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Access Profit-Sharing Regulation with Information Transmission and Acquisition

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Abstract
The paper analyses how information acquisition and transmission issues affect the determination of the optimal access pro.t-sharing plan in regulated network industries. It considers a regulated upstream monopoly with cost uncertainty and a downstream unregulated duopoly. It will be shown that, under an access price cap regulatory mechanism, the transfer of a sufficiently high share of access profits to consumers induces an integrated upstream monopolist to transmit to his downstream rival the information privately acquired on the upstream cost and this, in turn, may negatively affect welfare. On account of these effects the optimal access profit-sharing plan will depend on the variance and shape of cost distribution, on information acquisition costs as well as on the regulator's redistributive concerns.

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1 Introduction

The regulatory reforms of the last twenty years in network industries for the promotion of competition, have typically involved the vertical separation (ownership or functional) of potentially competitive segments, which have been gradually deregulated, from remaining naturally monopolistic segments which continue to be subject to price, network access, service quality and entry regulations. The performance of these regulated naturally monopolistic segments is of considerable economic importance, on account of the effects on the performance of the competitive segments when the regulated segments provide the infrastructure platform upon which the competitive segments rely. From this point of view a critical role is played by the regulatory mechanisms used to determine the access price, namely the price at which downstream competitors can acquire the essential input.

A regulatory mechanism widely applied in network industries is the access price cap which only sets the maximum price (cap) that the upstream monopolist is allowed to charge for each network element, leaving price discretion below it.

Price cap regulatory mechanisms are usually advocated in industries characterized by cost uncertainty and asymmetric information since they are easy to implement, require low information and, breaking the link between prices and realized costs, provide the firm with optimal incentives to undertake managerial effort.

However, in network industries where reliability considerations are of great political relevance, when there is uncertainty about the regulated firm's cost opportunities, the regulator will have to set a relatively high fixed price to ensure that if the firm is indeed inherently a high cost type, the cap will be high enough to cover the firm's (efficient) realized costs. This could lead to "excessive profits" also when the reduction in costs is due to exogenous reasons and not to the efficient behavior of the firm; in this case the profit is a pure informational rent due to an informative advantage of the firm. Accordingly, the efficiency gains promised by price cap regulation have to be balanced with the unavoidable higher informational rent that would have to be given up.

This main dranwback of the price cap regulation has led to the proposal of modifications aimed at redistributing to consumers part of firms' profits when considered excessive. These modifications have assumed the form of a profit-sharing contract, where a share of profits is rebated to consumers through lump sum transfers, or of a sliding scale regulatory mechanism where the price that the regulated firm can charge is partially responsive to change in realized costs and partially fixed ex ante (Schmalensee, 1989; Lyon, 1996). Regardless of the manner in which earnings are shared, the requirement to share earnings with consumers reduces the ability of the regulated firm to profit from regulatory ignorance or favourable cost shock, but at the cost of weakening the regulated firm's incentives to minimize operating costs (Mayer and Vickers, 1996; Sappington, 2002; Hawdon et al., 2007).[1] One of the results of the

[1] It is worth noticing that, in a dynamic context, the price cap mechanism itself involves some form of profit sharing, albeit with a lag, through the price reviews that periodically occur. As highlighted by the economic literature (see Mayer

empirical literature (see Schmalensee, 1989; Gasmi et al.,1994) is that higher levels of uncertainty and, thereby, of asymmetric information, tend to increase the welfare desirability of profit-sharing plans; this effect is particularly strong if the regulated firm must be guaranteed non-negative profits in all states of nature and when consumer surplus is of a much greater social value to the regulator than firms' profits.[2]

This paper highlights another effect generated by the adoption of a profit-sharing plan in an integrated network industry characterized by a regulated upstream monopolistic market with cost uncertainty and an unregulated downstream market with Cournot competition. It will be shown that, under an access price cap regulatory mechanism, the transfer of a sufficiently high share of access profits to consumers makes it profitable for an integrated upstream monopolist to disclose to his downstream rival the privately acquired information on the upstream cost and this, in turn, may negatively affect welfare.[3] In this case, a trade-off may result whenever the regulator is more concerned about consumer surplus than about firms' profits.

The aim of the present paper is to analyse how information acquisition and transmission issues affect the determination of the optimal access profit-sharing plan. The main result reached is that the optimal profit-sharing plan will depend on the variance and on shape of cost distribution, on information acquisition costs as well as on the regulator's concern about firms' profits compared to consumer surplus.

I consider a stylized model with an integrated network industry characterized by an upstream market, which is a regulated natural monopoly with cost uncertainty and an unregulated downstream market which is a Cournot duopoly. The upstream monopolist is regulated through an access price cap mechanism with access profit-sharing which sets the price the upstream monopolist has to charge for the essential input sold to his downstream rival and rebates a constant share of access profits to consumers. The structure of information is endogenously determined; indeed, the true value of the upstream cost can be observed by the upstream monopolist only through an investment of resources. This is quite a reasonable assumption in industries as complex as utilities where the measurement of the economic costs of network elements is a difficult undertaking for the firm itself on account of the forward-looking nature of these costs which requires a costly prediction of the evolution of technological and demographical characteristics.[4] The information acquisition is prohibitively costly both for the regulator and the

and Vichers, 1996), introducing cost pass-through in the price control formula (explicit profit-sharing) and shortening the lag between price reviews (implicit profit-sharing) are substitutes for satisfyng redistributive concerns, keeping the incentives the same.

[2] An innovative menu of sliding scale mechanisms was adopted in 2004 by the electricity regulator in the UK (OFGEM) to cover the costs of distribution companies with the aim of reducing the asymmetric problem faced by the regulator concerning future capital requirements, and, thereby, of reducing the level of cap which allows firms to undertake the necessary investments to satisfy the reliability target (see Ofgem, 2004 and Crouch, 2006).

[3] Information-sharing issues arising in oligopolistic markets have been extensively analyzed by economic literature which has shown that the incentives of firms to share information on demand and costs as well as the welfare implications of information-sharing depend on both the nature of the competition (Cournot versus Bertrand) and on the nature of the initially dispersed information (random shocks predominantly affecting all firms or shocks affecting individual firms). See, among others, Kuhn and Vives (1995) and Raith (1996) for a comprehensive review.

[4] This argument has been used by the Energy Network Association (ENA, 2006) in response to the regulator's proposal of introducing a sliding scale mechanism to cover the distribution costs in the electricity industry. Indeed, it argued that obtaining reliable forecasts of capital costs is a money and time consuming task for the firm because the appropriate investment programme mainly depends on variables such as customer growth rates, load growth rates, equipment age and

downstream firm who, however, are able to deduce whether or not the upstream monopolist is informed. The upstream monopolist is assumed to commit ex-ante, before the observation of the true cost realization, to an information transmission decision rule, namely to reveal to his rival all information or to keep it private; there is no cost of information transmission and information is verifiable by the downstream rival.[5]

In consideration of the above, this paper will determine the optimal share of access profits rebated to consumers when the regulator's objective function is a weighted sum of the expected consumer surplus and firms' profits. Firstly, it will show that the transfer of a high share of access profits to consumers may induce the upstream monopolist to precommit to fully reveal to his rival the information acquired and this transmission effect may, in turn, boost her incentives to acquire information.

