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Vertical Integration and Sabotage with a Regulated Bottleneck Monopoly

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Vertical integration and sabotage with a regulated bottleneck monopoly*

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Abstract

Consider a bottleneck monopoly that sells "access" at a regulated price and may compete with independent downstream firms through a subsidiary. We systematically study the vertical integration decision and the optimal intensity of sabotage.

The main results are as follows. First, unless the subsidiary is implausibly more efficient than independent firms, vertical integration *never* benefits consumers. Moreover, sabotage may prompt inefficient vertical integration, in which case welfare unambiguously falls.

Second, if the subsidiary and independent firms coexist in equilibrium, the intensity of sabotage increases with the subsidiary's market share and falls with the elasticity of the derived demand for access; only small subsidiaries do not sabotage. And the intensity of sabotage increases with the subsidiary's size and the intensity of economies of scope.

Third, when the bottleneck monopoly optimally excludes rivals, optimal sabotage is determined by a standard Lerner condition augmented to incorporate the direct cost of sabotage. Also, the intensity of sabotage falls with economies of scope and the subsidiary's size.

Keywords: bottleneck monopoly, sabotage, vertical integration, free entry, welfare

JEL classification: L12, L22, L51

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1. Introduction

In many network industries bottleneck monopolies produce inputs for competitive firms and their access charges are regulated.[1] It is well known, however, that price regulation stimulates sabotage—the intentional degrading of quality of service to raise the costs of downstream competitors.[2]

This problem is believed to be important in practice and it has generated a large literature dissecting the determinants of the sabotage decision.[3,4] Seminal contributions by Weisman (1995) and Economides (1998) pointed out many of the determinants of the sabotage decision, but reached seemingly contradictory conclusions. While Weisman's results suggested that the bottleneck monopolist may not have any incentives to discriminate against downstream rivals, Economides's indicated that it may want to go all the way until excluding independent firms altogether.[5] Research by Beard et al. (2001), Bergman (2000), Mandy (2000) and Reiffen (1998) significantly clarified the points at issue. True, the incentives to sabotage are weak or even nonexistent when the access charge is close to the bottleneck monopolist's unregulated optimum or the subsidiary is considerably less efficient than independent firms. But, on the other hand, the bottleneck monopoly will want to sabotage when price regulation constrains its upstream market power. Moreover, as Mandy (2000) reports, the subsidiary would have to be implausibly inefficient to rule out sabotage. Hence, there is no a priory presumption in favor of one or the other—it all depends on the data.

Further research has clarified these issues even more. So by now it is well known that whether sabotage pays depends on several factors: the cost of sabotage (Mandy[2000], Reiffen [1998], Weisman [1995, 1998]); the shape of the downstream cost function (Mandy [2000]); the size of the upstream margin granted by the regulated access charge (Beard et al. [2001], Bergman [2000], Engel et al. [2003], Kondaurova and Weisman [2003], Laffont and Tirole [2000, section 4.5], Mandy [2000], Reiffen [1998], Sand [2004], Weisman [2001]); the subsidiary's market share in the downstream market (Kondaurova and Weisman [2003], Sibley and Weisman [1998a,b], Weisman [1995]); the intensity and type of downstream competition (Mandy [2000, 2001]); and the extent of downstream product differentiation (Kondaurova and Weisman [2003], Mandy and Sappington [2006], Reiffen [1998], Sibley and Weisman [2005], Weisman [1995]).[6]

[1] For example, electricity generators need transmission and distribution facilities to reach retail consumers; ISPs, long distance carriers and mobile phone providers need access to the fixed local loop; and natural gas producers need pipelines to reach retailers.

[2] In the literature sabotage is also known as non-price discrimination. For example, the bottleneck monopoly may impose costly technical requirements to interconnection; delay interconnection adducing "technical problems"; choose closed standards that make some technologies incompatible; degrade the quality of service by inducing periodic breakdowns of service to independent firms; and so on.

[3] For surveys see Mandy (2000) and Sappington (2005, 2006).

[4] For evidence on discrimination see Mini (2001), Reiffen et al. (2000) and Reiffen and Ward (2002).

[5] In any case, Weisman (1995, p.257) was careful to indicate that the no-sabotage result obtains when the bottleneck monopoly's aim is to lower the equilibrium downstream price to stimulate the demand for access.

[6] See Mandy (2000) for a summary.

Also, a central trade off has been identified: sabotage increases profits made downstream, but reduces access charge revenue (Reiffen [1998], Sibley and Weisman [1998a], Weisman [1995]) and may, as Mandy (2000) puts it, "kill the goose that may have laid the golden egg." And there also seems to be a regulatory tradeoff: vertical integration may stimulate sabotage but generates vertical economies of scope.[7] Thus, vertical integration has ambiguous effects on social and consumer welfare (Reiffen [1998], Crew et al. [2005], Sappington [2006]).[8]

This paper aims towards the consolidation of this literature by systematically studying how the decision to integrate and the intensity of sabotage vary with fundamental cost and demand parameters. It is, in essence, a comparative statics exercise which unifies in a single model a number of results that appear in the literature and links both the vertical integration and sabotage decisions with observable market parameters and outcomes. We obtain some new results and show that the intensity of sabotage depends ultimately on two simple, mutually exclusive, conditions: either a relation between the subsidiary's market share and the elasticity of the derived demand for access; or a standard Lerner condition augmented by the direct cost of sabotage. These standard conditions yield approximate quantitative estimates which are helpful to gauge whether sabotage should be a concern in a specific circumstance and industry.

