterized by dis-economies of scope.

JEL Classification: L43, L51 and L52
Keywords: asymmetric information, competition, informational externality, multi-utility firms, regulation and scope economies

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1 Introduction

More and more regulated firms operate now in competitive markets as well. In this paper we determine the optimal regulated price in such a situation. Moreover, we address the structural issue, of whether a regulated firm should be allowed to operate in unregulated markets as well, and to exploit the economies of scope between the two types of productions. We prove that social welfare maximization requires the firm to be allowed to operate joint productions.

The relevance of the issue is significant as many firms active in regulated utility sectors now operate in unregulated markets as well, either by way of mergers or entering as new operators. For example, Centrica in the UK operates both in gas and electricity transmission and in some competitive segments of energy sectors as well as in telecommunications and financial services. Suez-Lyonnaise des Eaux in France and other countries, RWE in Germany and Enel in Italy operate in regulated as well as unregulated markets in energy and other utility sectors. In US one third of over two hundred electricity retailers (e.g. Northern States Power and Potomac Electric and Power Company) also offer telecommunication services. Local telephone service operators such as the Regional Bell Operating Companies, also provide unregulated broadband Internet services. In Europe we also have a multitude of municipal enterprises (e.g. in Italy and Scandinavian countries) which are locally embedded but offer a wide array of services both in regulated and unregulated sectors. As it can be seen, very often the unregulated markets in which these firms are active are utility sectors too.[1]

There are several motivations for (regulated) firms to expand and diversify their activities in unregulated markets. For example, a multi-market strategy may facilitate collusion among firms. Alternatively, regulated activities may leave some free-cash flow that managers want to invest in unregulated sectors either because they can then operate aggressively in those markets or simply because they are "empires builders". However, the most commonly cited motivation goes under the heading "synergy", a catch-all term indicating economies of scope in the joint production and supply of horizontally diversified services.

The institutional response to this phenomenon of expansion into unregulated sectors has been frequently negative, although sometimes differentiated. In the EU several Directives referring to utility services have stated that firms operating in regulated sectors that would like to operate in competitive sectors as well must operate the so called "unbundling", namely a separation of the assets and personnel pertaining to the two sectors.[2] In the US, some Regional Bell Operating Companies have been prohibited from expanding into long distance telecom (unregulated) services.

The reason for these limitations is a double concern. First, given that the actual entity of such cost savings is generally unknown, a regulator facing a complex multi-product firm may suffer a very substantial asymmetric information, which, since the seminal papers by Baron and Myerson (1982) and Laffont and Tirole (1986), is seen as the main problem of regulation. For example, in a joint document issued by the sectorial utility regulators in UK (OFWAT, 1998), the lack of information about joint costs in the several multi-utility's activities emerged as the first issue to be properly addressed for effective regulation of this type of firms. Indeed, for regulators, external auditors but also for rival firms, the measurement of scope economies in multi-product firms is a

[1] This "multi-utility" expansion is (also) a consequence of the process of de-regulation taking place at different pace in different utility sectors some of whom have already been deregulated and liberalized, whilst others (will) remain heavily regulated.

[2] The unbundling may be of several types. The Directives require at least keeping different accounts, or forming separate companies, which may or may not belong to different groups of shareholders.

complex and often inconclusive task.[3]

A distinct but related worry is the "level playing field" argument, according to which a multi-utility firm would enjoy an unfair advantage *vis à vis* its competitors and this would distort competition and would be eventually detrimental to consumers. Also in this case, the issue emerges as a combination of the multiproduct nature of a multi-utility and the asymmetric information problem, which affects a multi-utility's rivals as well as its regulator. This consideration also emphasizes that the lack of information on the costs of horizontally diversified utilities is an issue not only for the regulators but also for the rival firms in unregulated markets.

In this paper we assess the trade-off between the potential benefits of multi-utility firms and their potential cost. To perform this analysis we first study how a multi-utility operates both in a regulated and in an unregulated sector where it competes with rival firms either in prices or in quantities for (possibly) differentiated goods. In this context, the size of scope economies is private information of the multi-utility when it is allowed to integrate ("bundle") its productions. Furthermore, the regulatory process and the multi-utility's activity in the regulated market (e.g. the price implemented) may deliver important information to the rival firms about the cost of the multi-utility in the unregulated market. In other terms, the game in the unregulated market may or may not be one of asymmetric information, depending on the flow of information originated by the regulatory process and this in turn affects the multi-utility firm's incentives to disclose information to the regulator.

The effects of this informational externality from the regulated to the unregulated market depend on the type of competition occurring in the unregulated market. When firms compete in quantities, the regulator can more easily elicit information on scope economies thus reducing the distortions in the regulated sector. Behaving as if economies of scope were low so as to obtain lenient regulation, the multi-utility obtains the countervailing effect of inducing the rival firms to expand output in the unregulated market. On the contrary, with price competition, the externality makes the regulatory process more difficult since behaving as if scope economies were low induces an accommodating reaction by the rivals in the unregulated market. The regulator may thus be forced to use a uniform regulatory policy, independent of the actual level of scope economies.

After discussing the effects of unregulated activities (and of features such as the size of the unregulated market and the number of competitors) on the optimally regulated price, we compare the welfare when the multi-utility is allowed to run joint productions for the two markets with the welfare level when separation is imposed, thus preventing a firm from exploiting its economies of scope for the sake of regulatory clarity. On the one hand, if there are significant economies of scope, consumers in the two markets may benefit from the efficiency gain of integrated production. On the other hand, the lack of information on the part of the regulator and the rival firms distorts the price in the regulated market and may negatively impact on competition in the unregulated market.[4] In this respect we show that, despite horizontal integration brings about informational problems, nonetheless these negative effects are of lesser importance relative to the efficiency gains

[3] In a survey among managers of multi-utilities ("*EU Multi-utilities,*" Marketline International, 1998, London), respondents showed a large variability in their reports. In Germany horizontal integration is responsible for a 25% of total cost reduction, in Austria only 18%, in UK 17% and much less in other countries. Event studies that evaluate abnormal stock returns in occasion of mergers among (regulated and unregulated) utilities provide mixed evidence showing both negative and positive abnormal returns which seem to account for economies but also dis-economies of scope (see Berry, 2000 and Leggio and Lien, 2000). Similar opposing results emerge form the few econometric studies, such as in Fraquelli, Piacenza and Vannoni (2004).

[4] It is well-known from the literature on information sharing in oligopolies (see Sakai 1985 and Vives 1999, Chapter 8, for a survey) that total welfare may reduce when firms compete under asymmetric information.

of integration. Letting the multi-utility integrate productions is desirable, unless there is the risk that joint production is rather characterized by dis-economies of scope (which may be the case, for example, if the managers of the regulated firm want to expand simply to build their empires).

Some early papers such as Braeutigam and Panzar (1989), Brennan (1990), Brennan and Palmer (1994) have addressed the problems and the desirability of horizontal diversification with regulated firms mainly in terms of cross-subsidies. This literature has analyzed how cost shifting can occur so that an integrated firm attributes to the regulated activity costs that should pertain non-regulated ones. By so doing the firm is able to claim higher regulated prices, and at the same time it can also behave more aggressively in the unregulated sectors.

Another very relevant analysis is the one by Sappington (2003) in a model where effort can be allocated to regulated and unregulated activities. Although the analysis of optimal regulated prices and competition in the unregulated market remains limited by modelling choice, this paper contains an interesting discussion of the optimal regulatory policy towards diversification which is complement to our analysis. It is shown that for diversification to be undesirable it must be true at the same time that not only the regulator cannot control effort diversion, but also that the firm can inflate expenditures (with cost padding) of unregulated activities.

All these papers widely illustrate the potential risks of diversification in terms of cross-subsidies and effort diversion. With our analysis we emphasize a different informational issue related to the size of scope economies both for the regulator and the rival firms. Unlike these papers, in our analysis we explicitly account for the reactions of the unregulated market both to the regulatory decisions (of the regulator and the multi-utility) and to the information flow originated by regulation itself. Furthermore, when studying the desirability of integrated production we account for welfare in both sectors so that we can control the potential negative effects of the lack of information on the unregulated market as well.

These characteristics also differentiate our analysis from that of Lewis and Sappington (1989a) who study a model where the costs of regulated activities are negatively correlated to profitability in the unregulated sector. Within this specific setting and with a black-boxed description of profitability in the competitive market, they show how "countervailing incentives" may affect regulation.[5]

Informational externalities among markets arise in many different contexts. Iossa (1999) considers the design of a regulated two-product industry with interdependent and unknown demand. She shows that the desirability of an integrated monopolist rather than two separate firms depends on the interplay between the demand complementarity/substitutability of the two products and the informational externality generated by the two independent firms. Katzman and Rhodes-Kropf (2002) and Zhong (2002) examine the revenue effect of different bid announcement policies in standard auctions followed by Bertrand and Cournot competition. Calzolari and Pavan (2006) study the optimal exchange of information (or disclosure policy) between two sellers who contract sequentially with the same privately-informed buyer. They show that the upstream seller may gain by disclosing information downstream when there are countervailing incentives or if the goods of the two sellers are substitutes.

The paper is organized as follows. The next section introduces the model. Section 3 provides an analysis of benchmark cases, with full information and separation of activities. Section 4 derives

[5] Chaaban (2004) studies the effects of various cost-apportionment rules for a joint fixed-cost which is privately known by the multi-utility.

optimal regulation when the multi-utility is allowed to integrate its productions. Section 5 uses these results to study the welfare effects of integration both in the case of quantity and price competition. Section 6 concludes the paper. All the proofs are in the Appendix.

2 Model Set-up

We consider two markets. Market R is a regulated natural monopoly while the other sector U is an unregulated oligopoly.

Demand functions are decreasing, (twice) differentiable and the demand of regulated and unregulated products are independent. The inverse demand in R is $p(q)$ where q is output. Market U consists of n operating firms indexed by $i = 1, ..., n$, each producing (possibly differentiated) output y_i with price p_i^U. Inverse demand functions are $p_i^U(y_i, Y_{-i})$ $i = 1, ..., n$, where Y_{-i} denotes the vector of the output levels of other firms. The vectors of prices and output levels in the unregulated market are denoted by p^U and Y respectively.

In sector R, the price is determined by a regulatory authority. Prices in the unregulated sector emerge from the market game; competition in this market may take place either in quantities or in prices.

A multi-utility firm operates in both markets, respectively producing outputs q and y_1 (so that index $i = 1$ will denote the multi-utility). This firm may be allowed to run the production in the two markets in an integrated way, or may be forced to "unbundle" its activities, running separate production units.[6] If this firm is allowed to operate productions together, it learns that there are economies of scope. On the contrary, separating production makes impossible for the multi-utility to share assets and internal resources that may bring about cost savings. Formally, let $C(q, y_1; \theta)$ denote the total production cost of the multi-utility absent any bundling restriction, where θ is an efficiency parameter. If instead separation is imposed, the multi-utility's total costs is $C(0, y_1; \theta) + C(q, 0; \theta)$. Bundling production thus generates a cost saving corresponding to

$$C(0, y_1; \theta) + C(q, 0; \theta) - C(q, y_1; \theta) \geq 0, \tag{1}$$

which is nil when either $q = 0$ or $y_1 = 0$. The size of scope economies is parametrized by θ so that the expression in (1) is nil if $\theta = 0$ and for any $\theta'' \geq \theta'$,

$$C\left(0, y_1; \theta''\right) + C\left(q, 0; \theta''\right) - C\left(q, y_1; \theta''\right) \geq C\left(0, y_1; \theta'\right) + C\left(q, 0; \theta'\right) - C\left(q, y_1; \theta'\right),$$

with $C\left(q, y_1; \theta''\right) = C\left(q, y_1; \theta'\right)$ if either $q = 0$ or $y_1 = 0$. Thus, the larger is θ the higher are scope economies and if unbundling is imposed θ has no bite on costs.[7] Assuming that the cost function is twice differentiable with respect to q and y_1, the previous conditions imply that (i) a larger output for one of the two markets induces a marginal cost reduction for the output in the other market,

[6] As stressed in the introduction, this is required for instance by the EU Directives on electricity and gas, and by various provisions by regulators in different countries.

[7] Although we concentrate on economies of scope related to variable costs, when scope economies are due to common fixed costs some cost-allocation rules are typically required (e.g. by the regulator), which allocate fixed costs proportionally to output. This may well re-introduce variable-cost non separability as in the present setting (see Calzolari, 2001). A related analysis of regulation with common fixed costs is in Chaaban (2004).

(ii) this cost reduction is larger the higher is θ (and vanishing when $\theta = 0$),

$$\frac{\partial^2 C(q, y_1; \theta'')}{\partial q \partial y_1} \leq \frac{\partial^2 C(q, y_1; \theta')}{\partial q \partial y_1} \leq 0, \text{ for any } \theta'' \geq \theta', \tag{2}$$

and (iii) a higher value of θ (weakly) reduces the marginal cost for both outputs,

$$\frac{\partial C(q, y_1; \theta'')}{\partial z} \leq \frac{\partial C(q, y_1; \theta')}{\partial z} \text{ for } z \in \{q, y_1\} \text{ and any } \theta'' \geq \theta'. \tag{3}$$

The following specification of the cost function that we will use in some examples in the sequel satisfies all the previous properties,

$$C_1 (q, y_1; \theta) = c(q + y_1) - \theta q y_1. \tag{4}$$

On the other hand, the technology available to all other firms in market U (i.e. firms with index $i = 2, ..., n$) is $C(y_i) \equiv C(0, y_1; \theta)$ for any $y_1 = y_i$ and profits are

$$\pi_i(y_i, Y_{-i}) \equiv y_i p_i^U (Y) - C(y_i). \tag{5}$$

When the multi-utility is allowed to integrate production its *total* profit is (the apex I will stand for integration)

$$\Pi^I (q, y_1, Y_{-1}; \theta) \equiv qp(q) + y_1 p_1^U (Y) - C(q, y_1; \theta) - T, \tag{6}$$

where T is a tax/transfer which is part of the regulatory contract in market R (see below). On the contrary, multi-utility must keep apart its production for the two markets its profit becomes (the apex S will stand for separation) $\Pi^S + \pi_1(y_1, Y_{-1})$ where

$$\Pi^S \equiv qp(q) - C(q, 0; \theta) - T. \tag{7}$$

The regulator maximizes a utilitarian objective function which is a weighted sum of net consumer surplus in the two markets, firms profits and taxes (or transfers). Let V_j denote gross consumer surplus in sector $j = R, U$. The regulator's welfare function then is

$$W(q, T, \theta) = V_R(q) - qp(q) + V_U(Y) - Yp^U(Y) + T + \alpha(\Pi + \sum_{i=2}^{n} \pi_i), \tag{8}$$

where $Yp^U(Y) = \sum_{i=1}^{n} y_i p_i^U(Y)$, Π is the total multi-utility's profit and the weight to profits is $\alpha < 1$.[8] By definition of unregulated market U, the institutional set-up is such that the regulator cannot explicitly control output (of single firms or total output) in that market.

