The optimal institutional design of vertically related markets with unknown upstream costs

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Abstract

This paper examines the design of vertically related industries with a regulated monopolistic upstream input and competitive downstream activities. Two institutional patterns are investigated. Ownership separation entails full unbundling between upstream and downstream activities. Legal separation allows a downstream firm to own the upstream monopolist but requires the two entities to be legally unbundled so that each service is stand-alone profitable and only upstream profits are regulated. Under regulatory limited information about upstream costs, the legally separated monopolist exhibits countervailing incentives to manipulate costs. This alleviates the regulator's control problem and yields higher welfare than ownership separation.

Keywords: access price, legal separation, ownership separation, regulation, vertical integration

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1. Introduction

The large-scale liberalization process that occurred over the last decades has affected many sectors where naturally monopolistic and potentially competitive activities are vertically related. This is especially the case in network industries, such as electricity, natural gas, railways and water utilities. The supply of a service to final consumers, which admits competition at least to some extent, requires the use of an essential facility-based input - the network - provided by a monopolistic firm usually subject to regulation.

A crucial issue in policy debates is how to design the institutional structure of an industry before the liberalization process. In practice, this question has received different answers. The Electricity Act of 1989 divided the Central Electricity Generating Board (CEGB) of England and Wales, which operated as a vertically integrated statutory monopoly, into four public limited companies, and transmission grid activities were separated from generation. Following the 1982 Modification of Final Judgment, AT&T, which was a vertically integrated monopolist in the US telecommunications sector, divested itself of its local network activities.

Conversely, in 1984 British Telecom (BT) was privatized as a vertically integrated firm, and the accounting separation of its operations into network and retail businesses was realized only in 1995. According to the agreement with the UK regulator Ofcom, the network provider Openreach must now act independently while being an affiliate of BT. In the US, similar forms of unbundling characterize the natural gas pipelines and large parts of the electricity transmission systems.[1]

More recently, the European Union dealt with the design of institutional structure in network industries. The European Directives 2009/72/EC and 2009/73/EC, which concern common rules for the internal market in electricity and natural gas respectively, prescribe that a transmission system owner, which is part of a vertically integrated undertaking, must be independent at least in terms of its legal form, organization, and decision-making from other activities not relating to transmission. Interestingly, these rules do not create an obligation to separate the ownership of assets of the transmission system from the other activities. Along these lines, the Directive 2009/140/EC reformed the telecommunications sector.

Therefore, two main alternatives to the classical full vertical integration have been so far implemented. The regime of *ownership separation* entails full unbundling between upstream and downstream activities. The alternative pattern, usually defined as *legal separation*, allows a downstream firm to own the upstream monopolist but requires the two entities to be legally unbundled, so that the provision of each service is stand-alone profitable and only monopolistic operations are regulated.

The aim of our paper is to investigate the two aforementioned institutional patterns in industries where the provision of competitive downstream services requires access to a regulated monopolistic bottleneck. We show that, in the presence of regulatory limited information about upstream costs, the regime of legal separation alleviates the regulator's incentive problem, thereby generating higher social welfare than ownership separation.

[1] See the Order 636 of 1992 for natural gas and the Order 2000 of 1999 for electricity. We refer to Newbery (1999) and Viscusi et al. (2005) for an overview of the most important regulatory reforms in the UK and US network utilities.

The intuition for this result is that a higher access price which stems from the monopolist's cost exaggeration improves profits from upstream activities but penalizes downstream profits because the input access is more expensive, which reduces the downstream price-cost markup. Under ownership separation, the monopolist maximizes profits from upstream activities and neglects the impact of its behavior on the downstream market. Conversely, a legally separated monopolist (partially) internalizes downstream losses from cost exaggeration incurred by the parent company. The trade-off between upstream gains and downstream losses from cost manipulation creates *countervailing incentives*, which reduces the informational costs of regulatory policy implementation and therefore mitigates the regulator's critical control problem. As a result, the regime of legal separation improves social welfare. Interestingly, the social benefit of legal separation is maximized when the upstream affiliate is concerned about the full profits of the parent company, since it fully internalizes the negative impact of its strategic behavior on downstream activities.

Under certain circumstances, legal separation can also outperform the classical regime of full vertical integration, where the integrated firm constitutes a unique entity whose profits are entirely regulated. As we stressed above, our results show that the upstream monopolist's cost exaggeration imposes a negative externality on downstream activities. Under legal separation, this generates countervailing incentives, which are stronger when the monopolist internalizes to a larger extent the profits of the downstream parent company. This effect is also more pronounced in the presence of informational unbundling, namely, when the downstream parent company does not know the costs of the legally separated monopolist. On the other hand, legal separation provides smaller scope for profit extraction than vertical integration, since only upstream profits are regulated rather than the firm's full profits. The result of the trade-off between countervailing incentives and profit extraction is that, if the degree of internalization of downstream profits is sufficiently high and informational unbundling applies, the regime of legal separation can dominate full vertical integration.

The analysis in this paper is conducted in a fairly general setting, without placing any relevant restrictions on functional forms. Afterwards, using explicit functions, we derive the main features of the optimal regulatory policy and study how the institutional design affects the access pricing rule.

Our contribution suggests the regime of legal separation as an institutional response to regulatory informational problems in network industries. We believe that the analysis of the potential benefits of legal separation can enrich the relevant policy debate of how to vertically structure industries with a monopolistic bottleneck.

2. Related literature

The early literature on vertically related markets focused on two extreme alternatives, namely, full vertical integration and ownership separation in the absence of regulation (e.g., Perry 1989). Standard arguments in favor of the former regime are that it might provide better investment incentives for upstream activities and overcome the double marginalization problem. On the other hand, one of the most relevant benefits of ownership separation is the prevention of discriminatory practices against downstream competitors.

Lewis and Sappington (1989a) emphasize that the regulator can improve social welfare by allowing a regulated firm to operate in a competitive market whose profitability is positively correlated with costs in the regulated market. Since cost exaggeration yields an overstatement of competitive profits, countervailing incentives to manipulate information arise, which alleviates the regulator's incentive problem (Lewis and Sappington 1989b). In our setting, the design of the institutional structure drives this type of incentives.

Despite its relevance to the policy debate, the investigation of the optimal institutional design and of the optimal regulatory policy in vertically related markets with regulatory limited information has so far received little theoretical attention (Armstrong and Sappington 2007; Vogelsang 2003). Vickers (1995) studies a relevant trade-off between vertical integration and ownership separation. When competing directly in the downstream market, the upstream monopolist will anticipate larger profits from downstream operations as the costs of its rivals increase. This exacerbates the monopolist's incentive to exaggerate costs and makes the regulatory task more burdensome. On the other hand, full vertical integration gives the regulator larger scope for profit extraction, since the firm's total profits are regulated. Moreover, this regime may result in fewer downstream firms and thereby less duplication of fixed costs.

In this paper, we explore a third alternative: legal separation between upstream and downstream operations.[2] Our study may therefore provide a contribution to the infant literature on legal separation. Contrary to our work, all relevant papers on this topic examine a complete information setting. Sibley and Weisman (1998) show that an upstream monopolist, which also operates downstream via a separate subsidiary, may not have any incentive to raise the rivals' costs. Cremer et al. (2006) find that legal separation improves the incentives to invest in network assets.

A seminal contribution to this strand of literature is Höffler and Kranz (2011a) who investigate the benefits of legal separation in the presence of non-tariff discrimination. They suppose that the legally separated upstream affiliate only maximizes its own profits. However, as the two authors recognize, this assumption does not reflect most experiences from network industries. In a companion paper (2011b), Höffler and Kranz allow the legally separated upstream affiliate to (partially) internalize downstream profits. We prefer to follow this approach, which illustrates the benefits of different degrees of legal separation. We also consider an alternative form of legal separation - studied in Cremer et al. (2006) and Sibley and Weisman (1998) - which allows the upstream monopolist to hold interests in the downstream firm while the latter acts independently.

Our work is also related to the literature on the regulation of network access pricing. Laffont and Tirole (1994) derive optimal Ramsey prices in a setting where the regulator can control both the access charge and the price for the final product. Our paper shares some similarities with their approach, such as the presence of asymmetric information. However, in line with Vickers (1995) and the more recent deregulatory policies, regulation is relegated to the upstream part of the industry while downstream prices are fully liberalized.[3] More relevantly, the focus of our analysis is on the optimal institutional design.