This result can be explained as follows. When the rival becomes informed on the upstream cost, he adjusts his output accordingly. This adjustment has two opposite effects on the upstream monopolist's expected profits. On the one hand, it increases the variability of the upstream monopolist's equilibrium output, which, in turn, raises the expected profits obtained in the downstream market. This result is in line with those obtained by the literature on information-sharing which shows that firms competing in an unregulated Cournot market with a homogeneous good find it profitable to symmetrically share information about their own costs (see Fried, 1984; Shapiro, 1986; Raith, 1996).[6] On the other hand, the rival's output variability, caused by information transmission, reduces the expected access profits which the monopolist obtains from selling the essential input. This result strictly depends on the access price cap breaking the link between access price and cost, which gives a linear access revenue in the cost parameter.

It follows that the greater the share of access profits transferred to consumers, the more information transmission is likely to increase the upstream monopolist's expected profits and, thereby, his gain from acquiring information. It will be shown that whether or not the upstream monopolist's (ex-ante) information transmission decision affects his information acquisition decision will depend on the value of the information acquisition costs.

On account of the above results, the optimal access profit sharing plan will be determined by taking into account the welfare effects of information transmission as well as the welfare gain which is generated

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replacement expenditure with few necessary connection with the historical trends.

[5]On account of the above, the assumption that the firm voluntarily precommits to an extreme transmission rule, i.e. full transmission or full concealment, is not restrictive. Indeed, the economic literature has shown that, even without precommitment, there are conditions under which one of these extreme disclosure regimes emerges endogenously from the strategic information-sharing choices of the firms (see Ziv, 1993). The results of the literature is that if it is known that firms have information and disclosure is costless and verifiable, then strategic firms will disclose all information since they cannot credibly conceal unfavourable news (see Darrough, 1993; Milgrom, 1981; Okuno-Fujiara et.al.,1990; van Zandt and Vives, 2007). Instead, if it is possible to verify the information but not to find out if the firm is informed, then the firms can selectively disclose acquired information (see Gigler, 1994 and Jansen, 2008).

See also note 11 for a justification of the precommitment assumption referred to the present context.

[6]Fried (1984) explores the firm's incentives to produce and disclose information on the duopolist's cost functions; Shapiro (1986) analyzes the profit and welfare effects of cost sharing in standard oligopoly models; Raith (1996) proposes a general model.

by the redistribution of access profits to consumers whenever the regulator is more concerned about consumer surplus than about firms' profits.

I will show that only when the regulator is equally or almost equally concerned about consumer surplus and firms' profits, information transmission may generate a welfare gain whenever it induces information acquisition. In this case, the optimal access profit-sharing plan will require that all access profits be rebated to consumers. Instead, if information transmission does not affect information acquisition or if firms' profits are less socially valuable than consumer surplus, information transmission generates a welfare loss. In this case a trade-off will occur. On the one hand, the transfer of all access profits to consumers, inducing information transmission, causes a welfare loss; on the other, reducing the share of access profits transferred to consumers may eliminate this welfare loss but at the cost of reducing the welfare gain due to the redistribution of profits. Therefore, whenever welfare loss due to information transmission prevails over welfare gain due to the redistributive effect, the optimal access profit-sharing plan will require that a share of access profits be retained by the upstream monopolist to reduce his incentives to reveal information.

The rest of the paper is organized as follows. Section 2 outlines the model, derives the equilibrium levels of output under Cournot competition and analyzes the regulator's choice of the access price cap. Section 3 analyses the upstream monopolist's incentives to acquire and transmit information under an access price cap regulatory mechanism with access profit-sharing. Section 4 investigates the welfare effects of information transmission (4.1) and determines the optimal access profit-sharing plan (4.2). Section 5 concludes the paper. All proofs can be found in the Appendix.

2 The model

I consider a stylized model within an integrated network industry characterized by an upstream market, which is a regulated natural monopoly with cost uncertainty, and an unregulated downstream market which is a Cournot duopoly. It is assumed that there is only one firm operating in the downstream market apart from the upstream monopolist's affiliate.[7]

The marginal cost of producing the essential input is $c = \beta$, where β is a parameter of adverse selection, with $\beta \epsilon \left[\underline{\beta}, \overline{\beta}\right]$; it has density function $f(\beta)$ and distribution function $F(\beta)$ which are common knowledge; β_0 and σ^2 denote the mean value and the variance of the distribution of β, respectively. The realizations of β can be interpreted as the result of exogenous technological changes and any cost-reducing investment is assumed away. The upstream monopolist (she) is regulated through an access price cap mechanism with access profit-sharing which sets the price the upstream monopolist has to charge for the essential input sold to her downstream rival (he) and rebates, through lump sum transfers, a constant

[7] This assumption does not affect the results of the paper. Entry issues are assumed away because they go beyond the aim of the paper.

share of access profits to consumers.[8] The downstream market is characterized by a linear inverse demand function: $P(Q) = d - Q$. For the sake of simplicity, it is assumed that the technology used to produce the downstream output only requires the essential facility. Therefore, the cost of producing the final good is equal to the marginal cost of producing the essential input for the integrated upstream monopolist, since the access price paid by her subsidiary is merely an internal transfer, while for the downstream firm the cost of producing the final good is the regulated access price.

The structure of information is as follows. The realization of β is initially unknown to both the regulator and the firms. The upstream monopolist, however, can learn the true realization of β if she invests a fixed amount of resources, denoted by K, otherwise she observes nothing. Instead, the information acquisition is prohibitively costly for the regulator and for the downstream firm.[9] As the information acquisition cost K and the upstream monopolist's strategy are common knowledge, there is no uncertainty about whether or not the upstream monopolist is informed.

It is assumed that the upstream monopolist precommits to a decision transmission rule, namely, to fully reveal to her downstream rival all information acquired or to keep it private, before having observed the true realization of β; there is no transmission cost, the revealed information is verifiable by the rival at a negligible cost and, thereby, the revelation is truthful.[10]The regulator cannot enforce either information acquisition or transmission decisions.[11]

[8]I consider an access price cap mechanism without donward flexibility, i.e. the upstream monopolist is not allowed to charge the access monopoly price whenever it is below the access price cap. This is equivalent to assuming that the demand and cost distribution functions are such that the monopoly access price is greater than the access price cap for all values of the cost parameter and for any share of access profits rebated to consumers.This assumption helps to focus on the effects of an access profit-sharing plan on the upstream monopolist's incentives to transmit information to her rival which would be excluded if the upstream monopolist charged the monopoly access price.

It is also assumed that the integrated upstream monopolist cannot strategically manipulate her profits by reporting access profits as downstream profits. This assumption does not affect the results qualitatively.

[9]It is worth noticing that, even if the rival had the know-how to acquire information on the upstream monopolist's cost, he would prefer to remain ignorant. Indeed, the value of information on β for a firm is given by the difference between the expected profits if she acquires information and sets her output on the true realization of β and the expected profits if she remains ignorant and sets her output on the expected value of β (under linear demand function). Since the profit function of the upstream monopolist's rival is concave in β, the value of information on β is negative for him. Obviously, the information on β increases the rival's ex-post profit and, thereby, the upstream monopolist's information transmission is desirable for him.

[10]The revelation is not public so the regulator cannot learn the value of the cost. The assumption of the verifiability of the revealed information by the rival can be justified by the fact that he has been operating on the market for a considerable time.