We study a perfectly competitive downstream market with free entry where independent firms with U-shaped average cost curves produce an homogeneous good.[9] A bottleneck monopoly sells access to independent firms at a regulated and exogenous access charge τ, which is greater than marginal cost. It can sabotage independent firms and raise both their cost of entry (i.e. sabotage is akin to a barrier to entry) and their variable cost of production (i.e. sabotage raises rivals' costs). The aim of sabotage is to increase the profits of the bottleneck's monopoly subsidiary. This subsidiary operates m plants that produce each quantity at $1-\eta$ times the cost of an independent plant.[10] Essentially, we make the integration decision endogenous (like Beard et al. [2001]) and study how the incentives to sabotage vary with the subsidiary's size m and vertical economies (or diseconomies) of scope η, this for a given access charge and sabotage cost function.

To begin, we find that vertical integration does not increase consumer welfare in the long run, unless the subsidiary is implausibly more efficient than independent firms.[11] The economics is simple. In a market with free entry price is fixed by the average cost of entrants. If the bottleneck

[7] For a definition of vertical econnomies of scope see Kaserman and Mayo (1991, p. 488).

[8] Beard et al. (2001) show that this regulatory tradeoff can be relaxed if entry into the upstream segment can be successfully promoted.

[9] Quirmbach (1986) also models a perfectly competitive downstream market with free entry, but he is neither concerned about regulated industries nor sabotage.

[10] $\eta > 0$ models vertical economies of scope; $\eta < 0$ models vertical diseconomies of scope.

[11] For example, let the average cost of independent firms be 100. If the elasticity of demand is 2, and the access charge τ increases the cost of independent firms by 20% to 120, then the subsidiary's cost net of access charges would have to be at most 60 (i.e. 40% lower) for vertical integration to benefit consumers. With lower elasticities the cost advantage has to be even larger.

monopoly sabotages, the cost of independent firms and the equilibrium price is higher than with vertical separation. If, on the other hand, the bottleneck monopoly does not sabotage, vertical integration does not affect the equilibrium price—unless, of course, the subsidiary's cost advantage is such that the unconstrained monopoly price is less than the entrant's cost. But this only can occur when the subsidiary's cost advantage is very large. In addition, we also find that sabotage may prompt inefficient vertical integration—a subsidiary with higher costs produces only because the bottleneck monopoly can sabotage. In that case welfare falls unambiguously.

The previous results illustrate a more general point, namely that observed parameters and downstream market structure give information about the likelihood of sabotage and its intensity. Thus, for example, our model confirms the by now well known fact that an unregulated bottleneck monopolist does not sabotage (see Beard et al. [2001], Bergman [2000], Laffont and Tirole [2000, section 4.5], Mandy [2000], Sand [2004]). But we show that the argument of relaxing price regulation in order to prevent sabotage is probably weak. For example, if the elasticity of demand is 1.1, the monopolist's profit-maximizing access charge is 10 times the downstream cost; if the elasticity is 3, the monopolist's profit-maximizing access charge equals 50% of the downstream cost—values which are well beyond the share of access charges in the cost of most network industries.

Our model also clarifies the equilibrium relation between sabotage and the three possible downstream market outcomes: coexistence, exclusion of independent firms and vertical separation.

When the subsidiary and independent firms coexist in equilibrium, the optimal tradeoff between downstream profits and access charge revenue can be made more precise: for sabotage to emerge it is necessary for the subsidiary's market share to be greater than the elasticity of the derived demand for access. And, moreover, equilibrium sabotage is increasing in this difference. Thus, sabotage is not of much concern if demand for the downstream good is very elastic and the share of the access charge in the downstream price is large. But in many cases of practical relevance quite the contrary occurs: demand is inelastic or the share of the access charge in the downstream price is not large. For example, if the elasticity of the residential demand for energy is 0.3 and the share of distribution costs in the final price of energy is 40%, a distributor who competes with independent retailers would necessarily refrain from sabotage only if its market share is 14% or less.[12] Interestingly, we find that with coexistence the intensity of sabotage increases with economies of scope: then the subsidiary's market share is larger which makes sabotage more attractive at the margin. Thus, consumers are hurt by economies of scope.

The incentives to sabotage work quite differently when the subsidiary excludes independent firms by limit pricing them, for then sabotage has no opportunity cost. Exclusion may happen either because the direct cost of sabotage is low, the subsidiary is more efficient than independent

[12] These numbers come from actual data of the Chilean market.

firms or the subsidiary is large. But in all cases the aim of sabotage is to bring the downstream price closer to the monopolist's unconstrained optimum. Indeed, optimal sabotage is determined by a standard Lerner condition augmented by the direct cost of sabotage. Contrary to coexistence, optimal sabotage falls with economies of scope, for the same reason that a textbook monopolist charges less when its cost falls.