By directly operating joint production a firm is able to realize much better than the regulator and the rival firms whether there are economies of scopes and, if so, their actual entity. The size of the economies of scope is thus generally a source of asymmetric information. In particular, the exact value of θ is private information of the multi-utility and neither the regulator, nor the

[8]As usual we assume $\alpha < 1$ to avoid the well-known Loeb-Magat paradox and we will not consider the cost of public funds which in any case would not alter our analysis. We will not also discuss the possibility that the regulator uses different weights to profit of regulated and unregulated firms. In a different context of regulation, this is analyzed by Calzolari and Scarpa (2006).

competitors in the unregulated market know it. For simplicity, we assume there are no other pieces of private information. This is clearly a simplification as regulation of a traditional single-product firm is also often affected by informational issues. Nevertheless, we employ this assumption to single out the effects of asymmetric information issues explicitly related to economies of scope and to the complexity of integrated multi-utility firms. For simplicity, we also assume (it is common knowledge) that scope economies can be either high or low, i.e. $\theta \in \Theta \equiv \left\{\underline{\theta}, \overline{\theta}\right\}$ with $\nu = \Pr(\theta = \bar{\theta}) = 1 - \Pr(\theta = \underline{\theta})$ and $\overline{\theta} \geq \underline{\theta}$ so that high economies of scale correspond to $\theta = \bar{\theta}$, low ones to $\theta = \underline{\theta}$ and we rule out diseconomies of scale, i.e. $\underline{\theta} \geq 0$..

The timing of the game is the following:

1. The regulator decides and publicly announces whether or not to impose separation of productions to the multi-utility, then accordingly sets and publicly announces the regulatory policy consistent with the choice.

2. If allowed to integrate production, the multi-utility learns the size of scope economies, i.e. its type θ.

3. The multi-utility then decides whether to accept regulation thus also operating in market R and, if this is the case, regulation is publicly enforced.

4. Finally, competition in the unregulated sector takes place.

For simplicity, we have described our game with the same regulator being responsible of both decisions of stage 1 concerning production of the multi-utility and its regulation. However, it is also clear that these two decisions may well be in the hands of two different authorities, for example an antitrust authority and a sectoral regulator.

As discussed above, the exact entity of scope economies becomes clear to the multi-utility if it is allowed to integrate production and effectively does so. In this respect, we thus regard as impractical the possibility to condition the decision concerning integrated production on the realization of θ. In fact, this would require to let the multi-utility set up integrated production, learn θ and then impose separation by splitting the production organization in case it is $\theta = \underline{\theta}$.

Stage 3 illustrates that the multi-utility is not obliged to participate the regulated market and will do so only if it finds it profitable. As we will discuss in the sequel, if the firm prefers to serve the regulated market, then it always prefers to bundle production in the two sectors, if allowed to do so. Finally, the timing also shows that the execution of a regulatory contract naturally anticipates the determination of the equilibrium in the competitive sector. Indeed, regulation usually follows procedures and activities which are more complicated to modify than private firms' price decisions.

Before proceeding with the analysis it is useful to note that the model we have laid down is identical to one where the regulator's decision at $t = 1$ consists in banning or not multi-utility firms *tout court*. Indeed, imposing separation is equivalent to banning integrated multi-utility firms and having a single firm that uniquely serves market R earning profits Π^S and a distinct firm with profit π_1 in market U (together with other $n - 1$ firm). On the contrary, with no such restriction, it is as if the regulator let an integrated (multi-utility) firm earning profits Π^I. By properly adjusting the number of active firms in market U, the two interpretations lead exactly to the same model.[9]

[9] If integration entailed a reduction in the number of firms active in U, then we would have a "trivial" competitive effect against integration. By keeping constant n independently of the regime we will avoid this effect.

3 Efficient regulation

In this section we introduce two benchmarks which will help to discuss the pros and cons of bundling in the presence of asymmetric information. We first analyze the case where production separation of production is imposed, and then we study the case with integrated production and full information.

Optimal regulation with unbundling. As discussed in the model setup, asymmetric information matters only in case of bundling because economies of scope measured by the parameter θ uniquely arise when the firm can bundle productions for the two markets. Hence, the regulated firm's profit in sector R with separation is simply (7). Let firm i's *equilibrium* output in sector U be defined as y_i^S which depends neither on θ nor on q. In this case equilibrium profits in sector U are then (invoking symmetry),

$$\pi_i^S \equiv \pi_i\left(y_i^S, Y_{-i}^S\right) \geq 0, \text{ for } i = 1, ..., n.$$

The regulator then maximizes (8) with respect to q and T, subject to the participation constraint of the regulated firm, which assures that the multi-utility wants to serve (also) the regulated market, i.e. $\Pi^S \geq 0$. It is immediate that the regulator optimally sets the transfer at a level T^S so that the participation constraint binds, and the multi-utility earns no additional (total) profits with respect to π^S earned in the unregulated sector, i.e. $\Pi^S = 0$.[10] Furthermore, substituting $T = qp\left(q\right) - C\left(q, 0; \theta\right)$ into (8) the optimal regulated quantity q^S is efficient and such that the price in the regulated sector is equal to marginal cost,

$$p(q^S) = \frac{\partial C(q^S, 0; \theta)}{\partial q}.$$

For future reference we indicate with $\mathcal{C}^S \equiv (q^S, T^S)$ this optimal regulatory contract when separation is imposed and the associated social welfare as $W^S(\mathcal{C}^S)$ which is obtained substituting $\mathcal{C}^S$, π_i^S and using (5) in (8).

Multi-utility regulation with full information. Assume now that the multi-utility is allowed to integrate productions and that the regulator and the rival firms are fully informed on scope economies θ. The regulator now anticipates the outcome in the unregulated sector which depends on θ and q and will then affect multi-utility's behavior in the regulated market. Competition may take place either in quantities or in prices. For the generic strategic variables x_i, $i = 1, ..., n$ (either prices or quantities), the system of first order conditions

$$\frac{\partial \pi_i(x_i, X_{-i})}{\partial x_i} = 0, \text{ for } i = 2, ..., n, \; \frac{\partial \Pi^I(x_1, X_{-1}, q; \theta)}{\partial x_1} = 0$$

yields the market equilibrium in sector U. For the sake of convenience, in the following we express profits as functions of equilibrium output levels $y_1(q, \theta)$, $y_i\left(q, \theta\right)$ with $i = 2, ..., n$ so that profits

[10] If separation is interpreted *strictu sensu* so that the regulated firm cannot run also unregulated activities, then the participation constraint would be $\Pi^S \geq \max\{0, \pi_1^S\}$: the outside options are either quit any market, or quit market R and operate in U with the understanding that the firm acquires one of the n existing firms (so that the number of active firms in U is always n).

become

$$\pi_i^I(q,\theta) = \pi_i\left[y_i(q,\theta), Y_{-i}(q,\theta)\right], \text{ for } i = 2,...,n$$
$$\Pi^I(q,\theta) = \Pi^I\left[q, y_1(q,\theta), Y_{-1}(q,\theta);\theta\right].$$

Similarly, welfare can be rewritten as

$$\begin{aligned} W^I(q, Y(q,\theta),\theta) = \quad & V_R(q) + V_U\left[Y(q,\theta)\right] - C\left[q, y_1(q,\theta);\theta\right] - \sum_{i\neq 1} C\left[y_i(q,\theta)\right] + \\ & -(1-\alpha)\left[\Pi^I(q,\theta) + \textstyle\sum_{i\neq 1}\pi_i^I(q,\theta)\right], \end{aligned} \tag{9}$$

which shows that, as usual, distributive efficiency would require to reduce as much as possible firms' profits in the two markets.

Anticipating outputs in market U and for a given (and known) θ, the regulator maximizes (9) with respect to q subject to the multi-utility's participation constraint

$$\Pi^I(q,\theta) \geq Max\{\pi^S, \Pi^S\} = \pi^S$$

where Π^S is nil from the previous analysis on regulation with separation.[11] Knowing the value of θ, it is optimal for the regulator to set the transfer T such that the participation constraint binds for any θ and no extra-profits are given to the multi-utility, i.e. $\Pi^I(q,\theta) = \pi^S$.. Maximizing (9) with respect to q for any θ, the optimal regulated quantity with full information and integration $q_{FI}^I(\theta)$ is such that

$$p(q_{FI}^I(\theta)) = SMC[q_{FI}^I(\theta), \theta] \tag{10}$$

where the right hand side is the *social marginal cost* of q,

$$\begin{aligned} SMC\left[q,\theta\right] \quad \equiv \; & \tfrac{\partial C[q,y_1(q,\theta);\theta]}{\partial q} + \\ & -\left(p_1^U - \tfrac{\partial C[q,y_1(q,\theta);\theta]}{\partial y_1}\right)\tfrac{\partial y_1(q,\theta)}{\partial q} - \sum_{i\neq 1}^{n}\left(p_i^U - \tfrac{\partial C[y_i(q,\theta)]}{\partial y_i}\right)\tfrac{\partial y_i(q,\theta)}{\partial q} + \\ & +(1-\alpha)\sum_{i\neq 1}^{n}\tfrac{\partial \pi_i^I(q,\theta)}{\partial q}. \end{aligned} \tag{11}$$

The optimality condition (10) shows that the price is different from the simple marginal cost $\partial C/\partial q$ (in the first line) for two reasons. The second line in (11) indicates that the regulated quantity affects also the distortions (i.e. price-cost margins) due to market power in the unregulated sector which are weighted by the impact the regulated output has on individual firm's equilibrium output in that sector (i.e. $\partial y_1(q,\theta)/\partial q \geq 0$ and $\partial y_i(q,\theta)/\partial q \leq 0$ $i \neq 1$).[12] The term in the third line in (11) indicates an additional reason to give up standard allocative efficiency in the regulated market now due to a distributional concern. By inducing the regulated firm to produce more in market R, the regulator reduces the profits of other firms in the unregulated market (because $\partial\pi_i^I/\partial q \leq 0$), thus increasing social welfare through enhanced distributive efficiency.

Comparing the pricing condition for $q_{FI}^I(\theta)$ with that with separated multi-utility production (i.e. for q^S), we may have an ambiguous effect on regulated output q. Indeed, contrary to all other effects, the second term in the second line in (11) is positive and induces a restriction of q so as

[11] Although, it is allowed to integrate productions, when the firm prefers to operate in market R only, it is *de facto* also choosing the regulatory policy $\mathcal{C}^S$.

[12] This result reflects a departure from marginal cost pricing which is typical in the literature on mixed oligopolies (see for example De Fraja and Delbono, 1990), where the firm under public control distorts its choices to boost the efficiency of private firms.

to let the rival firms expand their outputs and reduce their market power distortions. However, we may reasonably expect that the overall effect of integration is an expansion of regulated output because having a more efficient firm in the unregulated market (i.e. this happens when q or θ increase) tend to reduce the market power inefficiencies leading to a negative second line of (11) so that $\overline{q}^I_{FI} \geq \underline{q}^I_{FI} \geq q^S$.[13] For future reference we indicate with $\mathcal{C}^I_{FI} = \left\{q^I_{FI}(\theta), T^I_{FI}(\theta)\right\}_{\theta\in\Theta}$ the optimal regulatory contract and with $W^I_{FI} = E_\theta[W^I(\mathcal{C}^I_{FI}, \theta)]$ the (expected) welfare with integrated multi-utility production when the regulator and all firms are fully informed about the multi-utility's cost structure.

4 Regulation of a privately informed multi-utility

We now turn to the situation where the multi-utility has been allowed to integrate its productions but the level of scope economies θ is its private information so that neither the regulator, nor the competitors in the unregulated market know it. The regulator has then to offer both the (optimal) regulatory policy $\mathcal{C}^S$ that will be in place if the firm ultimately prefers not to integrate its production activities and another policy $\mathcal{C}$ which will be used if the firm prefers to profit from integrated production.

Without loss of generality, we can rely on the Revelation Principle so that for the case of integration the regulator designs a menu of type-dependent contracts $\mathcal{C} = \{(q(\theta), T(\theta))\}_{\theta\in\Theta}$ which maximizes the (expected) social welfare and which induces the multi-utility to integrate, to serve also the regulated sector and to announce the true level of scope economies to the regulator so that a multi-utility with scope economies θ selects the regulatory policy $(q(\hat{\theta}), T(\hat{\theta}))$ by announcing scope economies $\hat{\theta} = \theta$.[14]

As a matter of fact, unregulated firms in sector U do not observe the communication (i.e. the announcement $\hat{\theta}$) between the multi-utility and the regulator. However, the implemented regulatory policy $q(\hat{\theta}), T(\hat{\theta})$ is clearly public information (each consumer observes the regulated price in her bill), so that, knowing the regulatory policy $\mathcal{C}$, rival firms obtain information on θ by simply observing the (implemented) regulated price $\widehat{p}$ or, equivalently, the quantity $\widehat{q}$ (in the sequel we will indicate updating with respect to $\widehat{q}$). This is an important *informational externality* of regulation which allows the competitors to update their beliefs about the level of the scope economies conditional on the implemented policy and then accordingly set their strategic variables in the unregulated market. It is important to realize that this informational externality in turn affects the regulated firm's incentives to truthfully report the value of the parameter θ, as we will discuss later.