[11]In the light of the results of the economic literature on information- sharing (see note 5), the assumption that the upstream monopolist voluntarily precommits to an extreme transmission decision rule rather than to decide ex-post after having observed β, can be justified as follows. First, notice that an increase in the rival's output affects the upstream monopolist's profits in two opposite ways: on the one hand, it reduces the upstream monopolist's output and, thereby, her downstream profits; on the other, it increases the demand for the essential input which, in turn, raises the access profits. It is easy to show that when the access price cap is always binding, as in this paper, the upstream monopolist's profit decreases with the rival's output which, in turn, increases with the upstream monopolist's cost. Therefore, if the upstream monopolist did not precommit to a transmission decision rule, but made her decision after having observed β, she would choose to reveal only the lowest value of the cost. In this case, if no information was revealed, not being attributable to lack of information, the rival would deduce that the cost was higher than the lowest and would set his output on the basis of the average of these values. On account of this, the upstream monopolist will prefer to disclose the true value of the cost whenever it is below the average of the non-disclosing values rather than be judged worse than the average. Since non-disclosure is interpreted as being the worst type, the upstream monopolist will be forced to disclose. Therefore, since the present paper assumes that there is no uncertainty on whether or not the upstream monopolist is informed, that there is no transmission cost and that the information is verifiable, it follows the ex-ante precommitment decision to full disclosure and the ex post decision will prove to be equivalent.

Following the above reasoning, it can be argued that if the upstream monopolist finds it profitable to precommit to

Consider now the payoff of the firms, net of the information acquisition cost. Denoting by γ the share of the access profits transferred to consumers, with $\gamma\epsilon\,[0,1]$, the upstream monopolist's profit function is given by

$$\Pi^M = (d - Q - \beta))q^M + (1-\gamma)(\overline{a} - \beta)q^R \tag{1}$$

where $Q_I = q^M + q^R$, and $q^M$and q^R denote the quantity produced by the upstream monopolist and the rival firm in the downstream market, respectively; $\overline{a}$ denotes the access price cap set by the regulator. The profit function of the rival is

$$\Pi^R = (d - Q - \overline{a})q^R \tag{2}$$

The welfare function is the sum of the net consumer surplus, the share of the access profits rebated to consumers and the firms' profits which are weighted by a coefficient α, with $\alpha\epsilon\,[0,1]$; the regulator's objective function can be written as[12]

$$\int_{\underline{\beta}}^{\overline{\beta}} \left[\frac{Q^2}{2} + \alpha\,(P(Q) - \beta)Q) - \alpha\xi K + (1-\alpha)\gamma(\overline{a} - \beta)q_r\right] dF(\beta) \tag{3}$$

with $\xi = 1$ under information acquisition and $\xi = 0$ without information acquisition.

The timing of the game is the following. 0) Nature chooses β. 1) The regulator optimally sets the access price cap and the share of access profits rebated to consumers. 2) The upstream monopolist decides whether to pay K to acquire information on β and, before having observed β, whether to transmit it to her downstream rival. 3) Firms in the downstream market simultaneously choose their quantities on the basis of the information available to them as a consequence of the information decisions made in (2); the access price is paid and the optimal share of access profits is rebated to consumers.[13]

The derivation of the equilibrium output levels is given in the appendix.

In the first stage the regulator sets the access price cap and the optimal share of access profits rebated to consumers. The access price cap is found by maximizing the expected welfare function (3), evaluated at the Cournot equilibrium output, with respect to $\overline{a}$, subject to the following constraint: $\overline{a} \geq \beta$ for all $\beta\epsilon\left[\underline{\beta}, \overline{\beta}\right]$ which means that the access price cap should not be lower than the long-run marginal cost of

keep information private rather to fully disclose it, she will have no incentive to ex-post undermine this decision after having acquired information by revealing favourable cost values and concealing the most unfavourable. Indeed, if the precommitment were not binding, the rival would anticipate the strategic partial disclosure of the upstream monopolist and, therefore, he would deduce from the concealment of information that the cost were high. Therefore, the upstream monopolist would be forced to disclose. In the light of this, the upstream monopolist has incentives to give credibility to the precommitment decision to no disclosure whenever this decision is, ex ante, preferable to full disclosure.

[12] The welfare function is given by $\left[S(Q) - P(Q) + \alpha\Pi^M + \alpha\Pi^R - \alpha\xi K + \gamma(a-\beta)q_r\right]$

where $S(Q)$ indicates the gross consumer surplus with $S(Q) - P(Q) = \frac{Q^2}{2}$.Substituting for eqs (1) and (2) in the above expression gives (3).

[13] Attention is restricted to access price cap regulatory mechanisms under which the upstream monopolist always agrees to produce. This gives a non-negativity constraint on the upstream monopolist's profit for each realization of β.

the essential input.[14]Since the welfare function decreases with the access price, it follows that $\overline{a} = \overline{\beta}$ for all $\gamma \epsilon [0, 1]$ and K.[15]

The next section will analyse how the adoption of an access profit-sharing plan affects the upstream monopolist's decisions to acquire and transmit information. By taking into account the welfare effects of these decisions, section 4 will determine the optimal access-profit sharing plan.

3 Information acquisition and transmission incentives

This section analyses the incentives of the upstream monopolist to acquire and transmit information on the upstream cost under an access price cap mechanism with access profit-sharing. Firstly, there will be an analysis of the upstream monopolist's incentives to transmit to her rival the information acquired; then a calculation of the upstream monopolist's value of information, as a function of the information transmission decision.

Information transmission allows the upstream monopolist's downstream rival to adjust his output to the true realization of β, which, in turn, affects the upstream monopolist's profits. The upstream monopolist will find it profitable to precommit to fully reveal to her downstream rival the information acquired on β if the expected profits obtainable from transmitting information are no lower than those obtainable from keeping the information private. This is stated in the following Lemma.

Lemma 1 *Under an access price cap mechanism with access profit-sharing, for all* $\gamma \leq 0,42$ *the upstream monopolist does not find it profitable to precommit to fully transmit to her rival the information on* β*, while for all* $\gamma > 0,42$ *she finds it profitable to do so.*

The economic intuition of Lemma 1 lies in the fact that the transmission of information has two opposite effects on the upstream monopolist's expected profits. On the one hand, it increases the expected downstream profits obtained by the upstream monopolist from selling her output in the downstream market. On the other hand, the information transmission reduces the expected access profits obtained from selling the essential input to her rival at the access price cap.

[14] This condition is usually justified, both by academic scholars and practitioners, with the need to favour good investments in the upstream market, ensuring the recovery of the related costs. It is worth noticing that $\Pi^M(\overline{\beta}, \overline{a}, \gamma) > 0$ at $\overline{a} = \overline{\beta}$, because of the positive downstream profits due to the imperfect competiton characterizing the downstream market. Therefore, for the participation constraint to be binding, namely $\Pi^M(\overline{\beta}, \overline{a}, \gamma) = 0$, the regulatory mechanism should set $\overline{a} < \overline{\beta}$. The exclusion of this rule is due to two reasons. First its implementation could require so much information as to make it prohibitively costly its adoption by the regulator. The second reason is connected with the aim of the present paper as I explain below. Under an access price cap $\overline{a} < \overline{\beta}$ the adoption of an access profit-sharing plan would lead to the sharing of access losses with consumers for high values of β creating two opposite effects on welfare. On the one hand, the sharing of losses would lead to a reduction in consumer income. On the other, it would increase the upstream monopolist's profits, thereby causing a reduction in the access price cap required to satisfy the firm's participation constraint. The following analysis will ignore these opposite welfare effects in order to isolate those related to information acquisition and transmission issues.