[2] We refer to Cave (2006) for an overview of different degrees of separation.

[3] In the presence of unregulated downstream prices and complete information, Armstrong and Vickers (1998) show that the optimal access price can be above or below marginal costs.

One access pricing formula deeply discussed in the literature is the efficient component pricing rule (ECPR), which prescribes that a vertically integrated incumbent should charge an access price equal to the cost of access plus the incumbent's foregone profit from supplying a unit of access to its rivals (e.g., Baumol 1983; Willig 1979). The ECPR ensures that a firm will enter the market if and only if it is more efficient than the incumbent. Our analysis differs in some relevant aspects. We allow for imperfect downstream competition, while the ECPR, at least in its basic formulation, takes retail prices as given.[4] More significantly, we do not address the issue of efficient entry but characterize Bayesian incentive mechanisms which have so far played a minor role in the regulation literature on access pricing.

The plan of the paper is as follows. Section 3 sets out the basic structures of the model. Section 4 considers the benchmark case of complete information. Section 5 investigates the impact of asymmetric information on the institutional design and provides some policy recommendations. Using explicit functional forms, Section 6 derives the main features of the optimal regulatory policy and studies how the institutional design affects the access pricing rule. Section 7 is devoted to robustness checks and extensions. Section 8 concludes. All relevant proofs are provided in the Appendix.

3. The model

We examine a vertically related industry where downstream firms require access to a monopolistic upstream input (the network) in order to supply a homogeneous final product. In this setting, two alternative institutional structures are investigated, namely, ownership separation and legal separation. The regime of ownership separation entails full unbundling between upstream and downstream operations. Legal separation allows a downstream firm to own the input provider but requires the two entities to be legally unbundled so that the provision of each service is stand-alone profitable and only upstream profits are regulated.

Upstream market

The regulated monopolist's upstream profit is

$$\pi_u = (a - c_u)\, Q + T. \tag{1}$$

The monopolist receives an access price a for each unit of downstream output Q together with a transfer T via the regulatory process (see below). In order to ensure a system of "third party access", price discrimination among input users is forbidden. Moreover, the bypass of access service is unfeasible so that exactly one unit of upstream input is needed for each unit of the final product. The monopolist is privately informed about its constant marginal costs $c_u \in [c_u^-, c_u^+]$.[5] The regulator has some prior probability distribution for these costs. We let $F(c_u) : [c_u^-, c_u^+] \to [0,1]$ denote the (continuous and differentiable) cumulative distribution function for this probability distribution.

[4] Armstrong et al. (1994) provide extensions of the ECPR. We also refer to Armstrong and Sappington (2006) and Vogelsang (2003) for a review of this topic.

[5] Fixed costs that make the activity naturally monopolistic are irrelevant for the welfare analysis and can be ignored.

In both regimes, only the upstream profits in (1) are regulated. This implies that the condition of non-negative upstream profits also applies under legal separation. As Vickers (1995, p. 14) emphasizes, regulatory agencies usually implement policies which yield a reasonable rate of return on a firm's regulated activities, without interfering in its competitive operations. Consequently, a natural formulation requires the firm to at least break even in its regulated activities.[6]

Downstream market

We let $p(Q)$ be the (inverse) downstream demand function which is positive, twice continuously differentiable, decreasing, and concave. Consumer surplus (net of prices) $V(Q)$ is twice continuously differentiable and strictly convex in Q.[7]

We suppose that $n > 1$ downstream firms compete in quantities (à la Cournot), consistently with the real world experiences from some relevant network industries such as natural gas. Downstream firms obtain profits $\pi_h = p(Q) q_h - C(q_h) - aq_h$, where q_h ($\sum_{h=1}^{n} q_h \equiv Q$) is the quantity produced by firm $h = 1, ..., n$. Downstream profits π_h are given by the revenues from the marketplace net of downstream costs C ($C' \geq 0$, $C'' \geq 0$),[8] minus the access price for the upstream input. Because downstream firms cannot bypass the monopolist's infrastructure, their total costs $\varphi(q_h, a) \equiv C(q_h) + aq_h$ are such that $\varphi''(a) = 0$ (Armstrong and Sappington 2007).

Without loss of generality, under legal separation the downstream firm 1 owns the upstream monopolist. Legal separation between the two entities implies that firm 1 is concerned about total profits, while the monopolist maximizes

$$\pi_u + \phi\pi_1, \tag{2}$$

which is a weighted sum of the profits from upstream and downstream activities. Following Höffler and Kranz (2011b), the parameter $\phi \in [0, 1]$ captures the weight the upstream monopolist attaches to downstream profits. Experiences from network industries reveal that the management of the upstream affiliate often cares about downstream profits. This may follow from career concerns or stock options of the parent company. If $\phi < 1$, the interests of the upstream affiliate are (partially) separated from those of the parent company. If $\phi = 1$, the affiliate perfectly internalizes total profits. This case also covers the pattern of "accounting separation", a common tool, for example, in telecommunications regulation.

Regulation

The regulator maximizes a social welfare function of the form

[6] The Telecommunications Act of 1996 explicitly excludes earnings from unregulated activities for the computation of a reasonable profit accruing to US incumbent local exchange carriers (Sidak and Spulber 1998, ch. 9). In Japan, the regulated local affiliates of Nippon Telegraph and Telephone Corporation, NTT East and NTT West, must be viable per se and cannot be cross-subsidized. The European Directives 2009/72/EC and 2009/73/EC provide a similar prohibition in electricity and gas markets.

[7] We abstract from income effects, which provides a rationale for a partial equilibrium analysis.

[8] If firms exhibit different costs, the question of efficient entry may be raised, which is beyond the scope of this paper. Since firms sell a homogeneous good, the cost difference should be small, and therefore only the allocation of total output among firms will change while the welfare analysis remains unaffected.

$$W = V - T + \gamma\left(\pi_u + \sum_{h=1}^{n} \pi_h\right), \tag{3}$$

which aggregates consumer surplus, net of transfers to the monopolist, and the firms' profits, weighted by a parameter $\gamma \in [0,1]$. In line with the optimal regulation literature, the regulator's social preferences reflect a greater concern with (net) consumer surplus than with the firms' profits.[9] The function W is assumed to be twice continuously differentiable and strictly concave in the access charge a.

The regulatory policy $\{a, T\}$ specifies an access charge a paid by downstream firms and a transfer T. The regulator is supposed to have appropriations that may be used to subsidize the regulated firm, and therefore the transfer T is financed by consumers/taxpayers (e.g., Baron and Myerson 1982; Laffont and Tirole 1986). If T is negative, then it represents a tax on the firm.

Timing

We consider the following sequence of events. First, Nature draws a type $c_u \in [c_u^-, c_u^+]$ for the monopolist. Second, the regulator decides on the institutional pattern.[10] Third, the monopolist learns its type. Fourth, the regulator offers the monopolist a take-it-or-leave-it policy $\{a, T\}$. If the monopolist rejects the offer, it obtains its reservation utility (i.e., upstream profits normalized to zero) and the game ends. If the monopolist accepts the offer, downstream firms compete.

In summary, our model is a two-stage game. After deciding on the institutional pattern, in the first stage the regulator determines the regulatory policy. In the second stage, competition takes place. We solve this game by backward induction.

4. The benchmark case of complete information

To suitably study the impact of regulatory limited information on the optimal institutional design, we first examine the benchmark case of complete information. With a fully-informed regulator, legal separation can perform (at least) as well as ownership separation. Some considerations are helpful to understand the rationale for this result. Under complete information, the monopolist has no room for strategic behavior and therefore the different profit objectives driven by two institutional patterns are inconsequential. Moreover, using the monopolist's profit function in (1), legal separation can achieve the same second-stage equilibrium outcome as ownership separation via a transfer $T = \pi_u - (a - c_u) Q$, which ensures the monopolist a fixed payment π_u and extracts its net revenues $(a - c_u) Q$ from the downstream market. This allows firm 1 to only affect its downstream profits, exactly as under ownership separation.[11] As

[9] See, e.g., Baron (1988) for theoretical foundations. Using (1), social welfare in (3) can be rewritten as $W = V + (a - c_u) Q - (1 - \gamma) \pi_u + \gamma \sum_{h=1}^{n} \pi_h$. Hence, the regulator's distributional concerns imply that the monopolist's rents are socially costly. In Section 6 we consider a consumer surplus objective ($\gamma = 0$).