As said before, sabotage not only hurts consumers but may prompt inefficient vertical integration. We show that a bottleneck monopoly who suffers diseconomies of scope may vertically integrate and even limit price rivals out of the market only because it can sabotage; it would never integrate without sabotage. Moreover, we also find that inefficient vertical integration tends to occur when the subsidiary is large. At some point, however, diseconomies of scope and the opportunity cost of sabotage become too large and the monopolist is better off if vertically separated. Thus, we find, in line with the literature, that when the subsidiary is considerably less efficient than independent firms, the bottleneck monopoly does not sabotage. Yet, when the integration decision is endogenous, one should observe vertical separation—there should be no subsidiary to begin with.

The rest of the paper proceeds as follows. In section 2 we present the model and derive some preliminary results. Section 3 studies vertical integration with sabotage. Section 4 concludes with policy implications and some suggestions for further research.

2. The model

2.1. Model description

Production A bottleneck monopoly produces access at zero marginal cost and sells it at a regulated access charge τ to a continuum of n identical and perfectly competitive firms in the downstream market. Like Quirmbach (1986), but in departure with most of the literature on sabotage, we assume that measure n is endogenously determined by free entry.

Each firm uses access in fixed proportions to produce an homogeneous good with cost function

$$(1+s)C(q) + \tau q \equiv (1+s)[k + c(q)] + \tau q,$$

where k is the fixed investment cost; c is the total variable cost of operation; $s \geq 0$ is the intensity of sabotage—sabotage s increases costs by $(100 \cdot s)\,\%$. We assume $c_q, c_{qq} > 0$, that is c is an increasing and convex function of production q (the supply curve is strictly increasing.)

If the bottleneck monopolist vertically integrates into the downstream market it operates a subsidiary who owns a measure $m > 0$ of plants, each with cost function $(1-\eta)C(q)$, where $\eta \in (-\infty, 1)$. When $\eta > 0$ there are vertical economies of scope: plants owned by the subsidiary have lower costs for any given production q. When $\eta < 0$ there are diseconomies of scope. In addition, we assume that m is exogenous—thus, diminishing returns eventually set in and coexistence can emerge in equilibrium. Given this, the subsidiary is fully characterized by a pair (m, η). Hence, in what follows we will refer to "subsidiary (m, η)."

Q_M is the total quantity produced by subsidiary (m, η). The subsidiary will minimize costs by producing $q_M = Q_M/m$ in each plant and its total cost function is $m(1-\eta)C(q_M)$.

REMARK (The effect of sabotage): Note that sabotage increases both the cost of setting up a plant (the entry cost) and the variable cost. Also, in agreement with most of the literature, we assume that sabotage does not increase the subsidiary's cost—its effect is asymmetric.[13]

As Beard et al. (2001) point out, these specific characteristics differ somewhat from the traditional strategies to raise rivals' costs described by Krattenmaker and Salop (1986) in that they involve non-price conditions of supply and provide neither direct nor indirect control of the independent firms' outputs. Also, in their seminal papers Salop and Scheffman (1983, 1987) have in mind horizontal cost-raising strategies, not a bottleneck monopoly as in the sabotage literature. Moreover, they assume that cost-raising strategies increase average and marginal costs of rivals, and the average cost of the saboteur. ■

REMARK (Perfect competition and free entry): Assuming a continuum of firms is just a technical devise to avoid the integer problem; it is a standard assumption in the literature, for example see Quirmbach (1986). It ensures that the equilibrium with free entry exists and that we can use standard differentiation to perform comparative statics.[14] The substantive assumptions are free entry and perfect competition. Are they warranted?

During the last 20 years network industries have been restructured and deregulated in many countries. The premise is that returns to scale are not significant in some segments. Consequently, these can be opened to competition and functionally separated from bottleneck monopolies. For example, in electricity generation the minimum efficient scale (MES) is between 300 and 500 MW, which is far smaller than most electrical systems.[15] Thus, generation can be liberalized, but high voltage transmission, a natural monopoly, must be regulated. Sea shipping is quite competitive, but economies of scale in ports are significant and some, especially in small countries, are bottleneck monopolies. Similarly, telecom service providers like ISPs or long-distance carriers do not seem to enjoy significant economies of scale, but density economies in the local loop are important.

Of course, perfect competition (or contestability) might seem an extreme assumption nonetheless. But even in sectors where a few firms capture a significant market share, like in electricity

[13] For an analysis when sabotage also rises the cost of the saboteur see Sibley and Weisman (2005).

[14] In addition, notice that our analysis would also apply had we assumed that the cost function c has a flat bottom at the optimum level of production, which is one avenue followed in the literature to ensure existence when the number of firms is an integer (see Baumol et al. [1982, p. 32-36]).