[15] Notice that, since the welfare function decreases with $\overline{a}$, whatever the Cournot equilibrium output, the access price cap value does not depend on the upstream monopolist's information acquisition and transmission decisions.

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The key to understanding intuitively the effects on downstream expected profits is to realize that, whether or not the information is transmitted to the rival, the downstream expected profits of the upstream monopolist are equal to

$$E\left[q^M(.)^2\right] = E\left[q^M(.)\right]^2 + var\left[q^M(.)\right]$$

Due to linear demand, information transmission does not affect the expected equilibrium quantity of the upstream monopolist, while it increases the variance of the equilibrium output. Indeed, if the rival firm learns that the cost of the upstream monopolist is higher (lower) than expected, it will produce more (less) in equilibrium. These strategic adjustments to the true realization of β increase the variability in the upstream monopolist's equilibrium output, which is beneficial to the firm.

On the contrary, the rival's output variability caused by information transmission reduces the expected access profits. This strictly depends on the access price cap breaking the link between access price and cost which gives linear access revenues in β. As a consequence, the information transmission does not affect the expected access revenues, while it raises the upstream monopolist's expected costs of supplying the access.

The above analysis implies that the greater the share of access profits transferred to consumers (i.e., the greater γ), the more likely it is that information transmission increases the upstream monopolist's expected profits and that the upstream monopolist chooses to transmit information.

In the light of Lemma (1), the upstream monopolist's incentives to acquire information on β will depend on her information transmission decision which, in turn, is determined by the share of access profits rebated to consumers.

Indeed, for $\gamma \leq 0,42$, the upstream monopolist prefers to incur an information cost K to observe β and adjust her output accordingly rather than to remain ignorant and sets her output on the expected value of β, if

$$E\Pi^M(\beta, \beta_0, \overline{a}, \gamma) - E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) \geq K$$

where $E\Pi^M(\beta, \beta_0, \overline{a}, \gamma_0)$ and $E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma)$ denote the upstream monopolist's expected profit functions under information acquisition and under ignorance, respectively. For $\gamma > 0,42$, the upstream monopolist finds it profitable to acquire information and transmit it to her downstream rival rather than to remain ignorant if

$$E\Pi^M(\beta, \overline{a}, \gamma) - E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) \geq K$$

where $E\Pi^M(\beta, \overline{a}, \gamma)$ denotes the expected profits under information acquisition and transmission.

Denote by K_1 the value of K solving $E\Pi^M(\beta, \beta_0, \overline{a}, \gamma) - E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) = K_1$ for $\gamma \epsilon\, [0; 0,42]$ where $K_1 = \frac{\sigma^2}{4}$ and by $K_2(\gamma)$ the value of K solving $E\Pi^M(\beta, \overline{a}, \gamma) - E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) = K_2(\gamma)$, for $\gamma \epsilon\, (0,42; 1]$ where $K_2(\gamma) = \frac{\sigma^2}{9} + \gamma\frac{\sigma^2}{3} > \frac{\sigma^2}{4}$ and $\frac{\partial K_2(\gamma)}{\partial \gamma} > 0$.

Thus, the following Lemma is obtained

Lemma 2 *i)If* $\gamma \leq 0,42$, *the upstream monopolist finds it profitable to acquire but not to transmit information for all* $K \leq K_1$, *while she prefers to remain ignorant for all* $K > K_1$. *ii) If* $\gamma > 0,42$, *she acquires and transmits information for all* $K \leq K_2(\gamma)$ *and she remains ignorant for all* $K > K_2(\gamma)$.

The economic intuition of Lemma 2 is the following. i)In the light of Lemma 1, when a share of access profits lower than $0,42$ is rebated to consumers, the upstream monopolist does not find it profitable to transmit to her rival the information acquired. In this case the information has a value for the firm because it allows her to adjust her output to the true value of β.The greater the variance of the cost parameter, the greater the increase in profits arising from the output adjustment and, therefore, the greater the gain from acquiring information. Besides, when the rival is ignorant, the access profits are the same whether or not the upstream monopolist is informed. In this case, the upstream monopolist's value of information does not depend on the access profits and so it does not alter, whatever the share of access profits transferred to consumers.

ii) Instead, for $\gamma > 0,42$, information transmission increases the upstream monopolist's expected profits which, in turn, raises the firm's gain from acquiring information as opposed to the case in which the rival remains ignorant. Besides, this increase in the upstream monopolist's value of information is greater, the greater γ ($\frac{\partial K(\gamma)}{\partial \gamma} > 0$ for $\gamma > 0,42$).

4 Welfare analysis

The adoption of an access profit-sharing plan affects welfare (given in 3) in two ways. On the one hand, the transfer of access profits to consumers has a positive welfare effect in all those cases in which the regulator is more concerned about consumer surplus than about firms' profits ($\alpha < 1$). I will call this effect the redistributive effect generated by the adoption of an access profit-sharing plan. On the other hand, in the light of Lemmas 1 and 2, the adoption of an access profit-sharing plan may affect the upstream monopolist's decisions to acquire and transmit information which, in turn, alter the equilibrium output levels and, through this, affect welfare. The determination of the optimal access profit-sharing plan will take into account both the welfare effects of information transmission and the redistributive effect.

4.1 Welfare effects of information transmission

This section will analyse the welfare effects of information transmission induced by the adoption of an access profit-sharing plan.

Let $\widehat{K}(\alpha)\epsilon\,(K_1, K_2(1))$, the following Lemma is obtained.[16]

Lemma 3 *i)For* $K \leq K_1$, *information transmission generates a welfare loss which increases with the variance of the cost parameter* (σ^2), *and decreases with the regulator's concern about firms' profits*

[16] $K_2(1) = K_2(\gamma)$ for $\gamma = 1$. As will be shown in the Appendix (proof of Proposition 4) $\gamma = 1$ maximizes welfare on the range of $\gamma\epsilon\,(0,42;1]$ where there is information transmission.

(α). ii)For $K\epsilon\,(K_1, K_2(1)]$, information transmission generates a positive welfare loss if $\alpha\epsilon\,[0;0,9]$ or if $\alpha\epsilon\,(0,9;1]$ and $K > \widehat{K}(\alpha)$; a negative welfare loss (i.e. a welfare gain) if $\alpha\epsilon\,(0,9;1]$ and $K < \widehat{K}(\alpha)$. Moreover, this welfare loss increases with σ^2 for $\alpha\epsilon\,[0;0,5]$ and decreases with σ^2 for $\alpha\epsilon\,(0,5;1]$.