Given the (truthful) announcement of economies of scope, the competitive market game may or may not be one of complete information, depending on whether the updating of the rivals' expectations about the multi-utility's cost leads to perfect information. More precisely, if the optimal regulatory contract contemplates *discriminatory regulation* (i.e. a "screening" contract) with different quantities and prices for different announcements $\widehat{\theta}$, the updating process is perfect so that $v(\widehat{q}) = \Pr(\overline{\theta}|\widehat{q}) = 1$ when $\widehat{q} = q(\overline{\theta})$ and $v(\widehat{q}) = 0$ when $\widehat{q} = q(\underline{\theta})$. On the other hand, if the regulator prefers *uniform regulation* (i.e. a "pooling" contract) in which the regulated quantity $\widehat{q}$ does not depend on the firm's type, then unregulated competitors are not able to perform any

[13] This is confirmed, for example, in the explicit model illustrated in Section 4.1.

[14] Acting before competition takes place in market U, the regulator cannot use the observation of activities therein to infer any information concerning θ.

updating so that $v(\widehat{q}) = v$.[15]

Given $\widehat{q}$, we can then illustrate the Bayesian equilibrium in the unregulated market in which the strategic variables x_i (either prices or quantities) satisfy the following set of necessary conditions,

$$\begin{array}{l} \frac{\partial}{\partial x_i} E_\theta \left[\pi_i(x_i, X_{-i}) | \widehat{q} \right] = 0, \text{ for } i = 2, ..., n \\ \frac{\partial}{\partial x_1} \Pi^I (\widehat{q}, x_1, X_{-1}; \theta) = 0, \text{ for } \theta \in \Theta \end{array}$$

where $E_\theta \left[\pi_i(x_i, X_{-i}) | \widehat{q} \right]$ is the rivals' expected profit (with expectation over θ), conditional on the information provided by $\widehat{q}$. We denote with $y_1 \left(\widehat{q}, \theta, v(\widehat{q}) \right)$ the equilibrium output in the competitive market for a multi-utility with (true) scope economies θ, producing a regulated output $\widehat{q}$ and when the rival firms' updated beliefs are $v(\widehat{q})$. Similarly, let $y \left(\widehat{q}, v(\widehat{q}) \right)$ be the rivals' output (which clearly does not depend on the *true* level of scope economies). Consistently with our notation, we will denote with $y_1 \left(\widehat{q}, \theta, 1 \right), y_1 \left(\widehat{q}, \theta, 0 \right)$ and $y \left(\widehat{q}, 1 \right), y \left(\widehat{q}, 0 \right)$ respectively the outputs of a type θ multi-utility and of its rivals when they believe that the true level of scope economies are either $\overline{\theta}$ or $\underline{\theta}$.

If the regulator knew the real level of scope economies with the rival firms still ignoring θ, she would then set a (generically discriminatory) regulated quantity $q\left(\theta\right)$ such that for any θ :

$$p\left(q(\theta)\right) = SMC\left(q(\theta), \theta\right),$$

where $SMC\left(q, \theta\right)$ is again defined as in (11) with outputs in market U also depending on beliefs $v(q)$. However, as the regulator is also uninformed, she has to induce the multi-utility to truthfully report θ so that the regulatory program becomes

$$(\mathcal{P}^I) \quad \left\{ \begin{array}{ll} \underset{\{(q(\theta),\Pi^I(\theta))\}_{\theta\in\Theta}}{Max} & E_\theta \left\{ W^I \left[q, \left(y_1 \left(q, \theta, v(q) \right), Y_{-1} \left(q, v(q) \right) \right), \theta \right] \right\} \\ \text{s.t.} & \\ \Pi^I\left(\theta\right) \geq \Pi^I\left(\widehat{\theta}; \theta\right) & \forall \left(\widehat{\theta}, \theta\right) \in \Theta \times \Theta \quad IC(\theta) \\ \Pi^I\left(\theta\right) \geq \pi^S & \forall \left(\widehat{\theta}, \theta\right) \in \Theta \times \Theta \quad IR(\theta) \end{array} \right.$$

where the objective is defined as in (9) with the difference that outputs in market U also depend on beliefs $v(q)$, the incentive compatibility constraint $IC(\theta)$ (illustrated below) assures that the firm with type θ indeed prefers to report its cost-type truthfully and the participation constraint $IR(\theta)$ has the same interpretation previously discussed.[16]

In order to analyze the regulatory contract and the incentive for the firm to announce the level of scope economies, consider a multi-utility with scope economies θ which declares $\widehat{\theta}$ and gets the

[15] Few comments are in order on rivals' updating. First, we implicitly assume that the multi-utility cannot credibly communicate θ to the rivals. Second, entry in sector R is uninformative because optimal regulation will induce entry for any type θ (see below). Third, the Revelation Principle is valid independently of rivals' updating. Although $\widehat{\theta}$ indirectly affects (also) rivals' beliefs, the effects of $\widehat{\theta}$ uniquely take place through the regulator's instruments $(q(\widehat{\theta}), T(\widehat{\theta}))$. Finally, the regulator may "fine tune" the information flow to the unregulated market with a stochastic regulatory contract. A theoretical framework with a principal optimally screening and signaling private information to third parties is in Calzolari and Pavan (2006). We postpone the discussion on this point to Section 6.

[16] With the usual change of variables, maximization in program $(\mathcal{P}^I)$ is equivalently taken over the contract $\left\{ \left(q\left(\theta\right), \Pi^I\left(\theta\right) \right) \right\}_{\theta\in\Theta}$ instead of $\left\{ \left(q\left(\theta\right), T\left(\theta\right) \right) \right\}_{\theta\in\Theta}$. To simplify notation in program $(\mathcal{P}^I)$ we do not explicitly express the feasibility constraints.

contract $(\widehat{q}, \widehat{T}) \in \mathcal{C}$. This firm would obtain a profit

$$\Pi^I\left(\widehat{\theta}, \theta\right) \equiv \widehat{q}\, p(\widehat{q}) + y_1\left(\widehat{q}, \theta, v(\widehat{q})\right)\ p_1^U\left[y_1\left(\widehat{q}, \theta, v(\widehat{q})\right), Y_{-1}\left(\widehat{q}, v(\widehat{q})\right)\right] + \\ - C\left[\widehat{q}, y_1\left(\widehat{q}, \theta, v(\widehat{q})\right); \theta\right] - \widehat{T}$$

and we denote with $\Pi^I(\theta)$ the (equilibrium) profit when the firm announces the true value of the economies of scope, i.e. $\Pi^I(\theta) = \Pi^I\left(\widehat{\theta}, \theta\right)$ with $\widehat{\theta} = \theta$. The incentive constraint $IC(\theta)$ for type θ can then be rewritten as follows

$$\Pi^I(\theta) \geq \Pi^I\left(\widehat{\theta}\right) + \Pi_U\left(\widehat{q}, \theta, v(\widehat{q})\right) - \Pi_U\left(\widehat{q}, \widehat{\theta}, v(\widehat{q})\right), \text{ with } \widehat{\theta} \neq \theta$$

where, for any θ and $\widehat{q}$,

$$\Pi_U\left(\widehat{q}, \theta, v(\widehat{q})\right) \equiv y_1\left(\widehat{q}, \theta, v(\widehat{q})\right)\ p_1^U\left[y_1\left(\widehat{q}, \theta, v(\widehat{q})\right), Y_{-1}\left(\widehat{q}, v(\widehat{q})\right)\right] - \left\{C\left[\widehat{q}, y_1\left(\widehat{q}, \theta, v(\widehat{q})\right); \theta\right] - C\left[\widehat{q}, 0; \theta\right]\right\} \tag{12}$$

can be seen as the profit earned in the unregulated market U by a multi-utility with (true) scope economies θ, producing $\widehat{q}$ in sector R. In (12) the costs attributed to unregulated production is simply the incremental cost of y_1 described by the curly bracket (similarly also for $\Pi_U(\widehat{q}, \widehat{\theta}, v(\widehat{q}))$).[17] Hence, with a more compact notation, constraints $IC(\overline{\theta})$ and $IC(\underline{\theta})$ become

$$\begin{array}{ll} \overline{\Pi}^I \geq \underline{\Pi}^I + \Delta_\theta \Pi_U\left(\underline{q}, v(\underline{q})\right) & IC(\overline{\theta}) \\ \underline{\Pi}^I + \Delta_\theta \Pi_U\left(\overline{q}, v(\overline{q})\right) \geq \overline{\Pi}^I & IC(\underline{\theta}) \end{array} \tag{13}$$

where

$$\Delta_\theta \Pi_U\left(q, v(q)\right) \equiv \Pi_U\left(q, \overline{\theta}, v(q)\right) - \Pi_U\left(q, \underline{\theta}, v(q)\right)$$

identifies the extra gain that a firm with large scope economies $\overline{\theta}$ obtains in market U with respect to a firm with low scope economies $\underline{\theta}$ when they both produce the same regulated output q.

The cost announcement $\widehat{\theta}$ by the multi-utility has here several interesting effects. First of all, as in standard models of regulation with asymmetric information, more efficient firms have incentives to understate their level of scope economies and to mimic less efficient firms in order to obtain more favorable regulation. Formally, this *cost-efficiency effect* of the announcement is captured in $\Delta_\theta \Pi_U\left(\underline{q}, v(\underline{q})\right)$ by the difference $-[C\left(\underline{q}, y_1; \overline{\theta}\right) - C\left(\underline{q}, y_1; \underline{\theta}\right)] \geq 0$. Indeed, if the efficient firm with type $\overline{\theta}$ mimics type $\underline{\theta}$, it produces the same regulated quantity $\underline{q}$ with a cost saving corresponding the previous cost difference.

On the other hand, the informational externality from the regulated market towards the unregulated one generates two additional effects. A *direct strategic effect* emerges because the rivals observe the output which the regulated firm produces and they know that, because of property (2), if regulated output is large their cost disadvantage (with respect to the multi-utility) is going to be large, and vice-versa, for any given level of θ.

Finally, we have a *beliefs-driven strategic effect* which is the consequence of asymmetric information in market U and would not exist if rivals knew θ. As long as $\overline{q} \neq \underline{q}$, the regulatory contract allows the rivals to update their beliefs about the value of θ. The incentive for the multi-utility to declare its type depends on the reaction of its rivals to this situation.

It is intuitive that the impact of these effects will depend on the type of competition prevailing

[17] Being $C[\widehat{q}, 0; \widehat{\theta}] = C\left[\widehat{q}, 0; \theta\right]$, the cost in Π_U can be indeed written in terms of incremental costs as in (12).

in the unregulated market.[18] Although for the moment we prefer to stick to a general analysis of optimal regulation, we will shortly discuss what happens in the two "classical" cases of price and quantity competition (i.e. respectively with strategic complementarity and strategic substitutability). Here, we describe optimal regulation by formally taking into account for all these novel effects introduced by the activities of the regulated firm in the unregulated market.

Proposition 1 (Optimal regulation) *Let $\tilde{q}(\theta)$ be defined by*

$$p\left(\tilde{q}(\theta)\right) = SMC\left(\tilde{q}(\theta), \theta\right) + \mathcal{I}(\theta)(1-\alpha)\frac{v}{1-v}\frac{\partial \Delta_\theta \Pi_U\left(\tilde{q}\left(\theta\right), 0\right)}{\partial q}, \tag{14}$$

where the indicator function $\mathcal{I}(\theta) = 1$ if $\theta = \underline{\theta}$ and 0 otherwise.

(i) The optimal regulated quantity q^* is discriminatory *with $q^*(\theta) = \tilde{q}(\theta)$ for any $\theta \in \Theta$ if*

$$\Delta_\theta \Pi_U\left(\tilde{q}(\overline{\theta})^*, 1\right) \geq \Delta_\theta \Pi_U\left(\tilde{q}(\underline{\theta})^*, 0\right), \tag{15}$$

otherwise it is uniform *with $q^*(\theta) = \tilde{q}$ where $\tilde{q}$ is independent of θ and solves*

$$p\left(\tilde{q}\right) = E_\theta\left[SMC\left(\tilde{q}, \theta\right)\right] + (1-\alpha)\frac{v}{1-v}\frac{\partial \Delta_\theta \Pi_U\left(\tilde{q}, v\right)}{\partial q}. \tag{16}$$

(ii) The profit of a multi-utility with scope economies θ is $\Pi^I\left(\theta\right) = \pi^S + (1-\mathcal{I}(\theta))\Delta_\theta \Pi_U\left(\underline{q}^*, v\left(\underline{q}^*\right)\right)$ with $\underline{q}^*$ as in point (i).

To interpret the results in the Proposition assume for the moment that (15) is satisfied. If the multi-utility with large scope economies $\overline{\theta}$ mimics type $\underline{\theta}$, it obtains the same profit $\underline{\Pi}^I$ plus an additional rent $\Delta_\theta \Pi_U(\underline{q}, v(\underline{q}))$ which corresponds to the larger profit it can obtain with respect to type $\underline{\theta}$ when asked to produce the same quantity $\underline{q}$ and the rivals' beliefs are *fixed* at $v(\underline{q}) = 0$ (i.e. they believe that the multi-utility is indeed inefficient). This additional rent in producing quantity $\underline{q}$ is positive, because only the standard cost-efficiency effect is at play here whilst the two strategic effects mentioned above play no role (we are confronting the profits of the types $\overline{\theta}$ and $\underline{\theta}$ when producing the same output $\underline{q}$ and the rivals hold the same associated beliefs $v(\underline{q})$).

Hence, as in standard models of regulation with asymmetric information, the regulator has to leave the efficient type an additional rent equal to $\Delta_\theta \Pi_U$, otherwise type $\overline{\theta}$ would prefer to mimic type $\underline{\theta}$. On the other hand, she leaves no rents in addition to the outside option π^S to the inefficient type $\underline{\theta}$. Furthermore, being the informational rent for type $\overline{\theta}$ an increasing function of the quantity designed for low scope economies (i.e. $\partial \Delta_\theta \Pi_U(\underline{q}, 0)/\partial \underline{q} \geq 0$), the optimal regulated quantity $\underline{q}$ is distorted downwards relative to full information output $\underline{q}_{FI}^I$. We also have that optimal regulated quantities are differentiated with respect to θ so that $q^*(\overline{\theta}) > q^*(\underline{\theta})$ (generically) holds which finally justifies the updating process described above.