[10] In line with some relevant literature (e.g., Iossa 1999; Vickers 1995), we restrict attention to the case where regulator must choose the institutional pattern before the firm learns its costs.

[11] With $T = \pi_u - (a - c_u) Q$, firm 1 maximizes $\pi_1 + \pi_u = p(Q) q_1 - C(q_1) - a q_1 + \pi_u$, where π_u is a fixed payment decided by the regulator. This clearly entails the same second-stage outcome as ownership separation.

discussed in Section 3, under both regimes the regulator's first-stage problem is to maximize social welfare W in (3) by ensuring non-negative profits from regulated upstream activities.

We formalize our result in the following proposition.

Proposition 1 *Under complete information, the regime of legal separation yields (at least) the same social welfare as ownership separation.*

5. The case of asymmetric information

Under asymmetric information, the monopolist privately knows its upstream marginal costs $c_u \in [c_u^-, c_u^+]$.[12] We assume that legal separation is able to implement informational unbundling, so that the downstream parent company (firm 1) does not know the upstream costs. In network industries, most jurisdictions prescribe strict rules on informational unbundling which forbid the exchange of private information between the downstream parent company and the legally separated network provider.[13]

5.1. Incentives to manipulate information

Economic literature long ago emphasized that a regulated firm has a natural incentive to overstate its costs if the regulator ignores asymmetric information and offers the firm the complete information regulatory policy. Clearly, under ownership separation the monopolist with costs c_u exhibits the standard incentive to inflate its costs, namely, to declare $\widehat{c}_u \in (c_u, c_u^+]$, since doing so increases the access charge received from downstream firms.

Under legal separation, we find the following result of some relevance.

Proposition 2 *Suppose that the regulator implements the complete information policy, despite asymmetric information about upstream costs $c_u \in [c_u^-, c_u^+]$. Under legal separation, the upstream monopolist's cost exaggeration yields gains in upstream activities and losses in downstream activities. This creates countervailing incentives to manipulate costs. Specifically, there exists a threshold value $c_u^*(c_u, \phi) \in (c_u, c_u^+]$ such that*

(i) the upstream monopolist with costs c_u has an incentive to report $\widehat{c}_u \in (c_u, c_u^*(c_u, \phi)]$

(ii) $c_u^*(c_u, \phi)$ decreases with ϕ.

Legal separation induces the monopolist to face a trade-off when manipulating its costs. A cost overstatement improves upstream profits since the access charge rises. On the other hand, a higher access charge reduces the downstream price-cost markup, and therefore penalizes downstream profits. Since the monopolist (partially) internalizes this negative effect on the downstream parent company, legal separation generates *countervailing incentives* to manipulate

Standard conditions for existence and stability of an equilibrium outcome are supposed to hold (e.g., Vives 1999, ch. 2).

[12] Even though the regulator may have many instruments at hand to collect data on the industry, its information usually remains imperfect. This problem is particularly severe in the bottleneck part. Conversely, in the downstream market firms sell a homogeneous good whose costs are likely to be correlated. Hence, the regulator can extract all relevant information at low cost.

[13] See, e.g., the European Directives 2009/72/EC and 2009/73/EC for the electricity and natural gas markets. Section 7.1 extends our results to the case where firm 1 is informed.

information. As we show later, this mitigates the regulator's incentive problem and therefore improves social welfare.

We illustrate the result in Proposition 2 with the help of Figure 1. Exactly as ownership separation, the regime of legal separation requires that the provision of upstream and downstream services must be stand-alone profitable and only upstream operations are regulated. This implies that, for any given downstream output, legal separation allows the monopolist to benefit from the same increase $\Delta\pi_u(\widehat{c}_u, c_u) \equiv \pi_u(\widehat{c}_u, c_u) - \pi_u(c_u) > 0$ in upstream profits due to cost exaggeration (i.e., $\widehat{c}_u > c_u$) as ownership separation.[14] On the other hand, the downstream profits of the parent company (firm 1) decrease with declared costs, since the more expensive access charge reduces the downstream price-cost markup, which entails $\Delta\pi_1(\widehat{c}_u, c_u) \equiv \pi_1(\widehat{c}_u) - \pi_1(c_u) < 0$.

The result of the trade-off between upstream gains and downstream losses is that, relative to ownership separation, the regime of legal separation shrinks the cost interval where cost exaggeration makes the monopolist better off, i.e., $\widehat{c}_u \in (c_u, c_u^*(.,.)] \subseteq (c_u, c_u^+]$. A higher misreport than the upper bound $c_u^*(.,.)$ does not pay off, since profits in (2) diminish.

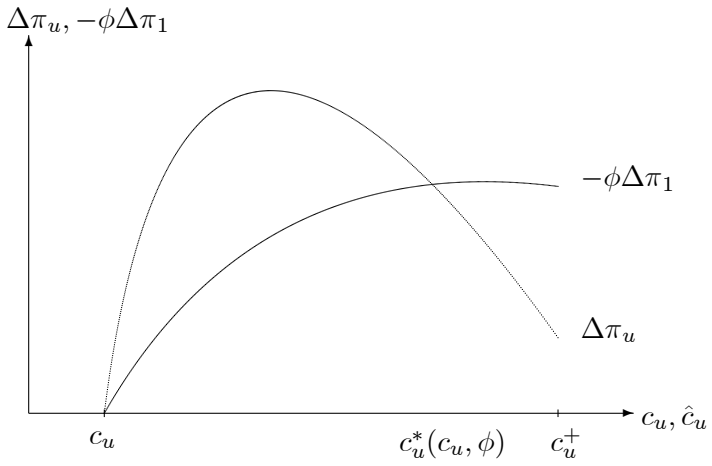

Figure 1: Incentive to manipulate information under legal separation

The threshold value $c_u^*(.,.)$ decreases with the weight ϕ the monopolist attaches to firm 1's profits. A higher ϕ induces a larger internalization of the downstream losses from cost exaggeration, which reduces the interval $(c_u, c_u^*(.,.)]$ of cost misreport.[15]

5.2. Optimal regulation and welfare comparison

Invoking the revelation principle (e.g., Myerson 1979), we can restrict attention to direct incentive compatible mechanisms which induce truthful information revelation. Consequently, the

[14] Regulated upstream profits are typically concave in declared costs. This is because cost exaggeration increases upstream profits via a higher access price but induces downstream firms to reduce their output, which makes this strategy less appealing for high-cost declarations.

[15] Notice from Figure 1 that the legally separated monopolist does not have any incentive to understate its costs, namely, to declare $\widehat{c}_u < c_u$, since the loss in upstream activities more than compensates the gain in downstream activities.

regulator designs a contract menu $\{a(c_u), T(c_u)\}$ which ensures that the monopolist with costs c_u will select the policy targeted at its type. Under ownership separation, incentive compatibility implies

$$c_u = \arg\max_{\widehat{c}_u} \pi_u(\widehat{c}_u, c_u) = \arg\max_{\widehat{c}_u} \ (a(\widehat{c}_u) - c_u) Q(\widehat{c}_u) + T(\widehat{c}_u),$$

where the second equality follows from (1). Combining terms yields

$$c_u = \arg\max_{\widehat{c}_u} \pi_u(\widehat{c}_u) + (\widehat{c}_u - c_u) Q(\widehat{c}_u),$$

where $\pi_u(\widehat{c}_u) = (a(\widehat{c}_u) - \widehat{c}_u) Q(\widehat{c}_u) + T(\widehat{c}_u)$ by (1). Taking the first-order condition yields $\frac{\partial \pi_u(c_u)}{\partial c_u} = -Q(c_u)$. Integrating by parts, we find after some manipulation

$$\pi_u(c_u) = \pi_u\left(c_u^+\right) + \int_{c_u}^{c_u^+} Q(\widetilde{c}_u)\, d\widetilde{c}_u, \tag{4}$$

which characterizes the incentive compatibility condition under ownership separation.