The economic intuition of Lemma 3 is as follows.

i)On the range of $K \leq K_1$ the only effect of information transmission is to allow the upstream monopolist's rival to adjust his output to the true realizations of β. These adjustments, increasing the variability of the rival's equilibrium output, lead to a reduction of the expected access profits which, in turn, reduces the expected consumer transfers as opposed to the case in which the rival is ignorant. This reduction, which increases with the variance of the cost parameter, has a negative effect on welfare whenever consumer surplus is more socially valuable than firms' profits (namely, the lower α) and it disappears when they are socially valuable to the same extent (i.e. for $\alpha = 1$). I will call this negative welfare effect, the transfer-reducing effect of information transmission. Besides, the adjustments of the rival's output to β cause a reduction in the variability of the industry equilibrium output, which, reducing both the expected industry downstream profits and the expected consumer surplus, further contributes to decreasing the expected welfare.[17] The greater the variance, the greater the reduction in the industry output variability and, thereby, the greater the welfare loss due to information transmission.

ii) Let us now consider the range of $K\epsilon\,(K_1, K_2(1)]$ where the upstream monopolist's ex-ante decision to transmit to her rival the information on β makes it profitable for her to acquire information. In this case information transmission generates three welfare effects. First, the negative transfer-reducing effect again occurs, which increases with the variance of the cost parameter (σ^2) and decreases with the welfare weight attached to firms profits (α). Second, information acquisition and transmission allow firms to adjust their output levels to the true realization of β which, in turn, raises the variability of the industry equilibrium output and, thereby, increases both the expected net consumer surplus and the expected industry downstream profits. This welfare gain increases with σ^2 and α. I will call this positive welfare effect, the information effect. Third, information acquisition involves an additional cost, namely $K\epsilon\,(K_1, K_2(1)]$, for the upstream monopolist compared to the case of no information acquisition and transmission. This causes a welfare loss which increases with α. I will call this negative welfare effect,

[17] As previously explained, when the rival is informed, his equilibrium output increases (decreases) if the upstream cost is higher (lower) than expected and this, in turn, reduces (increases) the upstream monopolist's output as opposed to the case in which the rival is ignorant. Since the direct effect of information transmission on the rival's output is stronger than its counter-effect on the upstream monopolist's output, information transmission reduces the sensitivity of the industry equilibrium output to β.Using (4) and (5) defined in the appendix, the equilibrium output levels, when the information on β is transmitted to the rival, can be written as

$q^M(\beta, \overline{a}) = q^M(\beta, \beta_0, \overline{a}) - \frac{\beta-\beta_0}{6}; q^R(\beta, \overline{a}) = q^R(\beta_0, \overline{a}) + \frac{\beta-\beta_0}{3}$

$Q(\beta, \overline{a}) = Q(\beta, \beta_0, \overline{a}) + \frac{\beta-\beta_0}{6}$

where $q^M(\beta, \beta_0, \overline{a})$, $q^R(\beta_0, \overline{a})$ and $Q(\beta, \beta_0, \overline{a})$ are the equilibrium output levels under no information transmission. The above eqs clearly show that the direct effect of information trasmission on the rival's output—measured by $\frac{1}{3}$— is greater than its counter-effect on the upstream monopolist's output —measured in the absolute value by $\frac{1}{6}$. As a consequence, since $\frac{\partial Q(\beta,\beta_0,\overline{a})}{\partial \beta} < 0$, information transmission reduces the sensitivity of industry output by $\frac{1}{6}$.

the acquisition cost effect.

When the regulator is much less concerned about firms' profits than about consumer surplus, i.e. $\alpha\epsilon\,[0;0,5]$, the negative transfer-reducing effect more than compensates the positive information effect. As a consequence, on account of the negative acquisition cost effect, information transmission generates a welfare loss which increases with σ^2.

The increase in the welfare weight attached to firms profits, namely $\alpha\epsilon\,(0,5;0,9]$, lowers the negative tranfer-reducing effect and raises the positive information effect so that a net positive welfare effect is produced, which increases with σ^2. This welfare gain, however, is more than compensated by the negative acquisition cost effect. As a consequence, information transmission generates a welfare loss which decreases with σ^2.

Only when the regulator is equally or almost equally concerned about firms' profits and consumer surplus, namely $\alpha\epsilon\,(0,9;1]$, the welfare gain due to information acquisition more than compensates the welfare loss due to both the transfer-reducing effect and the information acquisition effect for the lowest values of K, (namely for $K\epsilon\left(K_1,\widehat{K}(\alpha)\right)$). In this case information transmission produces a welfare gain which increases with σ^2.

4.2 Optimal access profit-sharing plan

This section will determine the optimal access profit-sharing plan (i.e. the optimal value of γ denoted by γ^*) by taking into account both the welfare effects of information transmission and the redistributive effect generated by the transfer of access profits to consumers. This effect, measured by $\gamma(1-\alpha)(\overline{a}-\beta_0)q_r$, decreases as α increases and disappears when $\alpha=1$, namely when the social value of consumer surplus and firms' profits is equal. Besides, it is positively related to the expected access profits obtainable by the upstream monopolist for each unit of input sold to the rival which, in turn, is greater, the greater the difference between the access price cap ($\overline{a}$) and the mean value of the cost distribution. Since the access price cap is equal to the highest value of the cost parameter ($\overline{a}=\overline{\beta}$), it follows that the more (less) right-skewed the cost distribution, the higher (the lower) the mean value of the cost distribution and, thereby, the lower the expected access profits for each unit of input sold.[18]

In the light of the above analysis, the following Propositions are obtained.

Proposition 4 *When information transmission does not induce information acquisition, the greater the variance of the cost and the more right-skewed the cost distribution, the less the transfer of all access profits to consumers is socially desirable. Moreover, if the regulator is equally or almost equally concerned about firms' profits and consumer surplus, the optimal profit-sharing plan will require that a share of access profits be retained by the upstream monopolist, whatever the variance of the cost.*

[18] Right -skewed cost distribution refers to cases where the probability of cost-reducing technological changes is greater when the cost is high than when the cost is low. Intuitively, this is likely to characterize sectors with very complex technology exhibiting a form of decreasing return to scale, where the greater the number of realized technological improvements, the lower the probability of realizing any others.

The economic intuition of Proposition 4 is the following.

From Lemma 3, when the upstream monopolist's ex-ante decision to transmit information does not affect her information acquisition decision, namely when $K \leq K_1$, information transmission generates a welfare loss which increases with the variance of the cost parameter. Therefore, a trade-off occurs. On the one hand, as shown in Lemma 1, the transfer of all access profits to consumers induces the upstream monopolist to transmit to her rival the information acquired on β and this affects welfare negatively. On the other, the reduction in the share of access profits transferred to consumers (i.e. $\gamma \leq 0,42$) eliminates the welfare loss due to information transmission, but it also reduces the positive redistributive effect occurring when a regulator is more concerned about consumer surplus than about firms' profits (i.e. $\alpha < 1$). As discussed above, this effect is positively related to the access profits obtainable for each unit of essential input sold, which, in turn, are lower the more right-skewed the cost distribution. It follows that the greater the variance of the cost and the more right-skewed the cost distribution, the more likely it is that the optimal profit-sharing plan will require that a share of access profits be retained by the upstream monopolist (i.e. $\gamma^* = 0,42$). If the regulator is equally concerned about firms' profits and consumer surplus, namely for $\alpha = 1$, the redistributive effect disappears and, as a consequence, $\gamma^* = 0,42$, whatever the value of σ^2.