[15] For example, installed capacity in the main system of a small country like Chile is around 8,000 MW.

generation, markets may be close to contestable and long-run prices determined by the costs of the marginal entrant. For example, Newbery (1999, pp. 217-18) argues that long-term contracts made entry contestable in the British electricity market. A distributor could sign a fifteen-year long contract with an independent power producer (IPP) who would build a gas-fired plant. This forced incumbents to sign contracts at prices comparable to those that IPPs could offer. ■

Demand D is the demand for the good and $Q = D(p)$ is the quantity demanded at price p. Also, $\varepsilon \equiv -\frac{D'}{pD}$ is the elasticity of demand. In order to ensure regularity of the solution we assume that the demand function satisfies the following property:

Property 1 (downward-sloping marginal revenue): Let $P \equiv D$. For all $Q \geq 0$, $2P'(Q) + QP''(Q) < 0$.

That is, the demand curve generates a downward-sloping marginal revenue curve as a function of Q. This is the standard demand curve drawn in the textbook monopoly example.

Sabotage technology As in most of the literature, the bottleneck monopoly can increase the cost of independent firms by degrading the quality of the input. Sabotage intensity s costs the bottleneck monopoly $\psi(s)$, with $\psi(0) = 0$, $\psi' \geq 0$ and $\psi'' \geq 0$. Notice that these may refer to the direct costs of sabotage as well as financial fines imposed by regulators or image costs if caught. In addition, we allow costless sabotage.

REMARK (The direct cost of sabotage): There is no agreement in the literature about the cost of sabotaging. Mandy (2000) points out that the direct cost of some sabotage activities like issuing standards that are costly for rival firms may be very small, but the cost of influence activities to obtain regulations that damage competitors or, on the other hand, of regulatory and antitrust backlash if sabotage is convincingly revealed, may be substantial.[16]

Here we allow sabotage to be either costless (when $\psi = \psi' = 0$ for all s), like Beard et al.(2001), Bergman (2000), Economides (1998), Engel et al. (2004), Foros et al. (2002), Kondaurova and Weisman (2003), Mandy (2000), Sibley and Weisman (1998); or convex, like Crew et al (2005), Mandy (2001), Mandy and Sappington (2006), Sand (2004), Sappington (2006b), Weisman (1995, 1999, 2001) and Weisman and Kang (2001)[17]. ■

[16] Weisman and Kang (2001) estimate the detection probability that deters sabotage when the penalty is large.

[17] Sappington (2006b), Weisman (1999) and Weisman and Kang (2001) assume a threshold such that, if exceeded, the saboteur is discovered and punished with probability 1—a particular case of convex costs. Reiffen (1998) argues that sabotage may even reduce the bottleneck monopoly's cost, as reliable service to rivals should cost more than poor service. But see Weisman's (1998) reply.

Timing The timing of actions is as follows. First, the bottleneck monopolist decides whether to establish a subsidiary and sabotage intensity s. Then independent firms decide whether to enter the downstream market by sinking $k(1+s)$. Last, independent firms and the subsidiary compete.

2.2. The intensity of sabotage and equilibrium in the downstream market

The decision of independent firms Assume that the bottleneck monopoly sabotages $s > 0$. Then each independent firm chooses optimal production given τ and s, call it $q_\tau(s)$. But free entry and perfect competition implies that $q_\tau(s)$ equals the MES given τ and s. Hence, the equilibrium price will equal the minimum average cost of an independent firm given τ and s.

Now it can be shown that for all τ and s, $q_\tau(s) = q_0$, where q_0 is the MES with $\tau = s = 0$ (see Lemma A.1 in Appendix A for a formal proof). It follows that in equilibrium

$$p_\tau(s) = \frac{(1+s)\left[c(q_0)+k\right] + \tau q_0}{q_0} = (1+s)c_q(q_0) + \tau. \tag{2.1}$$

Note that we do not need to know the amount produced by the subsidiary to obtain $p_\tau(s)$—the equilibrium price is determined by independent firms. It follows that the bottleneck monopolist cannot extend its market power just by vertically integrating, no matter its size.

The subsidiary and sabotage How much will the subsidiary produce? Assume first that the subsidiary coexists with independent firms in equilibrium. Given η, m and s it will equate marginal cost to $p_\tau(s)$. Thus, in equilibrium $q_M(s)$ is such that

$$p_\tau(s) \equiv (1-\eta)c_q q_M(s) + \tau \tag{2.2}$$

(which implies that $q_M > q_0$ if $s > 0$[18]) and $Q_M(s) = mq_M(s)$. Note that the access charge τ is also part of the subsidiary's marginal cost. Why? With perfect competition the subsidiary's production substitutes for output from independent firms one by one. Hence, each unit sold has an opportunity cost, the lost access charge τ.[19]

REMARK (Notation): We write $Q_M(s)$ for $Q_M(p_\tau(s))$ and $q_M(s)$ for $q_M(p_\tau(s))$. More generally, in what follows we will sometimes abuse notation and omit function arguments to reduce clutter. ■

It also follows from condition (2.2) that the subsidiary's production and market share will increase with s. Figure 1, which depicts market demand and the marginal cost function of a given

[18] See Lemma A.2 in Appendix A for a formal proof.