Using (2), under legal separation a regulatory policy is incentive compatible if and only if

$$c_u = \arg\max_{\widehat{c}_u} \pi_u(\widehat{c}_u, c_u) + \phi\pi_1(\widehat{c}_u) = \arg\max_{\widehat{c}_u} \pi_u(\widehat{c}_u) + (\widehat{c}_u - c_u) Q(\widehat{c}_u) + \phi\pi_1(\widehat{c}_u),$$

where $\pi_1(\widehat{c}_u)$ is firm 1's second-stage downstream profit which stems from a report $\widehat{c}_u$. Taking the first-order condition yields $\frac{\partial \pi_u(c_u)}{\partial c_u} = -Q(c_u) - \phi\frac{\partial \pi_1(c_u)}{\partial c_u}$. After integrating by parts, we find the following incentive compatibility condition under legal separation

$$\pi_u(c_u) = \pi_u\left(c_u^+\right) + \int_{c_u}^{c_u^+} Q(\widetilde{c}_u)\, d\widetilde{c}_u + \phi\left(\pi_1\left(c_u^+\right) - \pi_1(c_u)\right), \tag{5}$$

where the bracketed expression is negative since higher access costs result in a lower downstream price-cost markup and therefore lower downstream profits.[16]

Consider a transfer scheme $T = \pi_u - (a - c_u) Q$, which ensures the monopolist a fixed payment π_u and extracts its net revenues $(a - c_u) Q$ from the downstream market.[17] We know from the analysis of the benchmark case of complete information that this transfer scheme induces the regime of legal separation to yield the same second-stage downstream output $Q(a)$ as under ownership separation. Notice that, for any output $Q(a)$, the incentive constraint in (5) under legal separation provides the upstream monopolist with lower (socially costly) informational rents than the incentive constraint in (4) under ownership separation.

[16] We refer to the proof of Proposition 3 for technical details.

[17] This transfer scheme seems to be in line with some practical regulatory policies, which endow the regulated firm with transfers that take into account the revenues from the marketplace. For instance, with rate-of-return regulation, the firm is subsidized whenever the revenues from the marketplace do not allow it to achieve the authorized return.

This discussion leads to our main result, which is formalized in the following proposition.

Proposition 3 *Under asymmetric information, the regime of legal separation yields higher expected welfare than ownership separation.*

We know from Proposition 2 that legal separation generates countervailing incentives, which weakens the monopolist's interest in cost manipulation. Since the incentive constraint in (5) is less severe than the incentive constraint in (4), the informational costs of the regulatory policy implementation decrease under legal separation, which improves social welfare.[18]

The following proposition shows a further result of some interest.

Proposition 4 *The social benefit of legal separation increases with the degree of internalization of downstream profits.*

When the monopolist is only concerned about upstream profits ($\phi = 0$), legal separation provides the same incentive to manipulate information as ownership separation (the incentive constraints in (4) and (5) coincide). A larger internalization of downstream profits (higher ϕ) relaxes the incentive condition in (4) and therefore improves social welfare. The benefit of legal separation is maximized when the monopolist perfectly internalizes joint profits ($\phi = 1$).

It is now helpful to compare the patterns of legal separation and full vertical integration. We summarize our results in the following proposition.

Proposition 5 *Under asymmetric information, the regime of legal separation can generate higher expected welfare than full vertical integration if the degree of internalization of downstream profits is high enough and informational unbundling applies.*

A vertically integrated firm constitutes a unique entity whose profits are entirely regulated. Legal separation differs in some relevant aspects. We know that this regime creates countervailing incentives to manipulate costs, which are stronger when the upstream monopolist internalizes to a larger extent the profits of the downstream parent company. This effect is also more pronounced in the presence of informational unbundling, namely, when the downstream parent company does not know the upstream costs.[19] However, legal separation reduces the scope for profit extraction, since only upstream profits are regulated rather than the firm's full profits. The result of the trade-off between countervailing incentives and profit extraction is that, if the degree of internalization of downstream profits is high enough and informational unbundling applies, legal separation can dominate full vertical integration.

We are aware that regulatory experiences with legal separation have been so far ambiguous. Our analysis suggests the regime of legal separation as a potentially valuable institutional response to regulatory informational problems and identifies the conditions for its benefits to apply.

[18] While the choice of a transfer scheme $T = \pi_u - (a - c_u)\, Q$ does not affect the outcome under ownership separation, the regulator might find different transfer payments which generate higher welfare under legal separation. In this case, the result of welfare superiority of this regime stated in Proposition 3 would be strengthened. Significantly, if the regulator chooses a payment which is not contingent on the revenues from the marketplace, such as a fixed component of a two-part tariff, our qualitative conclusions carry over (see Proposition 9 in Section 7.3).

[19] In Section 7.1 we show that, if the downstream parent company is informed about the real upstream costs, legal separation still generates countervailing incentives, even though they are weaker.

6. Examples of regulatory policies

Using explicit functional forms, we now show how the institutional regime affects the optimal regulatory policies. The (inverse) demand function in the downstream market is given by $p(Q) = \alpha - \beta Q$, where Q denotes the downstream total quantity and $\alpha, \beta > 0$ are positive parameters. The consumer surplus (net of prices) is

$$V(Q) = \frac{1}{2}\beta Q^2. \tag{6}$$

A monopolist with profits in (1) operates in the upstream part of the industry. Two downstream firms compete in quantities. The profit of firm $i = 1, 2$ is

$$\pi_i = (p(Q) - c - a) q_i, \tag{7}$$

where $q_1 + q_2 \equiv Q$. The unit profit of each firm is the difference between the net revenue from the marketplace $p - c$ and the access price a.

The regulator is directed to maximize

$$W \equiv V - T, \tag{8}$$

which reflects the consumer surplus net of transfers to the monopolist. Notice that (8) is the social welfare function specified in (3) with zero weight on profits ($\gamma = 0$).[20]

Under ownership separation, the monopolist considers the upstream profits π_u in (1). A legally separated monopolist maximizes profits $\pi_u + \phi\pi_1$ in (2), while the downstream parent company (firm 1) internalizes joint profits $\pi_u + \pi_1$ in (1) and (7).

6.1. Complete information

Using from (1) a transfer $T = \pi_u - (a - c_u) Q$, the second-stage Cournot competition outcome under both regimes is given by

$$Q(a) = \frac{2}{3\beta}(\alpha - c - a). \tag{9}$$

Substituting (9) into (8), after some manipulation the regulator's objective becomes

$$\max_{\{a, \pi_u\}} \frac{2}{9\beta}(\alpha - c - a)^2 + \frac{2}{3\beta}(a - c_u)(\alpha - c - a) - \pi_u \quad s.t. \quad \pi_u \geq 0.$$

[20] A positive profit weight leaves our qualitative results unaffected. Analogously, a formulation that includes the shadow cost of public funds which captures distortionary taxation (e.g., Laffont and Tirole 1986) provides the same qualitative conclusions (Armstrong and Sappington 2007).

As discussed in Section 3, regulated activities must be viable per se. We summarize the main features of the regulatory policy in the following lemma.

Lemma 1 *Under complete information, the regimes of legal separation and ownership separation entail the same regulatory mechanism, i.e.,* $a = c_u + \frac{1}{4}(\alpha - c - c_u)$ *and* $\pi_u = 0$. *This yields* $p = c + c_u + \frac{1}{2}(\alpha - c - c_u)$.

The (net) consumer surplus objective in (8) induces the regulator to find a balance between allocative efficiency and subsidization of the monopolist, by minimizing profits which represent a mere welfare loss. The access price a is set above the marginal cost c_u ($\alpha - c - c_u > 0$) in order to reduce the amount of transfers to the monopolist, which breaks even in its regulated activities.[21] This results in some allocative inefficiency in the downstream market, since the final price is higher than the total marginal costs $c + c_u$.

6.2. Asymmetric information

Substituting (9) into (8), after some manipulation the regulator's problem is

$$\max_{\{a(c_u),\pi_u(c_u)\}} \int_{c_u^-}^{c_u^+} \left[\frac{2}{9\beta}(\alpha - c - a(c_u))^2 + \frac{2}{3\beta}(a(c_u) - c_u)(\alpha - c - a(c_u)) - \pi_u(c_u) \right] dF(c_u) \tag{10}$$

$$s.t. \quad \pi_u(c_u) \geq 0; \quad \pi_u(c_u) \geq \pi_u(\widehat{c}_u, c_u), \text{ for any } c_u, \widehat{c}_u \in \left[c_u^-, c_u^+\right].$$

The first constraint ensures that the upstream monopolist at least breaks even in its regulated activities. The second constraint requires incentive compatibility, which implies that the monopolist with costs c_u must at least obtain what it would get by reporting any other cost $\widehat{c}_u$.