Proposition 5 *When information transmission induces information acquisition, if the regulator is (not) much more concerned about consumer surplus than about firms' profits, the greater the variance of the cost and the more (less) right-skewed the cost distribution, the less (more) the transfer of all access profits to consumers is socially desirable. Instead, when the regulator is equally or almost equally concerned about consumer surplus and firms' profits, the optimal profit-sharing plan will require, for the lowest values of the information acquisition costs, that all access profits be rebated to consumers.*

Let us consider the range of $K \epsilon (K_1, K_2(1)]$ where the upstream monopolist's ex-ante decision to transmit to her rival the information on β makes it profitable for her to acquire information. From Lemma 3, information transmission generates a welfare loss for $\alpha \epsilon [0; 0,9]$ which increases with the variance of the cost parameter when the regulator is much less concerned about firms' profits than about consumer surplus (i.e. $\alpha \epsilon [0; 0,5]$) and it decreases with the variance when firms' profits are more socially valuable (i.e $\alpha \epsilon (0,5; 0,9]$). Since the only way for the regulator to make information transmission unprofitable for the upstream monopolist is to reduce the share of access profits transferred to consumers, it follows that the more uncertain the cost distribution, the less (more) the transfer of all access profits to consumers is socially desirable for $\alpha \epsilon [0; 0,5]$ (for $\alpha \epsilon (0,5; 0,9]$). Besides, the more right-skewed the cost distribution, the lower the welfare gain arising from the redistribution of profits to consumers and, thereby, the lower the likelihood that $\gamma^* = 1$ for $\alpha \epsilon [0; 0,9]$.[19]

[19] The appendix gives a more pecise characterization of the optimal profit-sharing plan. In particular, conditions are found which ensure that $\gamma^* = 0,42$ for $\alpha \epsilon [\alpha_1, 0,5]$ with $\alpha_1 > 0$ and $\gamma^* = 1$ for $\alpha \epsilon (0,5; \alpha_2]$ with $\alpha_2 < 1$, whatever the value of σ^2.

If the regulator is equally or almost equally concerned about firms' profits and consumer surplus, namely for $\alpha \epsilon (0,9;1]$, as shown in Lemma 3, information transmission produces a welfare gain for $K < \widehat{K}(\alpha)$. In this case the optimal access profit-sharing plan will require the transfer of all access profits to consumers (i.e. $\gamma^* = 1$) even in the absence of any redistributive effect (i.e. $\alpha = 1$).

Proposition 6 *In the absence of information transmission and acquisition, the optimal profit-sharing plan requires the transfer of all access profits to consumers, whenever the regulator is more concerned about consumer surplus than firms' profits, and the transfer of any share of access profits if consumers surplus and firms' profits are socially valuable to the same extent.*

When the upstream monopolist finds it profitable neither to acquire nor transmit information, namely when $K > K_2(1)$, the transfer of access profits to consumers generates a welfare gain whenever the regulator is less concerned about firms' profits than about consumer surplus ($\alpha < 1$). In this case the optimal profit-sharing plan requires that all access profits be rebated to consumers. Instead, when the regulator is equally concerned about consumer surplus and firms' profits, the adoption of an access profit-sharing plan does not affect welfare, whatever the share of access profits transferred to consumers.

5 Conclusion

This paper has determined the optimal access profit-sharing plan in integrated network industries characterized by an upstream natural monopoly with cost uncertainty regulated through an access price cap mechanism and an unregulated downstream Cournot duopoly. In this context I have shown that the requirement to share a sufficiently high amount of access profits with consumers may affect the upstream monopolist's incentives to acquire and transmit the information on the upstream cost to her downstream rival and this, in turn, affects welfare. On account of these effects the optimal profit-sharing plan will depend on the variance and shape of the cost distribution, on the value of the information acquisition costs as well as on the regulator's redistributive concerns. I have shown that for low information acquisition costs, the transfer of all access profits is never desirable when the regulator is equally concerned about consumer surplus and firms' profits, namely in the absence of any redistributive concern. Instead, for high information acquisition costs, it is *precisely* when the regulator is equally or almost equally concerned about consumers surplus and firms' profits that the optimal access profit-sharing plan may require the transfer of all access profits to consumers.

When consumer surplus is more socially valuable than firms' profits a trade-off occurs between the welfare loss due to information transmission and the welfare gain due to the redistribution of profits to consumers. I have shown that in highly dynamic network industries characterized by technologies exhibiting some forms of decreasing returns of scale, if the information acquisition costs are low or if both the information acquisition costs and the regulator's redistributive concerns are high, the welfare loss due to information transmission is likely to prevail over the positive welfare redistributive effect. In these cases the optimal access profit-sharing plan requires that a share of access profits be retained by the upstream monopolist.

A possible implication of the analysis carried out in this paper is that an access profit-sharing plan might perform better in network industries where the upstream monopolist is not allowed to produce in the downstream market. Indeed, in separated network industries, as there is no transmission effect, the requirement to share access profits with consumers would affect welfare positively whenever the regulator is more concerned about consumer surplus than about firms' profits.

The analysis carried out in this paper has assumed away any cost-reducing activity and, thereby, has excluded the negative effect produced by the requirement to share profits with consumers on the firm's incentives to minimize costs. A possible extension of the paper could be to analyze the performance of profit-sharing and sliding scale mechanisms in different industrial structures when the negative incentive effect is also present.

6 Appendix

Equilibrium analysis

Let us first consider the case in which the upstream monopolist has acquired information on the upstream cost and transmitted it to the rival. The maximization of (1) w.r.t. q^M and of (2) w.r.t. q^R yield the equilibrium variables in the downstream market as a function of β and $\overline{a}$

$$q^M(\beta,\overline{a}) = \frac{d-2\beta+\ \overline{a}}{3}; q^R(\beta,\overline{a}) = \frac{d-2\ \overline{a}+\beta}{3}; Q(\beta,\ \overline{a}) = \frac{2d-\ \overline{a}-\beta}{3}; \tag{4}$$

Let us then consider the case in which the upstream monopolist chooses not to disclose information on the upstream cost to her downstream rival who, as a consequence, will set his output so as to maximize his expected profits $E\Pi^R$, with Π^R given by (2) where the expectation is taken over β. Cournot competition between an informed upstream monopolist and an ignorant rival yields the following equilibrium output levels

$$\begin{aligned} q^M(\beta,\beta_0,\overline{a}) &= \frac{d+\overline{a}}{3} - \frac{\beta}{2} - \frac{\beta_0}{6}; q^R(\beta_0,\overline{a}) = \frac{d-2\overline{a}+\beta_0}{3}; \\ Q(\beta,\beta_0,\overline{a}) &= \frac{2d-\overline{a}}{3} - \frac{\beta}{2} + \frac{\beta_0}{6} \end{aligned} \tag{5}$$

Finally, when the upstream monopolist does not acquire information, she will choose q^M so as to maximize $E\Pi^M$ with Π^M defined by (1) and her rival will choose q^R so as to maximize $E\Pi^R$ where the expectations are taken with respect to β. The equilibrium output levels under no information acquisition are

$$\begin{aligned} q^M(\beta_0,\overline{a}) &= \frac{d+\overline{a}-2\beta_0}{3};\ q^R(\beta_0,\overline{a}) = \frac{d-2\overline{a}+\beta_0}{3}; \\ Q(\beta_0,\overline{a}) &= \frac{2d-\overline{a}-\beta_0}{3} \end{aligned} \tag{6}$$

Proof of Lemma 1. Lets $\Pi^M(\beta, \overline{a}, \gamma)$ and $\Pi^M(\beta, \beta_0, \overline{a}, \gamma)$ the upstream monopolist's profit functions under transmission and concealment of information, respectively. Substituting for (4)and (5), respectively in (1), yields

$$\Pi^M(\beta, \overline{a}, \gamma) = \left[\frac{d + \overline{a} - 2\beta}{3}\right]^2 + (1-\gamma)(\overline{a} - \beta)\left(\frac{d - 2\overline{a} + \beta}{3}\right) \tag{7}$$

$$\Pi^M(\beta, \beta_0, \overline{a}, \gamma) = \left[\frac{d + \overline{a}}{3} - \frac{\beta}{2} - \frac{\beta_0}{6}\right]^2 + (1-\gamma)(\overline{a} - \beta)\left(\frac{d - 2\overline{a} + \beta_0}{3}\right) \tag{8}$$