If the multi-utility's incentives in announcing the level of scope economies were solely driven by the cost efficiency effect, then the previous monotonicity on regulated output would also guarantee that the inefficient multi-utility has no incentives to mimic type $\overline{\theta}$. Constraint $IC(\underline{\theta})$ would be also satisfied because mimicking type $\overline{\theta}$ would require that type $\underline{\theta}$ produces a large output $q^*(\overline{\theta})$ which is too costly given its low efficiency.

However, we know that incentives in announcing the level of scope economies are also affected by the two strategic effects which may either facilitate or hinder the regulatory process. To start

[18] A complete formal analysis of the three effects of cost announcement is in the proof of Proposition 2.

with, it is no more true that an inefficient firm is persuaded not to mimic an efficient one simply by output monotonicity. To see that output monotonicity is no more sufficient for truthful revelation, note that being $\underline{\Pi}^I = \pi^S$ and $\overline{\Pi}^I = \underline{\Pi}^I + \Delta_\theta \Pi_U(\underline{q}, v(\underline{q}))$, constraint $IC(\underline{\theta})$ can be rewritten as

$$\underline{\Pi}^I = \pi^S \geq \pi^S + \Delta_\theta \Pi_U(\underline{q}, v(\underline{q})) - \Delta_\theta \Pi_U(\overline{q}, v(\overline{q}))$$

which corresponds to (15) in the Proposition. This shows that by mimicking type $\overline{\theta}$ the multi-utility with low scope-economies can change its profits by the term[19]

$$\Delta_\theta \Pi_U(\underline{q}, 0) - \Delta_\theta \Pi_U(\overline{q}, 1) = \left[\Pi_U(\overline{q}, \underline{\theta}, 1) - \Pi_U\left(\underline{q}, \underline{\theta}, 0\right)\right] - \left[\Pi_U\left(\overline{q}, \overline{\theta}, 1\right) - \Pi_U\left(\underline{q}, \overline{\theta}, 0\right)\right]. \quad (17)$$

With quantity competition in the unregulated market (i.e. strategic substitutability), a firm which appears to be more efficient induces its rivals' to behave less aggressively reducing their outputs thus increasing its profits. If $\overline{q} \geq \underline{q}$, because of the direct strategic effect, shifting regulated production from $\underline{q}$ to $\overline{q}$ induces a contraction of the rivals' outputs. Similarly, for the beliefs-strategic effect, declaring to be very efficient and thus producing a quantity $\overline{q}$ instead of $\underline{q}$, induces the rivals to revise their beliefs and again contract their outputs. Both these changes account for an *increase* of Π_U thus contributing to make the two brackets in (17) larger. Given that higher scope economies (i.e. higher θ) amplify any effect on profits Π_U of changes on regulated output q (by the property (3) of the cost function), the second bracket expands more than the first so that both the two strategic effects make the overall mimicking (potential) gain for type $\underline{\theta}$ even less attractive. Incentive compatibility for the inefficient firm (i.e. $IC(\underline{\theta})$ or (15) in Proposition 1) is thus less demanding than in the case in which the two strategic effects were absent and regulated output may be incentive compatible even if $\overline{q} \geq \underline{q}$ is violated, thus making the regulatory process "simpler".

If instead the unregulated market is characterized by price competition (i.e. strategic complementarity), the strategic effects generate an increase in profits Π_U if the multi-utility shifts from production $\overline{q}$ to $\underline{q}$ so that an accommodating response is induced on the rivals'. Given that this change is intensified by higher scope economies, the second bracket in (17) decreases now more than the first and the multi-utility's unregulated activities make the regulator's task more complex . It is more difficult to satisfy incentive compatibility and constraint $IC(\underline{\theta})$ (or (15) in Proposition 1)) may be violated even if regulated output is monotone. If this is the case, the regulator is obliged to give up with discriminating regulated output with respect to scope-economies and has to resort to uniform regulation, as indicated in the pricing condition (16).

These results are summarized in the following Proposition.

Proposition 2 .

*(i) With **quantity-competition** in the unregulated market, optimal regulation is discriminatory with $\underline{q}^* = \tilde{q}(\underline{\theta}) \leq \underline{q}^I_{FI}$, $\overline{q}^* = \tilde{q}(\overline{\theta}) = \overline{q}^I_{FI}$. The multi-utility is hurt by the lack of information about scope economies of the rival firms which also makes the regulator's task simpler.*

*(ii) With **price-competition**, optimal regulation may be either discriminatory with $q^*(\theta) = \tilde{q}(\theta)$ or uniform with $q^*(\theta) = \tilde{q}$ for any θ and $\underline{q}^I_{FI} \gtrless \tilde{q} \leq \overline{q}^I_{FI}$. In any case, the multi-utility gains by the lack of information of the rivals and the regulator's task is more complex.*

[19] If only the cost-efficiency effect were at play, (17) would reduce to $C(\underline{q}, y_1; \overline{\theta}) - C(\underline{q}, y_1; \underline{\theta}) - \left[C\left(\overline{q}, y_1; \overline{\theta}\right) - C\left(\overline{q}, y_1; \underline{\theta}\right)\right]$ which is negative if $\overline{q} \geq \underline{q}$ for the properties (2)-(3) of the cost function, thus implying incentive compatibility.

With price-competition it is clear that the informational rent $\Delta_\theta \Pi_U(\underline{q}, v(\underline{q}))$ of the efficient multi-utility is larger if mimicking an inefficient firm induces the rivals to believe that it is really inefficient, i.e. when $v(\underline{q}) = 0$. On the contrary, if the rivals were informed on the level of scope economies, so that their beliefs would be $v(\underline{q}) = 1$ in any case, then they would reduce their price by much lesser extent than when their beliefs are $v(\underline{q}) = 0$ so that, ultimately $\Delta_\theta \Pi_U(\underline{q}, 1) \leq \Delta_\theta \Pi_U(\underline{q}, 0)$. Clearly, the opposite holds with quantity-competition.

4.1 An explicit model

Here we present a simple explicit model which allows to further investigate the interplay between regulated and unregulated activities of the multi-utility. Let costs be described by (4) so that the level of scope economies here are simply assessed by the term $-\theta q y_1$ in the cost function and demands in the two markets are as follows:

$$\begin{array}{ll} \text{Market } R: & p_R = \gamma_R - q,\ \gamma_R \geq c \\ \text{Market } U: & \begin{cases} y_i = \gamma_U - b p_i^U + \sum\limits_{j \notin i} s p_j^U & \text{with price-competition} \\ p_i^U = \gamma_U - b y_i - \sum_{j \neq i} s y_j & \text{with quantity competition} \end{cases} \end{array} \tag{18}$$

where $\gamma_U \geq c$, $b \geq (n-1)s \geq 0$ and $s \geq 0$ is a substitutability parameter.[20]

When the regulated firm cannot integrate productions, regulation in market R takes place under full information, with optimal price $p(q^S) = c$ and quantity $q^S = \gamma_R - c$ and the regulated firm is left with profit π^S which depends on the type of competition in the unregulated markets. The regulatory contract in this case is $\mathcal{C}^S \equiv (\gamma_R - c, -\pi^S)$.

Quantity-competition. It will be useful to indicate the error on multi-utility' scope-economies incurred by the rival firms when the multi-utility chooses a regulated output $\widehat{q} = q(\widehat{\theta})$ and has a true level of scope economies θ,

$$\Delta(\widehat{q}, \theta) \equiv v(\widehat{q})\,\overline{\theta}\overline{q} + (1 - v(\widehat{q}))\underline{\theta}\underline{q} - \theta\widehat{q}.$$

so that with discriminatory regulation we have,

$$\Delta\left(\overline{q}, \overline{\theta}\right) = \Delta\left(\underline{q}, \underline{\theta}\right) = 0, \quad \Delta\left(\overline{q}, \underline{\theta}\right) = \overline{q}\left(\overline{\theta} - \underline{\theta}\right) > 0, \quad \Delta\left(\underline{q}, \overline{\theta}\right) = -\underline{q}\left(\overline{\theta} - \underline{\theta}\right) < 0.$$

Clearly, if the announcement $\widehat{\theta}$ corresponds to the true level of scope economies $\widehat{\theta} = \theta$, then observing $\widehat{q}$ the rivals will make no error and $\Delta = 0$. On the contrary, for $\widehat{\theta} \neq \theta$ the error may induce the rivals to over- or under-estimate scope economies. Finally, with uniform regulation $\tilde{q}$ we clearly have $\Delta\left(\tilde{q}, \overline{\theta}\right) = \tilde{q}\left[v\overline{\theta} + (1-v)\underline{\theta} - \theta\right]$ ..

Outputs in the unregulated market can then be written as

$$\begin{array}{l} y_1(q, \theta, v(q)) = y_1^{FI}(q, \theta) + \frac{(n-1)s^2}{2b(2b-s)[2b+s(n-1)]}\Delta(q, \theta) \\ y(q, v(q)) = y^{FI}(q, \theta) - \frac{s}{(2b-s)[2b+s(n-1)]}\Delta(q, \theta) \end{array} \tag{19}$$

where $y_1^{FI}(q, \theta)$ and $y^{FI}(q, \theta)$ are the outputs that would prevail were the rivals informed and the regulated quantity q (more details are in the Appendix). When the rivals overestimate the expected

[20] In case of price-competition, this system of demand for market U are derived from utility $V_U[y_1, y] = \mu(y_1 + (n-1)y) - \frac{1}{2}\beta\left(y_1^2 + (n-1)y^2\right) - \gamma(n-1)y_1 y$ where $\gamma_U = \frac{\mu}{\beta+(n-1)\sigma}$, $b = \frac{\beta+(n-2)\sigma}{(\beta+(n-1)\sigma)(\beta-\sigma)}$, $s = \frac{\sigma}{(\beta+(n-1)\sigma)(\beta-\sigma)}$.

scope economies so that $\Delta \geq 0$, the multi-utility expands its production and the rivals contract theirs, and the opposite holds with underestimation $\Delta \leq 0$. In the former case the multi-utility gains and the rivals lose and the opposite in the latter case.

In the Appendix we show that constraint $IC(\underline{\theta})$ is here equivalent to

$$\left(\overline{q}-\underline{q}\right) 4b(2b-s)\left(\gamma_U - c\right) + \overline{q}^2 k - \underline{q}^2 a \geq 0$$

with $k \geq a \geq 0$. This shows that monotonicity $\overline{q} \geq \underline{q}$ is sufficient but not necessary for this constraint, as we already illustrated in the previous section. Furthermore, along the same lines in the Appendix we also show that the multi-utility rent $\Delta_\theta \Pi_U(\underline{q}, 0)$ is reduced by the error $\Delta(\underline{q}, \overline{\theta}) < 0$. As discussed above the imperfect information of the rival firms indeed negatively affect the multi-utility and favours the regulator.

Price-competition. Equilibrium prices in market U are

$$\begin{array}{r} p_1^U = p_1^{FI}\left(q,\theta\right) - \frac{(n-1)s^2}{2(2b+s)(2b-(n-1)s)}\Delta\left(q,\theta\right), \\ p^U = p^{FI}\left(q,\theta\right) - \frac{bs}{(2b+s)(2b-(n-1)s)}\Delta\left(q,\theta\right). \end{array} \tag{20}$$

where $p_1^{FI}(q,\theta)$ and $p^{FI}(q,\theta)$ are the prices prevailing were the rivals informed on θ. Now, contrary to quantity competition, if rivals expect larger economies of scope than real ones (i.e. $\Delta(q,\theta) \geq 0$), then they reduce their price and, by complementarity, also the multi-utility reduces its price. Equilibrium multi-utility's profit then is decreasing in $\Delta(q,\theta)$.

It is also instructive to analyze the effects of cost announcement by the multi-utility. As previously explained, with price-competing firms multi-utility's incentives to understate scope economies are aligned in the two markets so that the regulator will find it more difficult to obtain information revelation. This reflects first into the constraint $IC(\underline{\theta})$ which is here equivalent to

$$2A\left(\overline{q}-\underline{q}\right) + B\left(\overline{q}^2-\underline{q}^2\right)\left(\overline{\theta}+\underline{\theta}\right) \geq \left(\overline{q}^2+\underline{q}^2\right)(n-1)s^2\left(\overline{\theta}-\underline{\theta}\right)$$

with $A > 0$ and $B > 0$ so that monotonicity $\overline{q} \geq \underline{q}$ is neither necessary nor sufficient for this constraint. Furthermore, we also show in the appendix that indeed the firm's rent $\Delta_\theta \Pi_U(\underline{q}, 0)$ is now increased by the error $\Delta(\underline{q}, \overline{\theta}) < 0$.

Proposition 3 *Let cost and demand in the two markets be as in (4) and (18). Simple comparative statics shows the following.*

Quantity-competition. *A less concentrated (i.e. large n) or smaller (i.e. small γ_U) unregulated market leads to a smaller informational rent for the multi-utility and a smaller asymmetric-information distortion on regulation.*

Price-competition. *Both effects of both concentration and size in the unregulated market are ambiguous. A more competitive and smaller unregulated market may increase both the informational rent and the regulatory distortion.*

We know that the standard cost-efficiency effect of the announcement depends on output y_1 in the unregulated market (we omit a discussion of the strategic effects since it would follow the same lines). The larger is y_1, the larger the scope economies term $\theta q y_1$ reducing costs, as well as the cost saving of firm with $\theta = \overline{\theta}$ as compared with type $\theta = \underline{\theta}$. Hence, when y_1 is large, for example due to a large unregulated market or limited competition in market U, the regulator has to leave a larger profit $\Delta_\theta \Pi_U$ to type $\overline{\theta}$ and this also increases the distortion arising when scope economies are low. This result shows that if a regulated firm wants to expand its activities in one out of several unregulated markets, when competition is on quantities it will enter into larger markets that are also less competitive. It is worth noticing that in this case the firm's entry decision is misaligned to consumers' preferences in the regulated market (whether it is desirable at all to let the firm enter any unregulated market will be thoroughly discussed in the next section).