[19] This, of course, occurs because the bottleneck monopolist and the subsidiary maximize joint profits. See Mandy (2001) for an analysis of alternative vertical control structures.

subsidiary (m, η), shows this condition graphically.

Figure 1 about here

With $s = 0$ the equilibrium price is $p_\tau(0)$ and the subsidiary optimally produces $Q_M(0)$. Sabotage offers the possibility of raising p_τ. As the intensity of sabotage increases, the subsidiary increases output and captures an increasing share of the market. As long as $p_\tau(s) < p_\tau(\widetilde{s})$ (with $\widetilde{s}$ the minimum intensity of sabotage needed to exclude all independent firms), the subsidiary coexists with independent firms, hence $Q_M < D$.

Now when the bottleneck monopoly sabotages $\widetilde{s}$ and the price reaches $p_\tau(\widetilde{s})$, $Q_M = D$—the subsidiary grabs all sales. From then on, for any $s > \widetilde{s}$, the subsidiary limit prices and $q_M = D/m$.

Note that with costless sabotage the bottleneck monopoly would choose s to increase the price all the way up to the monopoly price p_M. But if $\psi' > 0$, raising rivals' costs is costly. Studying how the incentive to sabotage varies with η, m, τ and ψ is the topic of the next section.

3. Vertical integration and the incentive to sabotage

3.1. Introduction: wither are we going

By now it is well known that whether sabotage pays depends on the specific values of the relevant parameters—m, η, τ and function ψ. This section is a systematic exploration of this dependence. Nevertheless, there are many different cases and the formal analysis will be easier to follow if we begin with a summary of the results. This we do with Figures 2 and 3, which show the optimal decision of each subsidiary in the (m, η) space. The formal derivation and characterization of these figures is relegated to appendices B and C.

Figure 2 about here   Figure 3 about here

Vertical integration with no sabotage A useful benchmark is to consider the vertical integration decision when sabotage is not an option. So consider first Figure 2, which summarizes this decision when the monopolist cannot sabotage and $\tau > 0$.[20] It can be seen that the parameter space (m, η) is split in four regions:[21]

[20] Let τ_M be the access charge that maximizes the profit of a vertically-separated bottleneck monopoly. Figure 2 also assumes that $\tau < \tau_M = c_q(q_0)/(\varepsilon - 1)$.

[21] The frontiers between regions are not necessarily straight lines, but they are always downward sloping. Nevertheless, let n_τ be the number of independent firms that would enter the market when the access charge is τ and the monopolist does not establish a subsidiary. Then it is always true that $\eta^{\mathrm{LP}}(n_\tau) = 0$.

- In Region I both m and η are large and the subsidiary efficiently excludes firms: the unconstrained monopoly price, call it p_M, is less than the equilibrium price $p_\tau(0)$ which would prevail if only independent firms would sell in the downstream market.[22] We call this "efficient exclusion" (EE). Note that along locus $\eta^{\mathrm{EE}}(m)$, $p_M = p_\tau(0)$.

- Subsidiaries in Region II still optimally exclude firms. Nevertheless, since $p_M > p_\tau(0)$, they charge $p_\tau(0)$ and limit price firms. Total production and sales equal, of course, $D(p_\tau(0))$, regardless of m and η. We call this "limit pricing."

- Now if m is small and economies of scope are weak then we are in Region III. The bottleneck monopoly vertically integrates but the equilibrium price is still $p_\tau(0)$ and part of $D(p_\tau(0))$ is produced by independent firms. We call this "coexistence."

- Last, in Region IV $\eta < 0$, and the subsidiary suffers diseconomies of scope. Then the bottleneck monopoly does not vertically integrate.

Basically, vertical integration is profitable when m and η are such that the subsidiary is more efficient than independent firms, at least before diminishing returns set in; in Appendix B we prove that this occurs whenever there are some economies of scope, however small. On the contrary, if there are diseconomies of scope the bottleneck monopoly does not vertically integrate.

Vertical integration with sabotage Figure 3 is the analogue of Figure 2, but now we assume that the bottleneck monopoly can sabotage. As can be seen, there are two types of (m, η) combinations such that there is no sabotage in equilibrium:

- (Region A) On the one hand, when both m and η are large and the subsidiary is very efficient. Then the bottleneck monopoly vertically integrates and the subsidiary excludes independent firms by optimally setting a low price. Some, namely subsidiaries (m, η) such that $p_M < p_\tau(0)$, will just set their unconstrained monopoly price (Region A[i], which is the same as Region I in Figure 2). But there will also be subsidiaries (m, η) such that $p_M > p_\tau(0)$, who limit price but do not sabotage (Region A[ii]).