Taking the expectation of (7) and subtracting the expectation of (8), yields

$$E\Pi^M(\beta, \overline{a}, \gamma) - E\Pi^M(\beta, \beta_0, \overline{a}, \gamma) = \frac{7}{36}\sigma^2 - \frac{(1-\gamma)}{3}\sigma^2 = \left(-\frac{5}{36} + \frac{1}{3}\gamma\right)\sigma^2 \tag{9}$$

where $\partial\left[E\Pi^M(\beta, \overline{a}, \gamma) - E\Pi^M(\beta, \beta_0, \overline{a}, \gamma)\right]/\partial\gamma > 0$ and $E\Pi^M(\beta, \overline{a}; 0,42) - E\Pi^M(\beta, \beta_0, \overline{a}; 0,42) = 0$

■

Proof of Lemma 2 Substituting for (6) in (1) and taking the expectation yields

$$E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) = \left[\frac{d + \overline{a} - 2\beta_0}{3}\right]^2 + (1-\gamma)(\overline{a} - \beta_0)\left(\frac{d - 2\overline{a} + \beta_0}{3}\right) \tag{10}$$

Taking the expectation of (8) and subtracting (10), by using Taylor's expansion yields

$$E\Pi^M(\beta, \beta_0, \overline{a}, \gamma) - E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) = \frac{\sigma^2}{4} \tag{11}$$

By adding (9) and (11) we have

$$E\Pi^M(\beta, \overline{a}, \gamma) - E\Pi^{MN}(\beta, \beta_0, \overline{a}, \gamma) = \frac{\sigma^2}{9} + \gamma\frac{\sigma^2}{3} > \frac{\sigma^2}{4} \text{for } \gamma\epsilon\,(0,42;1]$$

Proof of Lemma 3 Let us first derive the regulator's objective function, denoted by $EW(\beta, K, \gamma, \overline{a}, \alpha)$. In the light of Lemmas 1 and 2, it is given by (3) evaluated at different equilibrium output levels according to the values of γ and K, as follows

$$EW(\beta, K, \gamma, \overline{a}, \alpha) = \tag{12}$$

$$\frac{E\left[F(\beta, \beta_0, K, \overline{a})^2\right]}{2} + \alpha E(P(F(\beta, \beta_0, K, \gamma, \overline{a})) - \beta)F(\beta, \beta_0, K, \gamma, \overline{a}) +$$
$$(1-\alpha)\gamma E\left[(\overline{a} - \beta)f(\beta, \beta_0, K, \gamma, \overline{a})\right] - \xi K$$

where the functions $F(\beta, \beta_0, K, \gamma, \overline{a})$ and $f(\beta, \beta_0, K, \gamma, \overline{a})$ are so defined:

$$\begin{aligned} F(\beta, \beta_0, K, \gamma, \overline{a}) &= Q(\beta, \beta_0, \overline{a}) \text{ for } K \leq K_1,\ \gamma\epsilon\,[0;0,42] \\ &= Q(\beta, \overline{a}) \text{ for } K \leq K_2(\gamma),\ \gamma\epsilon\,(0,42;1] \\ &= Q(\beta_0, \overline{a}) \left\{ \begin{array}{c} \text{for } K\epsilon\,(K_1, K_2(\gamma)]\,,\ \gamma\epsilon\,[0;0,42] \\ \text{for } K > K_2(\gamma),\ \gamma\epsilon\,[0,1] \end{array} \right\} \end{aligned}$$

$$
\begin{aligned}
f(\beta,\beta_0,K,\gamma,\overline{a}) &= q^R(\beta_0,\overline{a})\left\{ \begin{array}{c} \text{for } K \leq K_2(\gamma),\ \gamma\epsilon\,[0;0,42] \\ \text{for } K > K_2(\gamma),\ \gamma\epsilon\,[0,1] \end{array} \right\} \\
&= q^R(\beta,\overline{a}) \text{ for } K \leq K_2(\gamma),\ \gamma\epsilon\,(0,42;1]
\end{aligned}
$$

with $Q(\beta,\beta_0,\overline{a})$ and $q^R(\beta_0,\overline{a})$ defined in (5) $Q(\beta_0,\overline{a})$ and $q^R(\beta_0,\overline{a})$ defined in (6); $Q(\beta,\overline{a})$ and $q^R(\beta,\overline{a})$ in (4). $\xi = 0$ if $K\epsilon\,(K_1,K_2(\gamma)]$ and $\gamma\epsilon\,[0;0,42]$ or if $K > K_2(\gamma)$ and $\gamma\epsilon\,[0,1]$; $\xi = 1$ otherwise.

The welfare effects of information transmission, denoted by $\Delta W^T(\alpha,\sigma^2,K)$, are given by the difference between the expected welfare function evaluated at the equilibrium output levels with information transmission (i.e. $\gamma > 0,42$) and the expected welfare function evaluated at the equilibrium levels without information transmission (i.e. $\gamma \leq 0,42$), keeping fixed the share of access profits transferred to consumers.

i) For $K \leq K_1$

$$
\begin{aligned}
\Delta W^T(\alpha,\sigma^2,K) &= \frac{E\left[Q(\beta,\overline{a})^{\ 2}\right]}{2} - \frac{E\left[Q(\beta,\beta_0,\overline{a})^{\ 2}\right]}{2} + \\
&\quad \alpha\left[(P(Q(\beta,\overline{a})\ ) - \beta)Q(\beta,\overline{a})\ ) - (P(Q(\beta,\beta_0,\overline{a})\ ) - \beta)Q(\beta,\beta_0,\overline{a})\ )\right] \\
&\quad +(1-\alpha)\gamma(\overline{a}-\beta)\left(q^R(\beta,\overline{a}) - q^R(\beta_0,\overline{a})\right)
\end{aligned}
$$

Easy calculations give

$$
\Delta W^T(\alpha,\sigma^2,K) = (-0,4 + \alpha 0,3)\sigma^2 \ < 0 \tag{13}
$$

with $\partial\Delta W^T(\alpha,\sigma^2,K)/\partial\sigma^2 < 0$ and $\partial\Delta W^T(\alpha,\sigma^2,K)/\partial\alpha > 0$.

ii) For $K\epsilon\,(K_1,K_2(1)]$

$$
\begin{aligned}
&\Delta W^T(\alpha,\sigma^2,K) = \frac{E\left[Q(\beta,\overline{a})^{\ 2}\right]}{2} - \frac{E\left[Q(\beta_0,\overline{a})^{\ 2}\right]}{2} + \\
&\alpha\left[(P(Q(\beta,\overline{a})\ ) - \beta)Q(\beta,\overline{a})\ ) - (P(Q(\beta_0,\overline{a})\ ) - \beta)Q(\beta_0,\overline{a})\ )\right] \\
&-\alpha K + (1-\alpha)\gamma(\overline{a}-\beta)\left(q^R(\beta,\overline{a}) - q^R(\beta_0,\overline{a})\right)
\end{aligned}
$$

which gives

$$
\Delta W^T(\alpha,\sigma^2,K) = -(1-\alpha)0,33\sigma^2 + (0,05 + \alpha 0,2)\sigma^2 - \alpha K \tag{14}
$$

where the first negative term is the transfer-reducing effect, the second positive term indicates the information effect and the third term, the acquisition cost effect. (8) can be written as

$$
\Delta W^T(\alpha,\sigma^2,K) = 0,27(2\alpha - 1)\sigma^2 - \alpha K \text{ for all } K\epsilon\,(K_1,K_2(1)] \tag{15}
$$

where $\Delta W^T(\alpha,\sigma^2,K) < 0$ for $\alpha\epsilon\,[0;0,5]$ with $\partial\Delta W^T(\alpha,\sigma^2,K)/\partial\sigma^2 < 0$.