The following proposition summarizes the main features of the regulatory policy under ownership separation.

Proposition 6 *Under asymmetric information, the regime of ownership separation yields*

$$\begin{aligned} a^{os} &= c_u + \frac{1}{4}(\alpha - c - c_u) + \frac{3}{4}H(c_u) \\ \pi_u^{os} &= \frac{1}{2\beta}\int_{c_u}^{c_u^+} (\alpha - c - \widetilde{c}_u - H(\widetilde{c}_u))\, d\widetilde{c}_u \\ p^{os} &= c + c_u + \frac{1}{2}(\alpha - c - c_u) + \frac{1}{2}H(c_u), \end{aligned} \tag{11}$$

where $H(c_u) \equiv \frac{F(c_u)}{F'(c_u)} \geq 0$.[22]

The optimal regulatory mechanism under ownership separation reflects the usual trade-off between allocative efficiency and rent extraction in the presence of asymmetric information.

[21] The transfer is indeed negative, namely, the monopolist pays taxes to the regulator.

[22] The hazard rate $H(c_u)$ is increasing in c_u. This standard assumption ensures the implementability of the regulatory policy.

The input price is set above its complete information level in order to reduce the total quantity produced and thereby the monopolist's informational rents. This clearly translates into an upward distortion for the final price.

Next, we derive the main features of the regulatory policy under legal separation.

Proposition 7 *Under asymmetric information, the regime of legal separation yields*

$$a^{ls} = c_u + \frac{1-\phi}{4-\phi}(\alpha - c - c_u) + \frac{3}{4-\phi}H(c_u)$$

$$\pi_u^{ls} = \frac{2}{\beta(4-\phi)^2}\int_{c_u}^{c_u^+}(\alpha - c - \widetilde{c}_u - H(\widetilde{c}_u))\left(4 - 2\phi - \phi H'(\widetilde{c}_u)\right)d\widetilde{c}_u \tag{12}$$

$$p^{ls} = c + c_u + \frac{2-\phi}{4-\phi}(\alpha - c - c_u) + \frac{2}{4-\phi}H(c_u).$$

We know from Proposition 2 that the regime of legal separation generates countervailing incentives to manipulate costs. Moreover, the incentive constraint in (5) under legal separation is less severe than the incentive constraint in (4) under ownership separation. This relaxes the implementation problem, and thereby the regulator can enforce a lower access price than under ownership separation, i.e., $a^{ls} < a^{os}$. As a result, legal separation also allows a reduction in downstream prices, i.e., $p^{ls} < p^{os}$.

The access price (and therefore the final price) decreases with ϕ. For $\phi = 0$, the legally separated monopolist is only concerned about upstream profits, exactly as under the regime of ownership separation. Consequently, the two institutional patterns yield the same regulatory policy. A higher internalization of downstream profits (higher ϕ) strengthens countervailing incentives, which allows the regulator to reduce the access charge.

Taking the expectation of (11) and (12),[23] and integrating by parts yields

$$E[\pi_u^{os}] = \frac{1}{2\beta}\int_{c_u^-}^{c_u^+}(\alpha - c - c_u - H(c_u))F(c_u)\,dc_u$$

$$E\left[\pi_u^{ls}\right] = \frac{2}{\beta(4-\phi)^2}\int_{c_u^-}^{c_u^+}(\alpha - c - c_u - H(c_u))\left(4 - 2\phi - \phi H'(c_u)\right)F(c_u)\,dc_u.$$

Combining terms implies

$$E[\pi_u^{os}] - E\left[\pi_u^{ls}\right] = \frac{\phi}{2\beta(4-\phi)^2}\int_{c_u^-}^{c_u^+}(\alpha - c - c_u - H(c_u))\left(\phi + 4H'(c_u)\right)F(c_u)\,dc_u > 0,$$

where the inequality follows since the two bracketed expressions in the integrand are positive.[24] Legal separation alleviates the incentive problem, which allows the regulator to distribute lower expected informational rents.

[23] Notice that π_u^{ls} in (12) is typically decreasing in c_u. This is true for any $\phi \in [0,1]$ if $H' < 2$, which is satisfied by commonly used distribution functions (e.g., the uniform and power distributions).

[24] Positive output and increasing hazard rate respectively ensure that the two expressions are positive.

7. Robustness and extensions

We now discuss the robustness of our results to some relevant assumptions.

7.1. Informational unbundling

Throughout the paper, we assume that the downstream parent company does not know the real upstream costs of the legally separated monopolist. Even though most jurisdictions establish strict rules on informational unbundling, these provisions may not be able to effectively hinder information flows. Using the setting in Section 6, we show that the result of welfare superiority of legal separation stated in Proposition 3 carries over in this scenario.

Proposition 8 *Suppose that the downstream parent company knows the costs* $c_u \in [c_u^-, c_u^+]$ *of the legally separated monopolist. Then, the welfare generated under legal separation decreases. However, this regime still yields higher welfare than ownership separation.*

In the absence of informational unbundling, the downstream parent company internalizes the upstream profit increase from cost manipulation.[25] This induces higher production and therefore mitigates the negative externality on downstream profits due to the manipulation of upstream costs. Even though they are weaker, countervailing incentives still operate since cost exaggeration results in a higher access charge, which reduces the downstream price-cost markup. Consequently, legal separation dominates ownership separation.

7.2. An alternative form of legal separation

Following Höffler and Kranz (2011a, 2011b), the legally separated upstream monopolist is owned by a downstream firm. This setup characterizes several regulations in the US and Europe that adopt legal separation. A relevant alternative, which is investigated in Cremer et al. (2006) and Sibley and Weisman (1998), prescribes the reverse pattern, namely, the downstream firm is owned by the upstream monopolist. This was the former regime in the US telecommunications sector, where the Regional Bell Operating Companies were obliged to legally separate the long-distance call business.[26] An analysis of this case also deserves some discussion. Notice that the second-stage outcome in (9) is unchanged. On the other hand, the monopolist now acts to maximize joint profits, namely, profits in (2) with $\phi = 1$. Using the result in Proposition 4, we can conclude that this alternative form of legal separation reinforces the beneficial effect of such a regime, since it induces the monopolist to fully internalize the negative impact of its strategic behavior on downstream profits.

7.3. Regulatory instruments

In line with the optimal regulation literature, we assume that transfers may be made available to the monopolist. Nevertheless, transfers financed through public funds are sometimes unfeasible,

[25] Since the downstream output also reflects real costs and, in case of cost manipulation, diverges from what the regulator anticipates (i.e., $Q(\widehat{c}_u, c_u) \neq Q(\widehat{c}_u)$), this case is relevant when the monopolist cannot be punished for its misreport.

[26] See Section 272 of the Telecommunications Act of 1996.

which implies that the regulator is endowed with a single instrument, i.e., the access price. Moreover, the access charge may be a two-part tariff, composed of a unit price and a fixed payment. Using the setting in Section 6, the following proposition indicates that our results apply in these alternative environments.

Proposition 9 *Suppose that the regulatory policy only specifies an access charge, which may consist of a two-part tariff. Then, the regime of legal separation still provides the upstream monopolist with countervailing incentives to manipulate costs.*

The rationale for this conclusion reflects the result in Proposition 2. The exaggeration of upstream costs inflates the access charge, which translates into higher upstream profits but penalizes downstream profits. Consequently, legal separation generates countervailing incentives that are welfare beneficial.

7.4. Downstream competition

In the analysis, we suppose quantity competition in the downstream market, which is consistent with the features of some relevant network industries, such as natural gas. Significantly, this assumption is not crucial for our results. Nothing substantial would change with price competition. For our aims, it is sufficient that downstream firms make positive profits,[27] otherwise the monopolist's internalization of downstream profits would be inconsequential.

Vertically related markets are sometimes characterized by a pre-existing incumbent (the monopolist before liberalization) which competes (in quantities) with one or more new entrants.[28] A natural way to model this environment is Stackelberg (quantity) competition where the incumbent is the first mover. Using the setting in Section 6, the second-stage output becomes $Q^s(a) = \frac{3}{4\beta}(\alpha - c - a)$, which is higher than the Cournot output in (9). Welfare is expected to be larger under both institutional patterns, but our qualitative results are clearly unaffected.