Things are different with price-competing firms in market U. In fact, in addition to the effects of the size and competitiveness of the unregulated market discussed for quantity competition, we know in this case the two strategic effects increase the firm's rents and the regulatory distortions. Since the characteristics of the unregulated market (i.e. n and γ_U) now have a complex impact on these strategic effects (also recall that optimal regulation can now be uniform), it turns out that a more competitive and larger unregulated market may increase the informational rent and negatively affect consumers in the regulated market.

5 The desirability of horizontal integration

We now investigate whether allowing the multi-utility to integrate production of regulated and unregulated outputs is desirable at all. Equivalently, we study the desirability of allowing a regulated firm to expand its activities into an unregulated and competitive market.

This is a complex question because on the one hand production integration brings (large or small) scope economies, but on the other hand scope economies are privately known by the multi-utility who can take advantage of this private information with respect to the regulator and also to the rival firms. As shown in Proposition 1, the asymmetric information associated with production integration allows the firm to earn informational rents that are a social cost and also induce inefficiencies in the regulatory process since the regulated price systematically entails a loss of allocative efficiency when economies of scope are small. Furthermore, when the regulator cannot discriminate regulation on the basis of the firm's efficiency (i.e. when uniform regulation is in place), then rival firms in the unregulated market face the additional problem that they operate under asymmetric information which may negatively impact on their profits and on consumer surplus in that market.

To analyze the desirability of integration it is first useful to consider two simplified informational setups. In particular, consider first the benchmark where *both the regulator and the rivals know the level of scope economies* (which has been developed in Section 3) When the multi-utility can integrate its activities, several effects emerge on welfare as compared with the case of separation. First, the multi-utility is more efficient in its activities in the unregulated market where total industry costs are then lower and equilibrium prices would be reduced. Second, the overall profits earned by the firms in the two industries are reduced. In fact, total profits earned by the firms in the two markets are $\pi^S + \sum_{i \neq 1} \pi_i^I(q, \theta)$ with integration and $\sum_{i=1}^n \pi_i^S$ with separation and we know that $\pi_i^I(q, \theta) \leq \pi_i^S$ since with integration the rivals face a tougher competitor. Hence, with this informational setup allowing integrated multi-utility production is clearly desirable. Note that this would be the case even if rivals were not informed on θ (with the regulator fully informed). In fact, regulation would convey all the information on θ since (generically) $\overline{q}_{FI}^I \neq \underline{q}_{FI}^I$ and $\overline{p}_{FI}^I \neq \underline{p}_{FI}^I$.[21]

This discussion shows that the problem with integrated production should relate first to the worsening of the *regulator's information.* Hence, we may consider a different informational setup

[21] The desirability of integration holds even if the regulator prefers to convey only partial information on θ to the unregulated market, for whatever reason. In fact, the welfare associated with full information disclosure is always attainable and is larger than that with separation.

in which the regulator does not know the level of scope economies but the rival firms are fully informed on θ. The following Proposition illustrates the desirability of integration in these two specific informational setups.

Proposition 4 .

(i) If the regulator is fully informed on scope-economies, letting the multi-utility to integrate production is socially desirable, independently of the information of the rivals in the unregulated market;

(ii) If the rivals are fully informed, then integration is socially desirable independently of the regulator's information.

The intuition for point (ii) in the Proposition is simple. Imagine that with integration the regulator simply offers the multi-utility exactly the same regulatory contract $\mathcal{C}^S$ that she would offer in case of separation. Clearly, the consumer surplus in the regulated sector would be unaffected relative to the case of separation because the firm produces exactly the same quantity q^S. The multi-utility would obtain a larger profit due to scope economies which increase social welfare proportionally to the weight α. Finally, being the rivals fully informed, the unregulated market simply becomes more efficient because one of the active firms (the multi-utility) now has lower costs.

However, rival firms in unregulated markets often claim their impossibility to ascertain the actual level of scope economies of the multi-utility firm, as much as regulators do. When this is the case none of the previous arguments is sufficient to reach a conclusion on the desirability of integration. In fact, employing with integration the contract $\mathcal{C}^S$ designed for separation would leave rival firms uninformed on scope economies; this may negatively affect their competitive response as well as welfare in the unregulated market. Hence, a more detailed analysis is called for and we need to distinguishes the type of competition taking place in the unregulated market.

Consider first price competition for differentiated products. From the analysis of Propositions 1 and 2 we know that being rivals uninformed information revelation is much more problematic possibly also leading to large distortions on regulated outputs independently of the level scope economies (e.g. when uniform regulation is only viable). However, consider again the contract $\mathcal{C}^S$ which the regulator designs in case of separation. As we know, the tricky issue with this policy applied when the multi-utility integrates production is that, if applied when rivals are uninformed, it leaves these firms with no information on scope economies. However, with price competition (in general with strategic complementarity) the possibility that the regulated firm has lower costs makes *rivals more aggressive* thus inducing a larger welfare in the unregulated market.

Hence, although regulation $\mathcal{C}^S$ is suboptimal and leaves the rivals uninformed, it still allows to reach a level of welfare that is larger than that obtainable if separation were imposed. With price competition, even a sub-optimal regulatory contract makes integration desirable.

This is no longer true with quantity competition (in general with strategic substitutability). Indeed, one cannot rely on the contract designed for separation $\mathcal{C}^S$ because now leaving the rivals with no information hurts the unregulated market. In particular, if the rival firms believe that with positive probability the multi-utility firm has lower costs they will react by *reducing* their output levels and *a priori* there are no reasons to believe that the overall effect on welfare will in general be positive. In particular, when the rivals do not know the value of θ and do not receive any information from the regulatory process, they act as if the multi-utility had an "average" level of scope economies so that when the real value of θ is $\overline{\theta}$, they underestimate the scope economies and produce more than they would otherwise do. On the contrary, when they overestimate the level of scope economies, they reduce production and it may well happen that the contraction of total production of the $n-1$ rivals exceeds the expansion of the multi-utility.[22] Now, using contract $\mathcal{C}^S$ which induces outputs $Y\left(q^S,\overline{\theta},v\right) \geq Y^S \geq Y\left(q^S,\underline{\theta},v\right)$ and being the gross consumer surplus a concave function of total output, it follows that the net effect of integration on consumer surplus may become negative. Integration with asymmetric information in the unregulated market induces larger variability on consumption relative to the case of separation and this may ultimately harm welfare in that sector.

Despite this negative consideration, we can nevertheless reach the following interesting conclusion.

Proposition 5 (Desirability of Integration) *Letting the regulated firm integrate its productions for the regulated and unregulated market is socially desirable, even if the rival firms and the regulator do not know the value of scope economies, and irrespective of the type of competition in the unregulated market.*

To understand why integration is ultimately desirable even if competition is in on quantities we can resort on our previous results on optimal regulation in Section 4 and on Proposition 4. The important reference point to consider now is that of optimal regulation when the regulator is uninformed but where the rivals are fully informed on θ. Let indicate the associated optimal policy with $\mathcal{C}'$. Imagine now to employ regulation $\mathcal{C}'$ in the current contest where rivals do not know θ. A first potential issue is that this policy may not be incentive compatible now. However, as discussed in Section 4, when rival firms are uniformed the regulator will find it easier to elicit information by the multi-utility. In fact, the firm with large scope economies obtains a smaller profit and the inefficient firm finds it less convenient to mimic high scope economies when the rivals are uninformed.

All this implies that even if regulation $\mathcal{C}'$ is designed for the case in which rivals are informed, it remains incentive compatible also when applied to the case in which rivals are uninformed. Hence, although this policy is potentially suboptimal in the latter case, nevertheless it induces truthful revelation and allows to reach a social welfare which is larger than that arising with integration when the regulator is uninformed but the rivals do know the level of multi-utility' scope economies. Applying result (ii) in Proposition 4, it follows immediately that integration is desirable even if firms compete in quantities, so that despite the asymmetric information that integration brings about and irrespectively of strategic complementarity or substitutability in the unregulated market, integration is preferable to separation as the reaction of competition in the unregulated market can be ultimately turned to the benefits of consumers and overall welfare.

6 Concluding remarks

We have analyzed optimal regulation of a multi-utility firm that serves both a regulated and an unregulated market. When the multi-utility is allowed integrate its production, scope economies arise which reduce the firm's costs. However, the extent of scope economies is not perfectly known by the regulator and by the rival firms in the unregulated market so that regulation is distorted

[22] In the explicit model of Section 4.1 we have $Y^S - Y(q^S,\underline{\theta},v) = (n-1)v\overline{q}\overline{\theta} - \underline{q}\underline{\theta}\left[2+v(n-1)\right]$ which is positive if $\underline{\theta}$ is sufficiently low, e.g. when $\underline{\theta}=0$. Furthermore, this uncertainty over θ may even induce some rivals to exit the market.

by asymmetric information and also competition may be negatively affected. The regulator has then to take into account how the unregulated market reacts to decisions in the regulated one also because this affects the multi-utility incentives in its regulated activity. A notable effect of regulation is an informational externality: the implemented regulatory policy provides valuable information to the rival firms and its effects (on both markets) depend on the nature of competition in the unregulated market. We have thus discussed optimal regulation and its distortions due to asymmetric information when competition in the unregulated market takes place either on quantities or on prices. We have shown that with quantity competition this externality simplifies the task of the regulator which instead becomes more complex in case of price competition.

We have then addressed the issue of desirability of joint production in the multi-utility's activities. In this respect a potential trade-off emerges. On one hand, allowing the multi-utility to integrate productions reduces its costs and, if this is at least partially passed on lower prices, then consumers (possibly in both markets) may benefit. On the other hand, the multi-utility's private information makes the regulator's task more difficult thus leading to distortions in the regulatory policy and also makes the unregulated market potentially less competitive. Notwithstanding this trade-off, we are able to show that if uncertainty is uniquely on the size of scope economies and diseconomies of scopes are ruled out, then integrated production is socially desirable, and if the multi-utility is allowed to do so, it always prefers to take profit of this opportunity.

In this paper we have not explicitly considered the possibility of diseconomies of scope (which in our model would correspond to $\underline{\theta} < 0$). If this could be the case, then the desirability of integration of multi-utility's activities may clearly break down and the regulator should add to the negative side of integration also the risk of ending up with a less efficient multi-utility.

A novelty in this paper is the informative role played by the regulatory policy. This informational externality from regulation towards the unregulated market has been addressed in a simple dichotomous way. Either the policy fully informs the rivals or it provides no information at all. This simple policy may be suboptimal if the regulator could "fine tune" the information provided to the unregulated market. However, being the regulated price naturally observable, a more sophisticated disclosure policy would then require stochastic regulatory contracts that deliver only partial information.[23] In this respect, it is important to notice that our results on the desirability of an integrated multi-utility would not be affected by this extension. Indeed, a more sophisticated regulatory policy that optimally controls for the information flow would simply make integrated production by the multi-utility even more desirable.

Moreover, it may be interesting to study the properties of optimal regulation associated with an optimal disclosure policy (for example along the lines illustrated in Calzolari and Pavan, 2006). Our results suggest that when competition in the unregulated market takes place in quantities, disclosing information should be optimal, while a "no disclosure" policy seems to be preferable with price competition. This is an interesting challenge that we plan to explore further in future research.

Another set of potential benefits of integrated production that we do not address in this paper relates to the demand side. Having captive customers in the regulated market may allow the multi-utility to capture those customers with the joint sale of the goods/services. This could be due to intrinsic advantages for customers of having only one provider for both services (joint billing, lower transaction costs summarized in the expression "one stop shop"). In addition, the possibility to

[23] Interestingly, the optimality of stochastic regulatory contracts may emerge in a context in which, absent the informative role of the regulatory policy, the optimal contract would be deterministic, as in standard models of regulation with asymmetric information.

tailor joint offers at more advantageous conditions can also be a source of gains for consumers but also of concerns for competitors. We leave this for future research.

References

[1] Baron, D. and R. Myerson, 1982, Regulating a firm with unknown cost, *Econometrica*, 50(4): 911-30.

[2] Berry, S.K., 2000, "Excess Returns in Electric Utility Mergers during the Transition to Competition", *Journal of Regulatory Economics*, Vol.18, No.2: 175-188.

[3] Braeutigam R. R. and J. C. Panzar, 1989, Diversification Incentives Under "Price-Based" and "Cost-Based" Regulation, *RAND Journal of Economics*, 20,3: 373-391.

[4] Brennan. T. 1990, Cross-Subsidization and Cost Misallocation by Regulated Monopolists, *Journal of Regulatory Economics*, 2, pp.37-51

[5] Brennan, T., Palmer, K., 1994. Comparing the costs and benefits of diversification by regulated firms. *Journal of Regulatory Economics* 6, 115–136.

[6] Calzolari G., 2001, The Theory and Practice of Regulation with Multinational Enterprises, *Journal of Regulatory Economics,* Vol. 20, 2: 191-211.

[7] Calzolari G. and C. Scarpa, 2006, "Footloose monopolies: regulating a "national champion," mimeo University of Bologna.

[8] Calzolari, G. and A. Pavan, 2006, "On the Optimality of Privacy in Sequential Contracting," forthcoming *Journal of Economic Theory.*

[9] Chaaban, J.M. 2004, "Partial regulation and cost allocation in multi-market utilities," Economics Working Paper Archive 200403, French Institute for Agronomy Research (INRA), Toulouse.

[10] De Fraja, G. and F. Delbono, 1990. "Game Theoretic Models of Mixed Oligopoly," *Journal of Economic Surveys*, 4(1), 1-17.

[11] Fraquelli, G., M. Piacenza and D. Vannoni, 2004, "Scope and scale economies in multi-utilities: evidence from gas, water and electricity combinations," *Applied Economics* , 36,18: 2045-2057.

[12] Iossa, E. (1999), "Informative Externalities and Pricing in Regulated Multiproduct Industries," *Journal of Industrial Economics*, 47, pp.195-219

[13] Katzman, B. and M. Rhodes-Kropf, (2002): "The Consequences of Information Revealed in Auctions", mimeo Columbia University, Graduate School of Business.

[14] Laffont J.J. and J. Tirole, 1986, "Using Cost Observation to Regulate Firms," *Journal of Political Economy*, vol. 94(3): 614-41.

[15] Leggio, K.B. and Lien, D., 2000, "Mergers in the Electric Utility Industry in a Deregulatory Environment", *Journal of Regulatory Economics*, Vol.17, No.2: 69-85.