- (Region D): On the other hand, the bottleneck monopolist will not sabotage when either m or η are small enough. Small subsidiaries that enjoy some economies of scope will vertically

[22] Obviously, if alone, the subsidiary would choose p_M defined by

$$\frac{p_M - (1-\eta)c_q}{p_M} = \frac{1}{\varepsilon}.$$

integrate, but their sales are too small to reap net benefits from the increase in price wrought by sabotage. Subsidiaries which suffer diseconomies of scope that are not compensated by size (Region E) will not even be observed, because then vertical integration is not profitable.

Consider now subsidiaries (m, η) that prompt the bottleneck monopoly to vertically integrate and sabotage; these are in regions B and C.

- With subsidiaries (m, η) in Region B sabotage will be used to increase the equilibrium price to $p_\tau(s) > p_\tau(0)$ and limit-price independent firms.
- Subsidiaries (m, η) in Region C coexist with independent firms, which are sabotaged.

Interestingly, now subsidiaries who suffer diseconomies of scope but are large enough prompt the monopolist to vertically integrate *because* it can sabotage (regions B[ii] and C[ii]). As we will see, raising the cost of independent firms through sabotage compensates diseconomies of scope, and size makes sabotage profitable.

Last, note the arrows in Regions B and C. These indicate how the intensity of sabotage varies with η and m. When independent firms and the subsidiary coexist (Region C), the intensity of sabotage *increases* with economies of scope and the subsidiary's size. By contrast, with limit pricing (Region B) the intensity of sabotage *falls* with η and m.

3.2. The basic economics of sabotage

3.2.1. Sabotage always increases p_τ and hurts consumers

The first result is that sabotage always increases $p_\tau(s)$ and hurts consumers.

Result 3.1. $\frac{dp_\tau}{ds} = c_q(q_0) > 0$ *and* $\frac{d^2 p_\tau}{ds^2} = 0$.

Proof. In equilibrium $p_\tau(s) = (1 + s)c_q(q_0) + \tau$, thus p_τ is linear in s. ■

In principle, one might think that there is a trade off between sabotage on the one hand and vertical integration and economies of scope on the other. Result 3.1 shows that, from the point of view of consumers, there is no trade off, regardless of economies of scope. The economics is simple: the aim of sabotage is to increase the price received by the subsidiary. Indeed, we will see next that sabotage intensifies with economies of scope when independent firms and the subsidiary coexist.

3.2.2. The sabotage decision

Sabotage with coexistence: the central trade off Consider first Region C in Figure 3. Such subsidiaries coexist with independent firms and the intensity of sabotage, s_o, maximizes

$$\pi(s; m, \eta, \tau) \equiv p_\tau(s)Q_M(s) - m(1-\eta)C(q_M(s)) + \tau\left[D(p_\tau(s)) - Q_M(s)\right] - \psi(s). \tag{3.1}$$

Note that Q_M is a function of s, because for a given intensity of sabotage the subsidiary chooses Q_M optimally according to equation (2.2) and one can derive an implicit function $Q_M(s)$. Thus, the first order condition that defines optimal sabotage s_o is

$$\frac{d\pi}{ds}(s_o; m, \eta, \tau) = Q_M\frac{dp_\tau}{ds} + \tau D'\frac{dp_\tau}{ds} - \psi' = 0. \tag{3.2}$$

Condition (3.2) shows the trade off behind the sabotage decision. The first term, $Q_M\frac{dp_\tau}{ds}$, is the increase in the value of the subsidiary's sales wrought by the higher price. Against this benefit, two costs are traded off. $\psi'(s_o)$ is, of course, the direct cost. But sabotage also has an opportunity cost, which is captured by the term $\tau D'\frac{dp_\tau}{ds}$. The higher price reduces the use of the bottleneck monopoly one-by-one with the fall of consumption of the final good, $D'\frac{dp_\tau}{ds}$, and this translates one-by-one to smaller sales of access to independent firms—in words of Mandy (2000), sabotage might have killed the goose that laid the golden egg.

Further insights can be gleaned by rearranging (3.2) as

$$\frac{d\pi}{ds}(s_o; m, \eta, \tau) = D\left(\mu - \frac{\tau}{p_\tau}\varepsilon\right)\frac{dp_\tau}{ds} - \psi' = 0, \tag{3.3}$$

where $\mu \equiv Q_M/D$ is the monopolist's market share and $\frac{\tau}{p_\tau}\varepsilon$ is the elasticity of the derived demand for access in the case of fixed proportions (see e.g. Brofenbrenner [1961]) . The basic trade off is neatly summarized by the term in parenthesis, $\mu - \frac{\tau}{p_\tau}\varepsilon$. On the one hand, a larger market share stimulates sabotage, because a given increase in p_τ returns more revenue for the bottleneck monopoly. On the other hand, the intensity of sabotage falls with a more elastic derived demand for access —the "killing the goose" effect.