8. Concluding remarks

In this paper we have dealt with the problem of how to design the institutional structure of vertically related markets in the presence of a regulated monopolist upstream input and competitive downstream activities. Despite its importance for the liberalization process, this issue has so far played a minor role in the economic literature.

In practice, two main institutional patterns have been recently implemented as alternatives to the classical full vertical integration. The regime of ownership separation entails full unbundling between upstream and downstream operations. Conversely, legal separation allows a downstream firm to own the upstream monopolist but requires the two entities to be legally unbundled so that the provision of each service is stand-alone profitable and only upstream activities are regulated. We have shown that under regulatory limited information about upstream costs the regime of legal separation creates countervailing incentives to manipulate information.

[27] For instance, this is the case of price competition with asymmetric costs or differentiated good competition. Room for positive profits is a natural feature of recently liberalized markets.

[28] Dixon and Easaw (2001) show that British Gas has retained the first mover and pre-entry advantage following the liberalization process.

This mitigates the regulator's problem and reduces the social costs of policy implementation. The social benefit of legal separation is maximized when the upstream affiliate perfectly internalizes the profits of the parent company. Interestingly, legal separation can also dominate full vertical integration if the upstream affiliate's degree of internalization of downstream profits is high enough and the parent company does not know the upstream costs (informational unbundling). We have also derived the main features of the optimal regulatory policy.

Our results suggest legal separation as a potentially valuable institutional pattern in the presence of regulatory limited information. We believe that our insights can shed some light on other related issues, such as merger policies involving regulated and unregulated firms.

Appendix

Proof of Proposition 2. Using (1), the difference in upstream profits which stems from a report $\widehat{c}_u$ instead of the real cost c_u is

$$\Delta\pi_u\left(\widehat{c}_u, c_u\right) \equiv \pi_u\left(\widehat{c}_u, c_u\right) - \pi_u\left(c_u\right) = \left(a\left(\widehat{c}_u\right) - c_u\right) Q\left(\widehat{c}_u\right) + T\left(\widehat{c}_u\right) - \pi_u\left(c_u\right).$$

If the complete information policy is implemented despite the problem of asymmetric information, i.e., $\left\{a\left(\widehat{c}_u\right), T\left(\widehat{c}_u\right)\right\}$ with $T\left(\widehat{c}_u\right) = \pi_u\left(\widehat{c}_u\right) - \left(a\left(\widehat{c}_u\right) - \widehat{c}_u\right) Q\left(\widehat{c}_u\right)$ by (1), we have

$$\Delta\pi_u\left(\widehat{c}_u, c_u\right) = \pi_u\left(\widehat{c}_u\right) + \left(\widehat{c}_u - c_u\right) Q\left(\widehat{c}_u\right) - \pi_u\left(c_u\right) = \left(\widehat{c}_u - c_u\right) Q\left(\widehat{c}_u\right),$$

where the second equality follows since any firm which declares its real costs obtains zero profits, i.e., $\pi_u\left(\widehat{c}_u\right) = \pi_u\left(c_u\right) = 0$. Notice that $\Delta\pi_u\left(\widehat{c}_u, c_u\right) > 0$ for any $\widehat{c}_u \in \left(c_u, c_u^+\right]$. Taking the second derivative with respect to $\widehat{c}_u$ yields $\frac{\partial^2 \Delta\pi_u(\widehat{c}_u, c_u)}{\partial \widehat{c}_u^2} = 2\frac{\partial Q(\widehat{c}_u)}{\partial \widehat{c}_u} + \left(\widehat{c}_u - c_u\right)\frac{\partial^2 Q(\widehat{c}_u)}{\partial \widehat{c}_u^2}$. Sufficient conditions for $\frac{\partial^2 \Delta\pi_u(\widehat{c}_u, c_u)}{\partial \widehat{c}_u^2} < 0$ when $\widehat{c}_u > c_u$ are $\frac{\partial Q(\widehat{c}_u)}{\partial \widehat{c}_u} < 0$ and $\frac{\partial^2 Q(\widehat{c}_u)}{\partial \widehat{c}_u^2}$ small enough.[29] The difference in firm 1's downstream profits from a report $\widehat{c}_u$ instead of the real cost c_u is

$$\Delta\pi_1\left(\widehat{c}_u, c_u\right) \equiv \pi_1\left(\widehat{c}_u\right) - \pi_1\left(c_u\right) = \left(p\left(Q\left(\widehat{c}_u\right)\right) - a\left(\widehat{c}_u\right)\right) q_1\left(\widehat{c}_u\right) - C\left(q_1\left(\widehat{c}_u\right)\right) - \pi_1\left(c_u\right).$$

Taking the derivative with respect to $\widehat{c}_u$ yields after some manipulation

$$\begin{aligned}
\frac{\partial \Delta\pi_1\left(\widehat{c}_u, c_u\right)}{\partial \widehat{c}_u} &= \left(\frac{\partial p}{\partial Q}\frac{\partial Q\left(\widehat{c}_u\right)}{\partial \widehat{c}_u} - \frac{\partial a\left(\widehat{c}_u\right)}{\partial \widehat{c}_u}\right) q_1\left(\widehat{c}_u\right) + \left(p\left(Q\left(\widehat{c}_u\right)\right) - C'\left(q_1\left(\widehat{c}_u\right)\right) - a\left(\widehat{c}_u\right)\right)\frac{\partial q_1\left(\widehat{c}_u\right)}{\partial \widehat{c}_u} \\
&= \left(\frac{\partial p}{\partial Q}\frac{\partial Q\left(\widehat{c}_u\right)}{\partial \widehat{c}_u} - \frac{\partial a\left(\widehat{c}_u\right)}{\partial \widehat{c}_u} - \frac{\partial p}{\partial Q}\frac{\partial q_1\left(\widehat{c}_u\right)}{\partial \widehat{c}_u}\right) q_1\left(\widehat{c}_u\right),
\end{aligned}$$

where the second equality follows from the first-order condition for q_1 in firm 1's profit maximization problem which yields $p - C' - a = -\frac{\partial p}{\partial Q} q_1$. We have $\frac{\partial \Delta\pi_1(\widehat{c}_u, c_u)}{\partial \widehat{c}_u} < 0$ for $\frac{\partial q_1(\widehat{c}_u)}{\partial \widehat{c}_u} < 0$ and $\frac{\partial p}{\partial Q}\frac{\partial Q(\widehat{c}_u)}{\partial \widehat{c}_u} - \frac{\partial a(\widehat{c}_u)}{\partial \widehat{c}_u} < 0$.[30] Since $\Delta\pi_1\left(\widehat{c}_u, c_u\right) = 0$ for $\widehat{c}_u = c_u$, we have $\Delta\pi_1\left(\widehat{c}_u, c_u\right) < 0$ for any $\widehat{c}_u \in \left(c_u, c_u^+\right]$. As $\Delta\pi_u\left(\widehat{c}_u, c_u\right) = \Delta\pi_1\left(\widehat{c}_u, c_u\right) = 0$ for $\widehat{c}_u = c_u$, if $\Delta\pi_u\left(\widehat{c}_u, c_u\right)$ is more concave in $\widehat{c}_u$ than $-\phi\Delta\pi_1\left(\widehat{c}_u, c_u\right)$,[31] then there exists a unique value $c_u^*\left(c_u, \phi\right) \in \left(c_u, c_u^+\right]$ such

[29] We find from Lemma 1 that $\frac{\partial Q(\widehat{c}_u)}{\partial \widehat{c}_u} = -\frac{1}{2\beta} < 0$ and $\frac{\partial^2 Q(\widehat{c}_u)}{\partial \widehat{c}_u^2} = 0$.

[30] We find from Lemma 1 that $\frac{\partial q_1(\widehat{c}_u)}{\partial \widehat{c}_u} = -\frac{1}{4\beta} < 0$ and $\frac{\partial p}{\partial Q}\frac{\partial Q(\widehat{c}_u)}{\partial \widehat{c}_u} - \frac{\partial a(\widehat{c}_u)}{\partial \widehat{c}_u} = \frac{1}{2} - \frac{3}{4} < 0$.