[16] Lewis T. and D. Sappington, 1989, "An informational effect when regulated firms enter unregulated market", *Journal of Regulatory Economics*, 1: 35-45.

[17] OFWAT, 1998, Regulatory issues associated with multi-utilities: A joint paper by the Directors General of Electricity Supply, Gas Supply, Telecommunications and Water Services, the Director General of Electricity Supply (Northern Ireland) and the Director General of Gas (Northern Ireland), available on Internet.

[18] Sakai, Y., 1985, The value of information in a simple duopoly model, *Journal of Economic Theory*, 36, 36-54.

[19] Sappington, D. 2003, Regulating horizontal diversification, *International Journal of Industrial Organization*, 21 291–315

[20] Sommer, D., 2001, *Multi Utilities: Trends. Blurring Industry Boundaries.* Viewpoint No. 227, World Bank, Washington D.C..

[21] Vives, X., 1999, *Oligopoly Pricing, old ideas and new tools*, MIT Press.

[22] Zhong, H., 2002, "Information revelation, post-bid market interaction and auction choice", mimeo Nuffield College, Oxford.

7 Appendix

Proof of Proposition 1. *Step 1.* Program $(\mathcal{P}^I)$ consists in maximizing

$$E_\theta \left\{ W^I \left[q, y_1 \left(q, \theta, v(q) \right), Y_{-1} \left(q, v(q) \right), \theta \right] \right\}$$

with respect to $\left\{ \left(\bar{q}, \overline{\Pi}^I \right), \left(\underline{q}, \underline{\Pi}^I \right) \right\}$ subject to constraints $IC(\theta)$ and $IR(\theta)$ for $\theta \in \Theta$:

$$\begin{array}{ll} \overline{\Pi}^I \geq \underline{\Pi}^I + \Delta_\theta \Pi_U \left(\underline{q}, v(\underline{q}) \right), & IC(\overline{\theta}) \\ \underline{\Pi}^I + \Delta_\theta \Pi_U \left(\overline{q}, v(\overline{q}) \right) \geq \overline{\Pi}^I, & IC(\underline{\theta}) \\ \overline{\Pi}^I \geq \pi^S, & IR(\overline{\theta}) \\ \underline{\Pi}^I \geq \pi^S. & IR(\underline{\theta}) \end{array}$$

For given quantity q and associated beliefs of the rival firms $v(q)$, a more efficient firm obtains in market U a larger profit so that $\Delta_\theta \Pi_U \left(q, v(q) \right) > 0$ for any $q > 0$. Hence, constraints $IC(\overline{\theta})$ and $IR(\underline{\theta})$ imply that $IR(\overline{\theta})$ is slack and can be disregarded. This in turn means that constraint $IR(\underline{\theta})$ must be binding at the optimum. In fact, at least one of the two participation constraints has to be binding at the optimum, because, otherwise, the regulator could reduce both profits $\underline{\Pi}^I$, $\overline{\Pi}^I$ by an equal amount, thus keeping incentive compatibility unaffected and increasing the objective function. Furthermore, constraint $IC(\overline{\theta})$ must also be binding at the optimum. In fact, reducing $\overline{\Pi}^I$ the regulator is able to increase the objective function without negatively affecting $IC(\underline{\theta})$. Hence, she optimally reduces $\overline{\Pi}^I$ as much as possible up to the point in which constraint $IC(\overline{\theta})$ binds.

As for constraint $IC(\underline{\theta})$, this can be written as

$$\Delta_\theta \Pi_U \left(\overline{q}, v(\overline{q}) \right) \geq \Delta_\theta \Pi_U \left(\underline{q}, v(\underline{q}) \right). \tag{21}$$

Note that if $\overline{q} = \underline{q}$, then $v(\overline{q}) = v(\underline{q})$ so that $\Delta_\theta \Pi_U \left(\overline{q}, v \right) = \Delta_\theta \Pi_U \left(\underline{q}, v \right)$ and constraint $IC(\underline{\theta})$ is trivially satisfied. The case with $\overline{q} \neq \underline{q}$ will be treated in the next steps.

Step 2. Using step 1, we can now further rewrite program $(\mathcal{P}^I)$ in the following equivalent way

$$(\mathcal{P}') \begin{cases} \underset{(\overline{q}, \underline{q})}{Max} E_\theta \left\{ V_R(q) + V_U \left[Y(q,\theta) \right] - C \left[q, y_1(q,\theta); \theta \right] - \sum_{i \neq 1} C \left[y_i(q,\theta) \right] + \right. \\ \qquad \left. -(1-\alpha) \sum_{i \neq 1} \pi_i^I (q,\theta) \right\} - (1-\alpha) v \Delta_\theta \Pi_U \left(\underline{q}, v(\underline{q}) \right) \\ s.t. \quad \Delta_\theta \Pi_U \left(\overline{q}, v(\overline{q}) \right) \geq \Delta_\theta \Pi_U \left(\underline{q}, v(\underline{q}) \right) \qquad IC(\underline{\theta}) \end{cases}$$

Hence, let $\tilde{q}(\theta)$ for $\theta \in \Theta$ be solution of the following two first order conditions

$$\begin{array}{l} \frac{\partial SMC\left(\overline{q}, \overline{\theta}\right)}{\partial q} = 0 \\ \frac{\partial SMC\left(\underline{q}, \underline{\theta}\right)}{\partial q} - (1-\alpha) \frac{v}{1-v} \frac{\partial \Delta_\theta \Pi_U \left(\underline{q}, 0\right)}{\partial q} = 0 \end{array}$$

where $v(q) = 0$ for $q = \tilde{q}(\underline{\theta})$, $v(q) = 1$ for $q = \tilde{q}(\overline{\theta})$ and generically we have $\tilde{q}(\overline{\theta}) \neq \tilde{q}(\underline{\theta})$.

If $\Delta_\theta \Pi_U \left(\tilde{q}(\overline{\theta}), 1 \right) \geq \Delta_\theta \Pi_U \left(\tilde{q}(\underline{\theta}), 0 \right)$, then the optimal regulated quantities $q^*(\theta)$ are $q^*(\theta) = \tilde{q}(\theta)$ for any θ, because these quantities maximize the objective in $(\mathcal{P}')$ and satisfy the unique constraint $IC(\underline{\theta})$.

If instead $\Delta_\theta \Pi_U \left(\tilde{q}(\overline{\theta}), 1\right) < \Delta_\theta \Pi_U \left(\tilde{q}(\underline{\theta}), 0\right)$, quantities $\tilde{q}(\overline{\theta}), \tilde{q}(\underline{\theta})$ violate $IC(\underline{\theta})$ so that the optimal solution requires that $IC(\underline{\theta})$ binds. Thus, consider a pair of quantities $\overline{q}, \underline{q}$ such that $\Delta_\theta \Pi_U \left(\overline{q}, v(\overline{q})\right) = \Delta_\theta \Pi_U \left(\underline{q}, v(\underline{q})\right)$. This implies $\overline{q} = \underline{q}$. In fact, suppose on the contrary that $\overline{q} \neq \underline{q}$ so that $v(\overline{q}) = 1$, $v(\underline{q}) = 0$ and $\Delta_\theta \Pi_U \left(\overline{q}, 1\right) = \Delta_\theta \Pi_U \left(\underline{q}, 0\right)$ or equivalently

$$\Pi_U \left(\overline{q}, \overline{\theta}, 1\right) - \Pi_U \left(\overline{q}, \underline{\theta}, 1\right) = \Pi_U \left(\underline{q}, \overline{\theta}, 0\right) - \Pi_U \left(\underline{q}, \underline{\theta}, 0\right).$$

This last equality is clearly generically impossible unless $\overline{q} = \underline{q}$, thus leading to a contradiction. Hence, when $IC(\underline{\theta})$ binds optimal regulation requires pooling so that quantities do not depend on θ. In this case, whatever its type θ, the multi-utility firm is required to produce a quantity $\tilde{q}$ independent of θ. This quantity can the be obtained by solving the following program,

$$\underset{q}{Max} E_\theta \Big\{ V_R(q) + V_U\left[Y(q,\theta)\right] - C\left[q, y_1(q,\theta);\theta\right] - \textstyle\sum_{i \neq 1} C\left[y_i(q,\theta)\right] + \\ -(1-\alpha)\textstyle\sum_{i\neq 1} \pi_i^I(q,\theta) \Big\} - (1-\alpha) v \Delta_\theta \Pi_U(q,v)$$

where constraint $IC(\underline{\theta})$ is omitted because, for what stated at the end of step 1, it is satisfied when $\overline{q} = \underline{q} = \tilde{q}$.

Step 3. Given the optimal quantities $q^*(\theta)$ obtained in step 2 we then have that the profit of the multi-utility with low scope economies is $\Pi^I\left(\underline{\theta}\right) = \pi^S$ from $IR(\underline{\theta})$ binding and for the efficient one is $\Pi^I\left(\overline{\theta}\right) = \pi^S + \Delta_\theta \Pi_U\left(\underline{q}^*, v\left(\underline{q}^*\right)\right)$ from $IC(\overline{\theta})$ binding. ■

Proof of Proposition 2. *Step 1.* We first derive the ranking on quantities $\tilde{q}(\underline{\theta}), \tilde{q}(\overline{\theta})$ defined in the text of Proposition 1.

We show that the distortion $\partial \Delta_\theta \Pi_U(q,v)/\partial q$ in the pricing conditions (14) and (16) is positive independently of the type of strategic interaction in the unregulated market. To see this, for the generic strategic variable x_1 of the multi-utility in market U consider the associated the first order condition,

$$\frac{\partial}{\partial x_1} \Pi^I(\widehat{q}, x_1, X_{-1}; \theta) = 0.$$

This condition depends on θ through the marginal cost $\frac{\partial C(q,y_1;\theta)}{\partial y_1}$. Now, the properties of the cost function (1)-(3) state that (i) this marginal cost is reduced by a larger q, due to scope economies, and (ii) this reduction is stronger the higher is θ (i.e. with large scope economies). Hence, for the implicit function theorem, it follows that the equilibrium profit $\Pi_U(q,\theta,v)$ is increasing in q, in θ and that the profit increase caused by a larger q is larger the higher is θ. Hence, keeping constant the rivals' beliefs for (i.e. for a given v) we have

$$\frac{\partial \Pi_U\left(q, \overline{\theta}, v\right)}{\partial q} \geq \frac{\partial \Pi_U\left(q, \underline{\theta}, v\right)}{\partial q} \geq 0, \tag{22}$$

and then

$$\frac{\partial \Delta_\theta \Pi_U(q,v)}{\partial q} \geq 0. \tag{23}$$

With the sign of (23) we then obtain the ranking on optimal regulated output. In particular, if with full information scope economies induce a larger regulated output $\underline{q}_{FI}^I \leq \overline{q}_{FI}^I$, then (23) implies $\tilde{q}(\underline{\theta}) \leq \tilde{q}(\overline{\theta})$ with strict inequality if $\overline{\theta} > \underline{\theta}$.

Step 2. Notwithstanding the monotonicity proved in the previous step, Proposition 1 illustrates that, quantities $\tilde{q}(\underline{\theta}), \tilde{q}(\overline{\theta})$ may fail to be incentive compatible. Here we analyze when this is the case and we check whether these outputs satisfy constraint $IC(\underline{\theta})$. As illustrated in (21), the incentive compatibility constraint for type $\underline{\theta}$ is equivalent to

$$\left[\Pi_U\left(\overline{q}, \underline{\theta}, 1\right) - \Pi_U\left(\underline{q}, \underline{\theta}, 0\right)\right] - \left[\Pi_U\left(\overline{q}, \overline{\theta}, 1\right) - \Pi_U\left(\underline{q}, \overline{\theta}, 0\right)\right] \leq 0. \tag{24}$$

We now decompose this inequality into the three effects of cost announcement. To consider the simple *cost-efficiency effect* of announcement, let us fictitiously assume that outputs y_1 and y do not depend on θ and q, in which case (24) would be

$$\begin{array}{l}\left[-C\left(\overline{q}, y_1; \underline{\theta}\right) + C\left(\overline{q}, 0; \underline{\theta}\right) + C\left(\underline{q}, y_1; \underline{\theta}\right) - C\left(\underline{q}, 0; \underline{\theta}\right)\right] + \\ -\left[-C\left(\overline{q}, y_1; \overline{\theta}\right) + C\left(\overline{q}, 0; \overline{\theta}\right) + C\left(\underline{q}, y_1; \overline{\theta}\right) - C\left(\underline{q}, 0; \overline{\theta}\right)\right] \leq 0\end{array}$$

or equivalently

$$\int_{\underline{q}}^{\overline{q}} \int_0^{y_1} \frac{\partial^2 C\left(h, u; \overline{\theta}\right)}{\partial y_1 \partial q} du dh - \int_{\underline{q}}^{\overline{q}} \int_0^{y_1} \frac{\partial^2 C\left(h, u; \underline{\theta}\right)}{\partial y_1 \partial q} du dh \leq 0.$$

It is then immediate that properties of the cost function (1)-(3) imply that the previous inequality is satisfied by standard monotonicity, i.e. for $\underline{q} \leq \overline{q}$.. Hence, the cost-efficiency effect alone would imply that outputs $\left(\tilde{q}(\underline{\theta}), \tilde{q}(\overline{\theta})\right)$ are implementable.