Now consider the range of $\alpha\epsilon\,(0,5;1]$. Denote by $\widehat{K}(\alpha) = \left[0,27(2\alpha-1)\sigma^2\right]/\alpha$ the value of $K\epsilon\,(K_1,K_2(1))$ which solves $\Delta W^T(\alpha,\sigma^2,K) = 0$ with $d\widehat{K}(\alpha)/d\alpha$ >0, $\widehat{K}(\alpha) \simeq K_1$ at $\alpha = 0,9$ and $\widehat{K}(1) = 0,27\sigma^2 <$

$K_2(1)$. Since $\partial \Delta W^T(\alpha, \sigma^2, K)/\partial K < 0$, it is easy to show that $\Delta W^T(\alpha, \sigma^2, K) < 0$ if $\alpha \epsilon\, (0,5; 0,9]$ and $K \epsilon\, (K_1, K_2(1)]$ or if $\alpha \epsilon\, (0,9; 1]$ and $K \epsilon \left(\widehat{K}(\alpha), K_2(1)\right)$; $\Delta W^T(\alpha, \sigma^2, K) > 0$ if $\alpha \epsilon\, (0,9; 1]$ and$K \epsilon \left(K_1, \widehat{K}(\alpha)\right)$.

Moreover $\partial \Delta W^T(\alpha, \sigma^2, K)/\partial \sigma^2 > 0$ for all $\alpha \epsilon\, (0,5; 1]$ ■

Proof of Proposition 4 The determination of $\gamma^*$is carried out in two stages for $K \leq K_2(\gamma)$. First, maximizing $EW(\beta, K, \gamma, \overline{a}, \alpha)$ w.r.t. γ, separately for $\gamma \epsilon\, [0; 0,42]$ —where there is no information transmission— and for $\gamma \epsilon\, (0,42; 1]$— where information transmission occurs—yields $\gamma = 0,42$ and $\gamma = 1$, respectively. This result derives directly from the fact that the expected welfare is an increasing function of γ, for the same equilibrium output.

Next, the value of γ^* is determined by solving

$$\max_{\gamma \epsilon \{0,42;1\}} EW(\beta, K, \gamma, \overline{a}, \alpha) \tag{16}$$

separately for $K \leq K_1$ and $K \epsilon\, (K_1, K_2(1)]$.

Let $\Delta W(K, \sigma^2, \alpha) = EW(K, 1, \overline{a}, \alpha) - EW(K, 0, 42, \overline{a}, \alpha)$, then

$$\begin{aligned} \gamma^* &= 0,42 \text{ if } \Delta W(K, \sigma^2, \alpha) \leq 0 \\ \gamma^* &= 1 \text{ if } \Delta W(K, \sigma^2, \alpha) > 0 \end{aligned}$$

For $K \leq K_1$

$$\Delta W(K, \sigma^2, \alpha) = \Delta W^T(\alpha, \sigma^2, K) + 0,58(1-\alpha)(\overline{a} - \beta_0) q^R(\beta_0, \overline{a})$$

where $\Delta W^T(\alpha, \sigma^2, K)$ is defined in (13). It follows that $\partial \Delta W(K, \sigma^2, \alpha)/\partial \sigma^2 < 0$ and $\Delta W(K, \sigma^2, \alpha) < 0$ at $\alpha = 1$. Besides , the more right-skewed the cost distribution function, the lower the value of $(\overline{\beta} - \beta_0)$ and, thereby, being $\overline{a} = \overline{\beta}$, the more likely it is that $\Delta W(K, \sigma^2, \alpha) < 0$.■

Proof of Proposition 5

For $K \epsilon\, (K_1, K_2(1)]$

$$\Delta W(K, \sigma^2, \alpha) = \Delta W^T(\alpha, \sigma^2, K) + 0,58(1-\alpha)(\overline{a} - \beta_0) q^R(\beta_0, \overline{a}) \tag{17}$$

where $\Delta W^T(\alpha, \sigma^2, K)$ is defined in (15). From the proof of Lemma 3 it follows that $\partial \Delta W(K, \sigma^2, \alpha)/\partial \sigma^2 < 0$ for $\alpha \epsilon\, [0; 0,5]$; $\partial \Delta W(K, \sigma^2, \alpha)/\partial \sigma^2 > 0$ for $\alpha \epsilon\, (0,5; 1]$; $\Delta W(K, \sigma^2, \alpha) > 0$ for $\alpha \epsilon\, (0,9; 1]$ and $K \epsilon \left(K_1, \widehat{K}(\alpha)\right)$.

Besides, the more right-skewed the cost distribution function, the more likely it is that $\Delta W(K, \sigma^2, \alpha) < 0$ for all $\alpha \epsilon\, [0; 0,9]$. More specifically, for sufficiently right-skewed cost distribution functions such that

$$\Delta W(K_1, 0; 0,5) = -K_1 + 0,58(\overline{a} - \beta_0) q^R(\beta_0, \overline{a})) < 0$$

it follows that

$$\Delta W(K, \sigma^2, \alpha) < 0 \text{ for } \alpha \epsilon\, [\alpha_1(K); 0,5] \Rightarrow \gamma^* = 0,42$$

with $\alpha_1 \epsilon \, (0; 0,5)$ satisfying $\Delta W(K, 0, \alpha_1) = 0$ and $d\alpha_1/dK < 0$;

for sufficiently left-skewed cost distribution functions such that

$$\Delta W(K_2(1), 0; 0, 5) > 0$$

it follows that

$$\Delta W(K, \sigma^2, \alpha) > 0 \text{ for } \alpha \epsilon \, [0, 5; \alpha_2(K)] \Rightarrow \gamma^* = 1$$

with $\alpha_2 \epsilon \, (0, 5; 0, 9]$ satisfying $\Delta W(K, 0, \alpha_2) = 0$ and $d\alpha_2/dK < 0$.■

Proof of Proposition 6 For $K > K_2(1)$ the regulator's problem is

$$\max_{\gamma \epsilon [0,1]} EW(\beta, K, \gamma, \overline{a}, \alpha)$$

where $EW(\beta, K, \gamma, \overline{a}, \alpha)$ is defined in (12). Being $\partial EW(\beta, K, \gamma, \overline{a}, \alpha)/\partial \gamma > 0$ for $\alpha < 1$, and $\partial EW(\beta, K, \gamma, \overline{a}, \alpha)/\partial \gamma = 0$ for $\alpha = 1$, it follows that $\gamma^* = 1$ for $\alpha < 1$ and $\gamma^* \epsilon \, [0, 1]$ for $\alpha = 1$■

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