[31] We find from Lemma 1 that $\left|\frac{\partial^2 \Delta\pi_u(\widehat{c}_u, c_u)}{\partial \widehat{c}_u^2}\right| = \frac{1}{\beta} > \frac{\phi}{8\beta} = \phi\left|-\frac{\partial^2 \Delta\pi_1(\widehat{c}_u, c_u)}{\partial \widehat{c}_u^2}\right|$ for any $\phi \in [0, 1]$.

that $\Delta\pi_u(\widehat{c}_u, c_u) + \phi\Delta\pi_1(\widehat{c}_u, c_u) \geq 0$ for $\widehat{c}_u \in (c_u, c_u^*(c_u, \phi)] \subseteq (c_u, c_u^+]$. Since $-\phi\Delta\pi_1(\widehat{c}_u, c_u)$ increases with ϕ, then $c_u^*(c_u, \phi)$ decreases with ϕ. ■

Proof of Proposition 3. The regulator's problem is to maximize W in (3) subject to the participation constraints of all firms and the incentive compatibility constraint of the monopolist, which is given by (4) under ownership separation and by (5) under legal separation. With a policy $\{a(c_u), T(c_u)\}$, where $T = \pi_u - (a - c_u)Q$ by (1), the two regimes yield the same second-stage outcome $Q(a)$. Firm 1's second-stage maximization problem entails $\frac{\partial\pi_1(c_u)}{\partial c_u} = \left(\frac{\partial p}{\partial Q}\frac{\partial Q(c_u)}{\partial c_u} - \frac{\partial a(c_u)}{\partial c_u} - \frac{\partial p}{\partial Q}\frac{\partial q_1(c_u)}{\partial c_u}\right) q_1(c_u) < 0$, where the inequality follows since $\frac{\partial q_1(c_u)}{\partial c_u} < 0$ and $\frac{\partial p}{\partial Q}\frac{\partial Q(c_u)}{\partial c_u} - \frac{\partial a(c_u)}{\partial c_u} < 0$ at the optimum.[32] Since the incentive constraint in (5) is less severe than the incentive constraint in (4), legal separation can replicate the outcome under ownership separation at lower costs in terms of informational rents and therefore improves (expected) social welfare. ■

Proof of Proposition 4. The proof of Proposition 3 reveals that the bracketed expression in (5) is negative. Hence, a higher ϕ relaxes the incentive constraint under legal separation. The social benefit of legal separation increases with ϕ and is maximized for $\phi = 1$. ■

Proof of Proposition 5. The profit of a vertically integrated firm which declares costs $\widehat{c}_u$ rather than its real costs c_u is

$$\begin{aligned}
\pi_v(\widehat{c}_u, c_u) &= (a(\widehat{c}_u) - c_u) Q(\widehat{c}_u, c_u) + T(\widehat{c}_u) + (p(Q(\widehat{c}_u, c_u)) - a(\widehat{c}_u)) q_v(\widehat{c}_u, c_u) - C(q_v(\widehat{c}_u, c_u)) \\
&= \pi_v(\widehat{c}_u) + a(\widehat{c}_u)(Q(\widehat{c}_u, c_u) - Q(\widehat{c}_u)) + \widehat{c}_u Q(\widehat{c}_u) - c_u Q(\widehat{c}_u, c_u) \\
&\quad + p(Q(\widehat{c}_u, c_u)) q_v(\widehat{c}_u, c_u) - p(Q(\widehat{c}_u)) q_v(\widehat{c}_u) + C(q_v(\widehat{c}_u)) \\
&\quad - C(q_v(\widehat{c}_u, c_u)) - a(\widehat{c}_u)(q_v(\widehat{c}_u, c_u) - q_v(\widehat{c}_u)).
\end{aligned}$$

A policy $\{a(c_u), T(c_u)\}$ is incentive compatible if and only if $c_u = \arg\max_{\widehat{c}_u} \pi_v(\widehat{c}_u, c_u)$. Taking the first-order condition yields after some manipulation

$$\begin{aligned}
\left.\frac{\partial\pi_v(\widehat{c}_u, c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u = c_u} &= 0 = \frac{\partial\pi_v(c_u)}{\partial c_u} + Q(c_u) + \left(a(c_u) - c_u + \frac{\partial p}{\partial Q} q_v(c_u)\right) \\
&\quad \times \left(\left.\frac{\partial Q(\widehat{c}_u, c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u = c_u} - \frac{\partial Q(c_u)}{\partial c_u}\right) + \left(p(Q(c_u)) - C'(q_v(c_u)) - a(c_u)\right) \\
&\quad \times \left(\left.\frac{\partial q_v(\widehat{c}_u, c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u = c_u} - \frac{\partial q_v(c_u)}{\partial c_u}\right).
\end{aligned}$$

Since $p - C'(q_v) - a = -\left(a - c_u + \frac{\partial p}{\partial Q} q_v\right)$ from the first-order condition for q_v in the second-stage, we obtain

$$\left.\frac{\partial\pi_v(\widehat{c}_u, c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u = c_u} = \frac{\partial\pi_v(c_u)}{\partial c_u} + Q(c_u) + \Psi(c_u) = 0,$$

where $\Psi(c_u) \equiv \left(p(Q(c_u)) - C'(q_v(c_u)) - a(c_u)\right) \sum_{h=2}^{n} \left(\frac{\partial q_h(c_u)}{\partial c_u} - \left.\frac{\partial q_h(\widehat{c}_u, c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u = c_u}\right)$.[33] Inte-

[32] The second condition requires the price to increase with upstream costs less than the access charge, which is ensured by downstream competition (see also the proof of Proposition 2).

[33] Without loss of generality, firm 1 is the downstream division of the vertically integrated company.

grating by parts yields

$$\pi_v(c_u) = \pi_v\left(c_u^+\right) + \int_{c_u}^{c_u^+} Q(\widetilde{c}_u)\, d\widetilde{c}_u + \int_{c_u}^{c_u^+} \Psi(\widetilde{c}_u)\, d\widetilde{c}_u = \int_{c_u}^{c_u^+} Q(\widetilde{c}_u)\, d\widetilde{c}_u + \int_{c_u}^{c_u^+} \Psi(\widetilde{c}_u)\, d\widetilde{c}_u, \quad (13)$$

where $\pi_v\left(c_u^+\right) = 0$ at the optimum since regulated profits are socially costly.

Under legal separation (with informational unbundling), a policy $\{a(c_u), T(c_u)\}$ is incentive compatible if and only if $\pi_u(c_u) = \int_{c_u}^{c_u^+} Q(\widetilde{c}_u)\, d\widetilde{c}_u + \phi\left(\pi_1\left(c_u^+\right) - \pi_1(c_u)\right)$, where $\pi_u\left(c_u^+\right) = 0$ at the optimum (see (5)). Manipulating terms yields

$$\pi_u(c_u) + \pi_1(c_u) = \pi_1\left(c_u^+\right) + \int_{c_u}^{c_u^+} Q(\widetilde{c}_u)\, d\widetilde{c}_u - (1-\phi)\left(\pi_1\left(c_u^+\right) - \pi_1(c_u)\right), \quad (14)$$

where the bracketed expression is negative as downstream profits decrease with access costs. Integrating by parts (13) and (14), we find that a given access charge $a(c_u)$, which determines the same second-stage outcome $Q(a)$ under the two regimes, yields lower expected profits under legal separation if and only if

$$\int_{c_u^-}^{c_u^+} \Psi(c_u) F(c_u)\, dc_u > \pi_1\left(c_u^+\right) - (1-\phi)\int_{c_u^-}^{c_u^+} \frac{\partial \pi_1(c_u)}{\partial c_u} F(c_u)\, dc_u. \quad (15)$$

Common linearity assumptions ensure $\Psi(c_u) > 0$.[34] As $\frac{\partial \pi_1(c_u)}{\partial c_u} < 0$, a higher ϕ relaxes condition (15), so that for $\pi_1\left(c_u^+\right)$ sufficiently low there exists a threshold value $\phi^* \in [0,1]$ such that for $\phi > \phi^*$ legal separation dominates full vertical integration. ■