We now add the *direct strategic effect* reintroducing the dependence of y_1 and y on θ and q, but *keeping the rivals' beliefs unchanged*. To this end let assume that rivals are fully informed so that even if regulated output is $q(\hat{\theta})$ and real scope economies are associated to type θ, rivals' beliefs are still such that $\Pr(\theta | q(\hat{\theta})) = 1$. Constraint (24) would then be

$$\begin{array}{l}\left[\Pi_U\left(\overline{q}, \underline{\theta}, 0\right) - \Pi_U\left(\underline{q}, \underline{\theta}, 0\right)\right] - \left[\Pi_U\left(\overline{q}, \overline{\theta}, 1\right) - \Pi_U\left(\underline{q}, \overline{\theta}, 1\right)\right] = \\ \int_{\underline{q}}^{\overline{q}} \frac{\partial \Pi_U(h, \underline{\theta}, 0)}{\partial q} dh - \int_{\underline{q}}^{\overline{q}} \frac{\partial \Pi_U\left(h, \overline{\theta}, 1\right)}{\partial q} dh \leq 0\end{array} \tag{25}$$

where the notable difference with (24) is that rivals' beliefs on θ are always correct: independently of q then $v(q) = 1$ if type is $\overline{\theta}$ and $v(q) = 0$ if $\underline{\theta}$. Now, from (1)-(3) we know that the marginal cost of y_1 is decreasing in q for any θ, i.e. $\frac{\partial^2 C(q, y_1; \theta)}{\partial q \partial y_1} \leq 0$ and this marginal cost reduction associated with a larger q is larger the higher is θ.. Hence, independently of the type of competition we have,

$$0 \leq \frac{\partial \Pi_U\left(q, \underline{\theta}, 0\right)}{\partial q} \leq \frac{\partial \Pi_U\left(q, \overline{\theta}, 1\right)}{\partial q}.$$

These inequalities imply that for both the cost-efficiency and the direct strategic effects, constraint (25) is verified by the simple monotonicity condition for outputs $\underline{q} \leq \overline{q}$.

We are now left to study the *belief-related strategic* effect. Adding and subtracting $\Pi_U\left(\overline{q}, \underline{\theta}, 0\right)$ and $\Pi_U\left(\overline{q}, \overline{\theta}, 0\right)$ from (24), constraint $IC(\underline{\theta})$ becomes

$$\begin{array}{l}\left[\Pi_U\left(\overline{q}, \underline{\theta}, 1\right) - \Pi_U\left(\overline{q}, \underline{\theta}, 0\right) - \left[\Pi_U\left(\underline{q}, \underline{\theta}, 0\right) - \Pi_U\left(\overline{q}, \underline{\theta}, 0\right)\right]\right] - \\ \left[\Pi_U\left(\overline{q}, \overline{\theta}, 1\right) - \Pi_U\left(\overline{q}, \overline{\theta}, 0\right) - \left[\Pi_U\left(\underline{q}, \overline{\theta}, 0\right) - \Pi_U\left(\overline{q}, \overline{\theta}, 0\right)\right]\right] \leq 0,\end{array}$$

or, equivalently

$$
\begin{array}{l}
\Pi_U\left(\overline{q},\underline{\theta},1\right)-\Pi_U\left(\overline{q},\underline{\theta},0\right)-\left[\Pi_U\left(\overline{q},\overline{\theta},1\right)-\Pi_U\left(\overline{q},\overline{\theta},0\right)\right]+\\
-\left[\int_{\underline{q}}^{\overline{q}}\left(\frac{\partial\Pi_U\left(h,\overline{\theta},0\right)}{\partial q}-\frac{\partial\Pi_U\left(h,\underline{\theta},0\right)}{\partial q}\right)dh\right]\leq 0.
\end{array}
\tag{26}
$$

The second line is negative whenever $\underline{q}\leq\overline{q}$ for the same reasons illustrated above on the direct strategic effect. On the contrary, the sign of the first line depends on the type of competition in market U. The function $\Pi_U\left(q,\theta,1\right)-\Pi_U\left(q,\theta,0\right)$ uniquely refers to the effect of a change of rivals' beliefs for any q and θ, that is for given marginal costs of y_1. With quantity competition, or more generally with strategic substitutability, we clearly have $\Pi_U\left(q,\theta,1\right)\geq\Pi_U\left(q,\theta,0\right)$, whilst $\Pi_U\left(q,\theta,1\right)\leq\Pi_U\left(q,\theta,0\right)$ with price competition or strategic complementarity. Furthermore, the absolute value $\left|\Pi_U\left(q,\theta,1\right)-\Pi_U\left(q,\theta,0\right)\right|$ is increasing in θ because a smaller marginal cost of y_1 (induced by a larger θ) amplifies the change induced by different beliefs, so that we have

$$
\begin{array}{ll}
\Pi_U\left(\overline{q},\underline{\theta},1\right)-\Pi_U\left(\overline{q},\underline{\theta},0\right)-\left[\Pi_U\left(\overline{q},\overline{\theta},1\right)-\Pi_U\left(\overline{q},\overline{\theta},0\right)\right]\leq 0 & \text{with substitutability,}\\
\Pi_U\left(\overline{q},\underline{\theta},1\right)-\Pi_U\left(\overline{q},\underline{\theta},0\right)-\left[\Pi_U\left(\overline{q},\overline{\theta},1\right)-\Pi_U\left(\overline{q},\overline{\theta},0\right)\right]\geq 0 & \text{with complementarity.}
\end{array}
\tag{27}
$$

From the signs in (27) and $IC(\underline{\theta})$ written as (26) we then obtain the following.

First, with strategic complementarity in market U the sign in (27) implies that monotonicity $\underline{q}\leq\overline{q}$ be not sufficient to satisfy $IC(\underline{\theta})$. When the (absolute value of the) first line in (26) is larger than the second line in the case $\underline{q}=\tilde{q}(\underline{\theta}),\overline{q}=\tilde{q}(\overline{\theta})$, then quantities $\tilde{q}(\theta)$ are not incentive compatible in which case optimal regulation is uniform and defined by (16). Quantity $\tilde{q}$ is obtained from a pricing condition averaging with respect to type $\overline{\theta}$ and $\underline{\theta}$ so that $\tilde{q}\leq\overline{q}^I_{FI}$ but $\tilde{q}\gtreqless\underline{q}^I_{FI}$ because two countervailing effects are at play. On one side, the distortionary term $\frac{\partial\Delta_\theta\Pi_U(\tilde{q},v)}{\partial q}$ in (16) reduces $\tilde{q}$.. On the other side, the averaging with respect tot $\overline{\theta}$ and $\underline{\theta}$ increases $\tilde{q}$ as compared with $\underline{q}^I_{FI}$.. Furthermore, for the same reasons, we also have that $\tilde{q}(\underline{\theta})\leq\tilde{q}\leq\tilde{q}(\overline{\theta})$ so that $\Delta_\theta\Pi_U\left(\tilde{q},v\right)\geq\Delta_\theta\Pi_U\left(\tilde{q}(\underline{\theta}),0\right)$ which implies that the multi-utility gains and the regulator's task is complicated by the rivals being uninformed on the level of scope economies. Finally, if the first line in (26) is larger than the second line with $\underline{q}=\tilde{q}(\underline{\theta}),\overline{q}=\tilde{q}(\overline{\theta})$, then optimal regulation is discriminatory, $\underline{q}^*=\tilde{q}(\underline{\theta})\leq\underline{q}^I_{FI}$, $\overline{q}^*=\tilde{q}(\overline{\theta})=\overline{q}^I_{FI}$. That the multi-utility gains from the rivals being uniformed can be seen in this case with discriminatory regulation by considering the firm's rent $\Pi^I\left(\overline{\theta}\right)=\pi^S+\Delta_\theta\Pi_U(\underline{q}^*,0)$ where $\Delta_\theta\Pi_U(\underline{q}^*,0)=\Pi_U(\underline{q},\overline{\theta},0)-\Pi_U(\underline{q},\underline{\theta},0)$. For strategic complementarity we have that $\Pi_U(\underline{q},\overline{\theta},0)\geq\Pi_U(\underline{q},\overline{\theta},1)$ and also in this case the multi-utility benefits being the rivals uninformed.

With strategic substitutability, the monotonicity $\underline{q}\leq\overline{q}$ implies that the incentive compatibility constraint (24) is satisfied from which it follows that optimal regulated quantities are $\tilde{q}(\underline{\theta}),\tilde{q}(\overline{\theta})$ defined by (14). This in turn gives the the comparison with quantities in the case of full information. Since the first line in (26) is negative the regulator's task is easened by the rivals being uninformed. Furthermore, since for strategic complementarity $\Pi_U(\underline{q},\overline{\theta},0)\leq\Pi_U(\underline{q},\overline{\theta},1)$, the multi-utility gains a smaller rent $\Pi^I\left(\overline{\theta}\right)$ being the rivals uninformed. Finally, monotonicity $\underline{q}\leq\overline{q}$ is here sufficient but not necessary for incentive compatibility. ■

Proof of Proposition 3. Quantity-competition.

Outputs in market U can be written as in (19) and the multi-utility's profits Π_U as follows,

$$\Pi_U(\widehat{q},\theta,v(\widehat{q})) = \frac{\left[2b\left[(2b-s)(\gamma_U-c)+(2b+(n-2)s)\,\widehat{q}\theta\right]+(n-1)s^2\Delta(\widehat{q},\theta)\right]^2}{4b(2b-s)^2\left(2b+s(n-1)\right)^2}. \tag{28}$$

We know from Proposition 2 that optimal regulation is discriminatory so that the optimal regulated quantities are $\overline{q}^* \neq \underline{q}^*$. Substituting $y_1(\widehat{q},\theta,v(\widehat{q}))$ and $y(\widehat{q},v(\widehat{q}))$ we have

$$\begin{aligned}
\Delta_\theta\Pi_U(\overline{q},1) &= \overline{q}\left(\overline{\theta}-\underline{\theta}\right)\frac{4b(2b-s)(\gamma_U-c)+\overline{q}k}{4b(2b-s)\left(2b+s(n-1)\right)}\\
\Delta_\theta\Pi_U\left(\underline{q},0\right) &= \underline{q}\left(\overline{\theta}-\underline{\theta}\right)\frac{4b(2b-s)(\gamma_U-c)+\underline{q}a}{4b(2b-s)\left(2b+s(n-1)\right)}
\end{aligned}$$

where a and k are constant with respect to output and defined as

$$\begin{aligned}
a &\equiv \overline{\theta}(2b-s)\left(2b+s(n-1)\right)+\underline{\theta}\left(2b(2b+s(n-2))+(n-1)s^2\right)\\
k &\equiv \overline{\theta}\left(2b(2b+s(n-2))+(n-1)s^2\right)+\underline{\theta}(2b-s)\left(2b+s(n-1)\right)
\end{aligned}$$

with $a \geq 0$, $k \geq 0$ and $a-k = -2(n-1)s^2\left(\overline{\theta}-\underline{\theta}\right) \leq 0$.

From these expressions for $\Delta_\theta\Pi_U(\overline{q},1)$ and $\Delta_\theta\Pi_U\left(\underline{q},0\right)$ we obtain

$$\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial\underline{q}} = \left(\overline{\theta}-\underline{\theta}\right)\frac{2b(2b-s)(\gamma_U-c)+\underline{q}a}{2b(2b-s)\left(2b+s(n-1)\right)} \geq 0$$

so that, as long as $\overline{\theta} > \underline{\theta}$, the distortion $(1-\alpha)\frac{v}{1-v}\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial\underline{q}}$ in the pricing condition (14) for $\theta = \underline{\theta}$ illustrated in Proposition 1 is strictly positive. Hence, generically we have $\overline{q} \neq \underline{q}$ and $\overline{q} > \underline{q}$ (which also confirm that optimal regulation is discriminatory).

Now, constraint $IC(\underline{\theta})$ can be here equivalently written as

$$\left(\overline{q}-\underline{q}\right)4b(2b-s)\left(\gamma_U-c\right)+\overline{q}^2k-\underline{q}^2a \geq 0$$

which is satisfied when $\overline{q} \geq \underline{q}$ because $k \geq a \geq 0$. Note that, as explained in the text, $IC(\underline{\theta})$ could be satisfied even if $\overline{q} < \underline{q}$ (monotonicity is not necessary for incentive compatibility).

To verify the effect of the error about scope-economies incurred by the rival firms on the multi-utility rent recall that $\Delta_\theta\Pi_U\left(\underline{q},0\right) = \Pi_U\left(\underline{q},\overline{\theta},0\right) - \Pi_U\left(\underline{q},\underline{\theta},0\right)$.. Clearly, given that $\Pi_U\left(\underline{q},\underline{\theta},0\right)$ is unaffected by the error Δ and $\Pi_U\left(\underline{q},\overline{\theta},0\right)$ is increasing in $\Delta\left(\underline{q},\overline{\theta}\right)$ we also have that the rent $\Delta_\theta\Pi_U\left(\underline{q},0\right)$ increases in the error $\Delta\left(\underline{q},\overline{\theta}\right)$.

Consider now comparative statics on the main parameters n, γ_U:

$$\begin{aligned}
\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial\gamma_U} &= \frac{\left(\overline{\theta}-\underline{\theta}\right)\underline{q}}{2b+s(n-1)} \geq 0\\
\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial n} &= \frac{\left(\overline{\theta}-\underline{\theta}\right)\underline{q}\left[-2b(\gamma_U-c)+s(\gamma_U-c+\underline{q}\underline{\theta})\right]}{(2b-s)\left[2b+s(n-1)\right]^2} \leq 0
\end{aligned}$$

where the second inequality follows from the fact that $y\left(\underline{q},0\right) = \frac{2b(\gamma_U-c)-s(\gamma_U-c+\underline{q}\underline{\theta})}{(2b-s)[2b+s(n-1)]}$ so that

$y\left(\underline{q},0\right)\geq 0$ if and only the numerator in $\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial n}$ is negative. We also have

$$\begin{aligned}\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial\underline{q}\partial\gamma_U} &= \frac{\overline{\theta}-\underline{\theta}}{2b+s(n-1)}\geq 0\\ \frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial\underline{q}\partial n} &= \frac{\left(\overline{\theta}-\underline{\theta}\right)\left[-2b(\gamma_U-c)+s(\gamma_U-c+2\underline{q}\underline{\theta})\right]}{(2b-s)\left[2b+s(n-1)\right]^2}\leq 0\end{aligned}$$

where again the second inequality follows from $y\left(\underline{q},0\right)\geq 0$.

Price-competition.