Result 3.2. *With coexistence sabotage increases with the subsidiary's market share.*

Result 3.3. *With coexistence the intensity of sabotage falls the more elastic the derived demand for access, i.e. the more elastic the demand for the final good and the higher the share of the access charge in the downstream price.*

REMARK (Coexistence and the cost of sabotage): Note that if sabotage were costless ($\psi(s) = \psi'(s) = 0$ for all s), $\frac{d\pi}{ds}$ would be greater than zero for a large enough market share and condition (3.3) would not hold. Hence, the bottleneck monopolist would sabotage until excluding rivals. It follows that whenever coexistence with large enough market shares is observed, the unobserved cost of sabotage must be positive and convex in s. ■

REMARK (Sabotage and imperfect competition): Simple manipulation of Sibley and Weisman's (1998a) condition (6), or Sand's (2004) condition (7), which come from a Cournot model, yield the same parenthesis as in (3.3). ■

Now ultimately the subsidiary's market share depends on its size and efficiency. Thus how does the intensity of sabotage vary with m and η? A straightforward application of the implicit function theorem shows that

$$\frac{\partial s_o}{\partial m} = -\frac{q_M}{\Delta} \cdot \frac{dp_\tau}{ds} > 0$$

and

$$\frac{\partial s_o}{\partial \eta} = -\frac{\frac{c_q \cdot m}{(1-\eta)c_{qq}}}{\Delta} \cdot \frac{dp_\tau}{ds} > 0,$$

with

$$\Delta = \frac{d^2\pi}{ds^2} = \left(\frac{dQ_M}{dp_\tau} + \tau D''\right)\left(\frac{dp_\tau}{ds}\right)^2 - \psi'' < 0, \tag{3.4}$$

the second order condition. Hence:

Result 3.4. *With coexistence the intensity of sabotage increases with size and economies of scope.*

It may not be surprising to find that size and vertical integration are deleterious to consumers. But it is probably somewhat surprising that economies of scope, far from benefitting consumers, actually hurt them. Why? The reason is that a more efficient subsidiary has a larger market share ceteris paribus, which makes sabotage more profitable at the margin.

Note, last, that the second order condition (3.4) is informative. Because $\frac{dQ_M}{dp_\tau} > 0$, it is necessary for coexistence either a convex cost of sabotage or a very concave demand. Otherwise, the FOC identifies a minimum and the bottleneck monopoly would sabotage to exclude independent firms. Thus, the mere fact that we observe coexistence in practice suggests that bottleneck monopolies cannot sabotage at will and incur costs when they do so (for further technical details see the Remark in Appendix C).

Sabotage with limit pricing: extending monopoly power Consider next Region B, where the subsidiary limit prices and the bottleneck monopoly sabotages in equilibrium. Now the problem is to maximize

$$\pi(s; m, \eta, \tau) \equiv p_\tau(s)D(p_\tau(s)) - m(1-\eta)C(q_M(s)) - \psi(s).$$

This time the first order condition is

$$\frac{d\pi}{ds}(s_o; m, \eta, \tau) = D\left[1 - \frac{p_\tau - (1-\eta)c_q}{p_\tau}\varepsilon\right]\frac{dp_\tau}{ds} - \psi' = 0. \tag{3.5}$$

All the economics is in the term in brackets, which is proportional to

$$\frac{1}{\varepsilon} - \frac{p_\tau - (1-\eta)c_q}{p_\tau} \geq 0$$

and resembles the Lerner condition. With limit pricing the subsidiary's market share equals 100% and sabotage has no opportunity cost. Instead, it becomes a means to push the downstream price closer to p_M, the monopoly price. Indeed, that's the price the subsidiary would charge if $\psi' = 0$ for all s. With costly sabotage, the inequality is strict and the optimal price $p_\tau(s_o)$ is lower than p_M.

What is now the relation between size and efficiency on the one hand, and sabotage on the other? Another application of the implicit function theorem yields

$$\frac{\partial s_o}{\partial m} = -\frac{\frac{1-\eta}{m^2}D' c_{qq}}{\Delta} \cdot \frac{dp_\tau}{ds} < 0$$

and

$$\frac{\partial s_o}{\partial \eta} = -\frac{c_q D'}{\Delta} \cdot \frac{dp_\tau}{ds} < 0,$$

with

$$\Delta = \frac{d^2\pi}{ds^2} = \left\{2D' - \tfrac{1-\eta}{m}c_{qq}\left(D'\right)^2 + [p_\tau - (1-\eta)c_q]D''\right\}\left(\frac{dp_\tau}{ds}\right)^2 - \psi'' < 0,$$

the second order condition, which always holds with a downward-sloping marginal revenue curve (Property 1) and convex c; see Proposition A.3 in Appendix A.2. Hence:

Result 3.5. *With limit pricing the intensity of sabotage s_o falls with size and economies of scope.*

Essentially, $p_\tau(s_o)$ is closer to p_M the larger and more efficient the subsidiary. Thus, with stronger economies of scope or a larger size, less is gained by sabotaging a bit more.

The maximum intensity of sabotage Thus, we have seen that the intensity of sabotage increases with m and η if the subsidiary coexists; on the contrary, it falls with m and η if the subsidiary limit prices. It follows that there exists a maximum intensity of sabotage, call it $s_o^{\max}$, which is chosen with subsidiaries that are just indifferent between coexistence and limit pricing.