Proof of Proposition 6. Substituting (4) and integrating by parts, the regulator's problem in (10) becomes

$$\max_{\left\{a(c_u), \pi_u\left(c_u^+\right)\right\}} \int_{c_u^-}^{c_u^+} \left[\frac{2}{9\beta}(\alpha - c - a(c_u))^2 + \frac{2}{3\beta}(a(c_u) - c_u)(\alpha - c - a(c_u))\right.$$
$$\left. -\pi_u\left(c_u^+\right) - \frac{2}{3\beta}(\alpha - c - a(c_u)) H(c_u)\right] dF(c_u) \quad s.t. \quad \pi_u\left(c_u^+\right) \geq 0.$$

The maximand decreases with $\pi_u\left(c_u^+\right)$, which implies $\pi_u^{os}\left(c_u^+\right) = 0$ at the optimum. Taking the first-order condition for $a(c_u)$ yields after some manipulation $\alpha - c - 4a(c_u) + 3c_u + 3H(c_u) = 0$, which entails the results of the proposition. ■

Proof of Proposition 7. Substituting (5) into (10) and integrating by parts, the regulator's program is

$$\max_{\left\{a(c_u), \pi_u\left(c_u^+\right)\right\}} \int_{c_u^-}^{c_u^+} \left[\frac{2}{9\beta}(\alpha - c - a(c_u))^2 + \frac{2}{3\beta}(a(c_u) - c_u)(\alpha - c - a(c_u)) - \pi_u\left(c_u^+\right)\right.$$
$$\left. -\frac{2}{3\beta}(\alpha - c - a(c_u)) H(c_u) - \phi\pi_1\left(c_u^+\right) + \frac{\phi}{9\beta}(\alpha - c - a(c_u))^2\right] dF(c_u) \;\; s.t.\; \pi_u\left(c_u^+\right) \geq 0.$$

Since the maximand decreases with $\pi_u\left(c_u^+\right)$, we have $\pi_u^{ls}\left(c_u^+\right) = 0$ at the optimum. Taking the

[34] Using the model in Section 6, we find from the second-stage outcome that $p - c - a = \beta q_2 > 0$ and $\frac{\partial q_2(c_u)}{\partial c_u} - \frac{\partial q_2(\widehat{c}_u, c_u)}{\partial \widehat{c}_u}\Big|_{\widehat{c}_u = c_u} = \frac{1}{3\beta} > 0$.

first-order condition for $a(c_u)$ yields after some computations $(1-\phi)(\alpha-c)-(4-\phi)a(c_u)+3c_u+3H(c_u)=0$, which implies the results of the proposition. ■

Proof of Proposition 8. With a transfer scheme $T=\pi_u-(a-c_u)Q$ by (1), the upstream profit of a legally separated monopolist with costs c_u which reports $\widehat{c}_u$ is $\pi_u(\widehat{c}_u,c_u)=\pi_u(\widehat{c}_u)+(\widehat{c}_u-c_u)Q$. Using (1) and (7), firm 1's profit maximization program in the second stage is given by

$$\max_{q_1}\left(p(Q)-c-a(\widehat{c}_u)\right)q_1+\pi_u(\widehat{c}_u)+(\widehat{c}_u-c_u)(q_1+q_2).$$

Standard computations yield $q_1(\widehat{c}_u,c_u)=\frac{1}{3\beta}(\alpha-c-a(\widehat{c}_u)+2(\widehat{c}_u-c_u))$ and $q_2(\widehat{c}_u,c_u)=\frac{1}{3\beta}(\alpha-c-a(\widehat{c}_u)-\widehat{c}_u+c_u)$. Firm 1's downstream profits are

$$\pi_1(\widehat{c}_u,c_u)=\frac{1}{9\beta}(\alpha-c-a(\widehat{c}_u)-\widehat{c}_u+c_u)(\alpha-c-a(\widehat{c}_u)+2(\widehat{c}_u-c_u)). \tag{16}$$

Since the legally separated monopolist maximizes profits in (2), incentive compatibility requires

$$c_u=\arg\max_{\widehat{c}_u}\pi_u(\widehat{c}_u,c_u)+\phi\pi_1(\widehat{c}_u,c_u)=\arg\max_{\widehat{c}_u}\pi_u(\widehat{c}_u)+(\widehat{c}_u-c_u)Q(\widehat{c}_u,c_u)+\phi\pi_1(\widehat{c}_u,c_u).$$

Taking the first-order condition yields $\frac{\partial\pi_u(c_u)}{\partial c_u}=-Q(c_u)-\phi\left.\frac{\partial\pi_1(\widehat{c}_u,c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u=c_u}$. Integrating by parts, we obtain after some manipulation

$$\pi_u(c_u)=\pi_u\left(c_u^+\right)+\int_{c_u}^{c_u^+}Q(\widetilde{c}_u)\,d\widetilde{c}_u+\phi\int_{c_u}^{c_u^+}\left.\frac{\partial\pi_1(\widehat{c}_u,\widetilde{c}_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u=\widetilde{c}_u}d\widetilde{c}_u. \tag{17}$$

It follows from (16) that

$$\left.\frac{\partial\pi_1(\widehat{c}_u,c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u=c_u}=\frac{1}{9\beta}(\alpha-c-a(c_u))\left(1-2\frac{\partial a(c_u)}{\partial c_u}\right).$$

Using (9), legal separation in the presence of informational unbundling yields $\left.\frac{\partial\pi_1(\widehat{c}_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u=c_u}=-\frac{2}{9\beta}(\alpha-c-a(c_u))\frac{\partial a(c_u)}{\partial c_u}<\left.\frac{\partial\pi_1(\widehat{c}_u,c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u=c_u}$ for a given a. The regulator can distribute lower informational rents for a given access charge, since the incentive condition in (5) is less severe than the incentive condition in (17). Consequently, social welfare decreases in the absence of informational unbundling. Moreover, we find from Proposition 6 that $\frac{\partial a^{os}(c_u)}{\partial c_u}=\frac{3}{4}\left(1+H'\right)>\frac{1}{2}$, which entails $\left.\frac{\partial\pi_1(\widehat{c}_u,c_u)}{\partial\widehat{c}_u}\right|_{\widehat{c}_u=c_u}<0$.[35] Since legal separation can replicate the outcome under ownership separation with the incentive condition in (17) which is less severe than the incentive condition in (4), the former regime still dominates the latter. ■

Proof of Proposition 9. In the absence of a transfer ($T=0$), firm 1's maximization problem in the second stage is given by

$$\max_{q_1}\left(p(Q)-c-a\right)q_1+(a-c_u)(q_1+q_2),$$

[35] Notice that $q_2(c_u)=\frac{1}{3\beta}(\alpha-c-a(c_u))>0$ entails $\alpha-c-a(c_u)>0$.

which yields $q_1(a) = \frac{1}{3\beta}(\alpha - c - 2c_u + a)$ and $q_2(a) = \frac{1}{3\beta}(\alpha - c + c_u - 2a)$. Since total quantity $Q(a) = \frac{1}{3\beta}(2(\alpha - c) - c_u - a)$ decreases in a, a fully-informed regulator which maximizes (8) with $T = 0$ sets $a = c_u$, so that the monopolist breaks even in its regulated activities. If the complete information policy is applied despite the problem of asymmetric information, i.e., $a(\widehat{c}_u) = \widehat{c}_u$, we find after some manipulation $\pi_1(\widehat{c}_u) = \frac{1}{9\beta}(\alpha - c - \widehat{c}_u)^2$, which implies $\frac{\partial \pi_1(\widehat{c}_u)}{\partial \widehat{c}_u} = -\frac{2}{9\beta}(\alpha - c - \widehat{c}_u) < 0$. A legally separated monopolist that exaggerates its costs increases upstream profits but penalizes downstream profits, and therefore countervailing incentives to manipulate information arise.

Consider now a two-part tariff $\{a, P\}$, composed of a unit price a and a lump-sum payment P. Standard techniques imply that the complete information policy is characterized by $a = \frac{1}{2}(\alpha - c + c_u)$ and $P = -\frac{1}{12\beta}(\alpha - c - c_u)^2$. If the regulator implements the complete information policy despite the problem of asymmetric information, we find $\pi_1(\widehat{c}_u) = \frac{1}{12\beta}(\alpha - c - \widehat{c}_u)^2$, which yields $\frac{\partial \pi_1(\widehat{c}_u)}{\partial \widehat{c}_u} = -\frac{1}{6\beta}(\alpha - c - \widehat{c}_u) < 0$. Hence, countervailing incentives to manipulate information still operate under legal separation. ■

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