With equilibrium prices as in (20) we can write multi-utility's profits Π_U in the market U as follows,

$$\Pi_U\left(\widehat{q},\theta,v\left(\widehat{q}\right)\right)=\frac{b\left[A+\widehat{q}\theta B-s^2(n-1)\Delta\left(\widehat{q},\theta\right)\right]^2}{4\left(2b+s\right)^2\left(2b-s(n-1)\right)^2}$$

where

$$\begin{aligned}A &\equiv 2(2b+s)(\gamma_U-c\left(b-(n-1)s\right))>0,\\ B &\equiv 2(2b^2-(n-1)s^2-(n-2)sb)>0.\end{aligned}$$

and the sign of B is implied by $b-(n-1)s>0$. In line with intuition, if the actual level of scope economies θ increases, multi-utility's profit increases and if rivals over-estimate scope economies (i.e. $\Delta\left(\widehat{q},\theta\right)\geq 0$), multi-utility's profit decreases. Hence, the informational rent $\Delta_\theta\Pi_U\left(\underline{q},0\right)$ of type $\overline{\theta}$ here can be written as,

$$\Delta_\theta\Pi_U\left(\underline{q},0\right)=\frac{b\left[A+\underline{q}\overline{\theta}B-s^2(n-1)\Delta\left(\underline{q},\overline{\theta}\right)\right]^2-b\left[A+\underline{q}\underline{\theta}B\right]^2}{4\left(2b+s\right)^2\left(2b-s(n-1)\right)^2}$$

which is decreasing in $\Delta\left(\underline{q},\overline{\theta}\right)$.

The asymmetric information distortion in the pricing condition (14) is

$$\frac{\partial\Delta_\theta\Pi_U\left(\underline{q},0\right)}{\partial q}=\frac{(B+1)\left(\overline{\theta}-\underline{\theta}\right)\left(A+\underline{q}\left(\left(\overline{\theta}-\underline{\theta}\right)+B\left(\overline{\theta}+\underline{\theta}\right)\right)\right)}{4\left(2b+s\right)^2\left(2b-s(n-1)\right)^2}\geq 0,$$

so that the solutions $\tilde{q}(\overline{\theta}),\tilde{q}(\underline{\theta})$ in Proposition 1 are generically monotone, i.e. $\tilde{q}(\overline{\theta})>\tilde{q}(\underline{\theta})$.

With some calculations we also have

$$\begin{aligned}\Delta_\theta\Pi_U\left(\overline{q},1\right) &= \frac{b\overline{q}\left(\overline{\theta}-\underline{\theta}\right)\left[2A+\overline{q}\left(-(n-1)s^2\left(\overline{\theta}-\underline{\theta}\right)+B\left(\overline{\theta}+\underline{\theta}\right)\right)\right]}{4\left(2b+s\right)\left(2b-(n-1)s\right)},\\ \Delta_\theta\Pi_U\left(\underline{q},0\right) &= \frac{b\underline{q}\left(\overline{\theta}-\underline{\theta}\right)\left[2A+\underline{q}\left((n-1)s^2\left(\overline{\theta}-\underline{\theta}\right)+B\left(\overline{\theta}+\underline{\theta}\right)\right)\right]}{4\left(2b+s\right)\left(2b-(n-1)s\right)},\end{aligned}$$

Constraint $IC(\underline{\theta})$, $\Delta_\theta\Pi_U\left(\overline{q},1\right)\geq\Delta_\theta\Pi_U\left(\underline{q},0\right)$, can then be written as

$$2A\left(\overline{q}-\underline{q}\right)+B\left(\overline{q}^2-\underline{q}^2\right)\left(\overline{\theta}+\underline{\theta}\right)\geq\left(\overline{q}^2+\underline{q}^2\right)(n-1)s^2\left(\overline{\theta}-\underline{\theta}\right)$$

which clearly shows that output monotonicity is not sufficient for incentive compatibility.

Consider now the comparative statics on the main parameters n, γ_U. If optimal regulation is discriminatory then

$$\begin{aligned}
\frac{\partial \Delta_\theta \Pi_U\left(\underline{q},0\right)}{\partial \gamma_U} &= -\frac{b\underline{q}\left(4b^2-2b(n-2)s-3(n-1)s^2\right)}{\left(2b+s\right)^2\left(2b-s(n-1)\right)^2} \leq 0 \\
\frac{\partial \Delta_\theta \Pi_U\left(\underline{q},0\right)}{\partial \underline{q}\partial \gamma_U} &= -\frac{b\left(4b^2-2b(n-2)s-3(n-1)s^2\right)}{\left(2b+s\right)^2\left(2b-s(n-1)\right)^2} \leq 0
\end{aligned}$$

where the sign of $4b^2-2b(n-2)s-3(n-1)s^2 \geq 0$ in the numerators can be derived by the expression for $\frac{\partial \Delta_\theta \Pi_U\left(\underline{q},0\right)}{\partial \underline{q}} \geq 0$ substituting A and B. We also have that the expressions for $\frac{\partial \Delta_\theta \Pi_U\left(\underline{q},0\right)}{\partial n}$ and $\frac{\partial \Delta_\theta \Pi_U\left(\underline{q},0\right)}{\partial \underline{q}\partial n}$ can be positive or negative which is also the case for all the comparative statics when optimal regulation is instead uniform. ■

Proof of Proposition 4. Point (i) in the Proposition is immediate from what stated in the text.

Concerning point (ii), let $\mathcal{C}^S$ be the optimal regulatory contract with separation, let $\mathcal{I}'$ be the particular information set in which the rivals but not the regulator are informed about θ, and let $\mathcal{C}'$ be the optimal regulatory contract associated with the information set $\mathcal{I}'$. Finally, let $E_\theta\left[W^I\left(\mathcal{C},\theta\right)|\mathcal{I}\right]$ be the expected social welfare associated with the optimal regulatory contract $\mathcal{C}$ and the associated information set $\mathcal{I}$, whilst W^S has been defined as the optimal welfare with separation and its optimal contract $\mathcal{C}^S$.

Clearly, being independent of θ, the regulatory contract $\mathcal{C}^S$ is individually rational and incentive compatible when applied to integration with information set $\mathcal{I}'$, i.e. $\mathcal{C}^S$ satisfies constraints $IC(\theta)$ and $IR(\theta)$ for any $\theta \in \Theta$. This allows to evaluate the expected welfare with integration when the regulator offers the regulatory contract $\mathcal{C}^S$ and rivals are fully informed with $EW^I(\mathcal{C}^S,\mathcal{I}')$ and proceed with the following comparison:

$$\begin{aligned}
&EW^I(\mathcal{C}^S,\mathcal{I}') - W^S = \\
&\quad E_\theta\left[V_U\left(Y(q^S,\theta,v(\theta))\right) - Y(q^S,\theta,v(\theta))p^U\left(Y(q^S,\theta,v(\theta))\right)\right] - \left[V_U\left(Y^S\right) - Y^S p^U\left(Y^S\right)\right] + \\
&\quad + \alpha\left[\sum_{i\neq 1}^{n}\pi^I\left(q^S,\theta\right) + \Pi_U\left(q^S,\theta\right) - \sum_{i=1}^{n}\pi_i^S\right]
\end{aligned}$$

where we have indicated with $v(\theta)=1$ if $\theta=\overline{\theta}$ and $v(\theta)=0$ if $\theta=\underline{\theta}$ the rivals' degenerate beliefs.

Both the second and the third lines are positive because the unique difference in $EW^I(\mathcal{C}^S,\mathcal{I}')$ and W^S is that in the former the multi-utility benefits of scope economies and is thus more efficient in market U. Thus we have $EW^I(\mathcal{C}^S,\mathcal{I}') \geq W^S$. Now, notice that regulation $\mathcal{C}^S$ is suboptimal with information $\mathcal{I}'$ so that clearly $EW^I(\mathcal{C}',\mathcal{I}') \geq EW^I(\mathcal{C}^S,\mathcal{I}')$ which proves the result (ii) in the Proposition, i.e. $EW^I(\mathcal{C}',\mathcal{I}') \geq W^S$. ■

Proof of Proposition 5. We separate the study of quantity and price competition in market U, respectively strategic substitutability and complementarity.

Strategic complementarity (price-competition) in market U. Let $\mathcal{I}^*$ be the information set in which neither the regulator nor the rivals know θ, as in the model setup, and $\mathcal{C}^*$ be the associated optimal regulatory contract illustrated in Proposition 1.

With information set $\mathcal{I}^*$, contract $\mathcal{C}^S$ satisfies all constraints $IC(\theta)$ and $IR(\theta)$ for any $\theta \in \Theta$ because $\mathcal{C}^S$ does not depend on θ and it is thus implementable. This allows to evaluate welfare with integration and information set $\mathcal{I}^*$ when the regulator offers the contract $\mathcal{C}^S$, i.e. $EW^I(\mathcal{C}^S,\mathcal{I}^*)$. We can now compare this welfare with the that associated with separation W^S. We now have

$$\begin{aligned} EW^I(\mathcal{C}^S,\mathcal{I}^*)-W^S = \; & E_\theta\left[V_U\left(Y(q^S,\theta,v)\right)-Y(q^S,\theta,v)p^U\left(Y(q^S,\theta,v)\right)\right]-\left[V_U\left(Y^S\right)-Y^Sp^U\left(Y^S\right)\right]+ \\ & +\alpha\left[\sum_{i\neq 1}^{n}\pi^I\left(q^S,\theta\right)+\Pi_U\left(q^S,\theta\right)-\sum_{i=1}^{n}\pi_i^S\right] \end{aligned}$$

The difference between this expression for $EW^I(\mathcal{C}^S,\mathcal{I}')-W^S$ with the expression for $EW^I(\mathcal{C}^S,\mathcal{I}')-W^S$ illustrated in the proof of Proposition 4 is that here rivals' beliefs correspond to their priors $\Pr(\theta=\overline{\theta})=v$ and $\Pr(\theta=\underline{\theta})=1-v$ and do not depend on $q(\theta)$. In fact, in the information set $\mathcal{I}^*$ they are not informed, contrary to $\mathcal{I}'$, and regulatory process associated with $\mathcal{C}^S$ is totally uninformative.

However, with price competition facing an integrated multi-utility induces the rivals' to reduce their prices and this increases both consumers' surplus and total profits in the market U. Hence, both the first and the second line in $EW^I(\mathcal{C}^S,\mathcal{I}^*)-W^S$ are positive so that we have

$$EW^I(\mathcal{C}^S,\mathcal{I}^*)\geq W^S.$$

Now note again that regulation $\mathcal{C}^S$ is sub optimal with information set $\mathcal{I}^*$ so that with the associated optimal regulation we have $EW^I(\mathcal{C}^*,\mathcal{I}^*)\geq EW^I(\mathcal{C}^S,\mathcal{I}^*)$ which finally implies the result,

$$EW^I(\mathcal{C}^*,\mathcal{I}^*)\geq EW^I(\mathcal{C}^S,\mathcal{I}^*)\geq W^S.$$

Strategic substitutability (quantity-competition) in market U. We first prove that optimal regulation $\mathcal{C}'$ for information set $\mathcal{I}'$ is discriminatory and in particular we generically have $\overline{q}'>\underline{q}'$. Optimal regulation with information set $\mathcal{I}'$ can be obtained following the proofs of Propositions 1 and 2, keeping in mind that the unique difference consists in the rivals being fully informed. Exactly as in the proof of Proposition 2, with (23) we show that, generically, $\frac{\partial\Delta_\theta\Pi_U(q,v)}{\partial q}>0$, which immediately implies that the optimal regulation $\mathcal{C}'$ with information set $\mathcal{I}'$ is generically monotone $\overline{q}'>\underline{q}'$.

Now we show that contract $\mathcal{C}'$ is incentive compatible and individual rational also with information $\mathcal{I}^*$, i.e. it satisfies all constraints $IC(\theta)$ and $IR(\theta)$ for any $\theta\in\Theta$. This is again proved in step 2 of the proof of Proposition 2. In fact, the only difference between information sets $\mathcal{I}^*$ and $\mathcal{I}'$ is that in the former rivals are informed but they are informed in the latter. We know from the proof of Proposition 2 that with strategic substitutability the belief strategic effect due to the rivals' lack of information relaxes the compatibility constraint $IC(\underline{\theta})$ so that any pair of monotone outputs $\overline{q}\geq\underline{q}$ is incentive compatible (see (27) and related analysis).

This allows to evaluate the welfare $EW^I(\mathcal{C}',\mathcal{I}^*)$ that would prevail with information set $\mathcal{I}^*$ if the regulator allowed the multi-utility to integrate its activities and offered the contract $\mathcal{C}'$. For what stated above, contract $\mathcal{C}'$ is discriminatory so that it discloses perfect information on scope economies. Hence, the rivals' choices are the same in the two different information sets $\mathcal{I}^*$ and $\mathcal{I}'$ so that $EW^I(\mathcal{C}',\mathcal{I}^*)$ differs from $EW^I(\mathcal{C}',\mathcal{I}')$ uniquely as for the multi-utility's rent:

$$\begin{aligned} EW^I(\mathcal{C}',\mathcal{I}^*)-EW^I(\mathcal{C}',\mathcal{I}') &= -(1-\alpha)v\left\{\Pi_U\left(\underline{q}',\overline{\theta},0\right)-\Pi_U\left(\underline{q}',\underline{\theta},0\right)-\left[\Pi_U\left(\underline{q}',\overline{\theta},1\right)-\Pi_U\left(\underline{q}',\underline{\theta},0\right)\right]\right\}= \\ &= -(1-\alpha)v\left[\Pi_U\left(\underline{q}',\overline{\theta},0\right)-\Pi_U\left(\underline{q}',\overline{\theta},1\right)\right], \end{aligned}$$

where for strategic substitutability we have $\Pi_U\left(\underline{q}',\overline{\theta},1\right) \geq \Pi_U\left(\underline{q}',\overline{\theta},0\right)$. It then follows

$$EW^I(\mathcal{C}',\mathcal{I}^*) \geq EW^I(\mathcal{C}',\mathcal{I}').$$

Now, recall that Proposition 4 shows

$$EW^I(\mathcal{C}',\mathcal{I}') \geq W^S$$

and we know that contract $\mathcal{C}'$ potentially suboptimal with information $\mathcal{I}^*$ so that

$$EW^I(\mathcal{C}^*,\mathcal{I}^*) \geq EW^I(\mathcal{C}',\mathcal{I}^*)$$

Hence, we finally obtain the following sequence of inequalities

$$EW^I(\mathcal{C}^*,\mathcal{I}^*) \geq EW^I(\mathcal{C}',\mathcal{I}^*) \geq EW^I(\mathcal{C}',\mathcal{I}') \geq W^S.$$

■