Indifference indicates where to look to characterize $s_o^{\max}$. On the one hand, coexistence implies that price is determined by the independent firm's marginal cost, viz.

$$\begin{aligned}(1+s_o^{\max})c_q(q_0) &= p_\tau(s_o^{\max})-\tau \\ &= (1-\eta)c_q\left(\frac{Q_M(s_o^{\max})}{m}\right).\end{aligned}$$

At the same time, limit pricing implies that $Q_M(s_o^{\max}) = D(p_\tau(s_o^{\max}))$. It follows that $s_o^{\max}$ is implicitly defined by

$$(1+s_o^{\max})c_q(q_0) = (1-\eta)c_q\left(\frac{D((1+s_o^{\max})c_q(q_0)+\tau)}{m}\right).$$

Lemmas A.5 and A.6 in Appendix A show that $s_o^{\max}$ exists, is unique and is, in fact, the highest equilibrium sabotage intensity that can be observed in equilibrium. That is, for all subsidiaries (m,η), $s_o^{\max} \geq s_o(m,\eta)$. Graphically, $s_o^{\max}$ defines locus $\eta^B(m)$ in Figure 3.[23]

Inefficient vertical integration Figure 3 also indicates that the bottleneck monopoly may vertically integrate despite diseconomies of scope. To see why note that the bottleneck monopolist gains by vertically integrating and sabotaging even when $\eta = 0$, provided that the subsidiary is large enough. Continuity implies that there must be subsidiaries which suffer diseconomies of scope but can still profit with sabotage.

To show this argument formally, think of a subsidiary with $\eta = 0$. We know that when $s = 0$ the bottleneck monopolist is indifferent between integrating and remaining vertically separated because $\pi(0;m,0) = \tau D(p_\tau(0))$.[24] But if the subsidiary is large enough, $s_o(m,0) > 0$ and $\pi(s_o(m,0);m,0) > \tau D(p_\tau(0))$ because we are inside Region C.

Now consider subsidiary (m,η_ϵ) who suffers small diseconomies of scope $\eta_\epsilon < 0$. If the bottleneck monopoly decides to vertically integrate, sabotages $s_o(m,0)$ and mimics production of subsidiary $(m,0)$ then total profits are

$$\pi(s_o(m,0);m,\eta_\epsilon) > \tau D(p_\tau(0)) > \pi(0;m,\eta_\epsilon).$$

The result follows after we notice that monopolist (m,η_ε) maximizes its profits selecting sabotage intensity $s_o(m,\eta_\epsilon)$ and not $s_o(m,0)$.

[23] Note that for subsidiaries (m,η) such that $s_o(m,\eta) = s_o^{\max}$, $\widetilde{s}(m,\eta) = s_o(m,\eta)$.

[24] If vertically separated, monopolist $(m,0)$ earns $\tau D\left[p_\tau(0)\right]$; if integrated it earns

$$p_\tau(0)Q_M - mC(q_M) + \tau\left[D(p_\tau(0)) - Q_M\right]$$

which, (using (2.1)) is equal to

$$\tau D(p_\tau(0)) + mq_0 \cdot \left[c_q(0) - C(q_0)/q_0\right].$$

But the second term equals zero because of free entry, hence total profits are $\tau D(p_\tau(0))$.

Sabotage makes vertical integration profitable because it reduces the relative cost disadvantage of a subsidiary with $\eta < 0$ and increases the equilibrium price. Thus, the subsidiary can sell at a higher price and profit by vertically integrating.

3.3. When sabotage isn't a concern

We now examine three cases such that sabotage is not a concern. In each case we discuss whether such conditions will be met in practice.

3.3.1. An unregulated bottleneck monopoly doesn't sabotage

Assume for a moment that the bottleneck monopolist is free to set the access charge τ. Then the following result follows:

Result 3.6. *An unregulated bottleneck monopoly does not sabotage.*

Proof. $>$From the derivative of (3.1) with respect to τ we get that for each s an unregulated bottleneck monopoly that coexists with independent firms sets $\tau = \tau_M = p_\tau(s)/\varepsilon$. Hence

$$\frac{d\pi}{ds}(s; m, \eta, \tau) = -D\,(1-\mu)\,\frac{dp_\tau}{ds} - \psi' \leq 0$$

for all $s \geq 0$ and $s = 0$ is optimal.

Consider now a bottleneck monopolist who efficiently excludes. In this case, for each s the monopolist chooses τ such that $\frac{p_\tau(s)-(1-\eta)c_q}{p_\tau(s)} = 1/\varepsilon$. Hence

$$\frac{d\pi}{ds}(s; m, \eta, \tau) = -\psi' \leq 0$$

for all s and $s_o = 0$. ■

Result 3.6 is well known.[25] Beard et al. (2001) explain the intuition when the subsidiary and independent firms coexist. For an independent firm the effect of cost increases due to τ or s are exactly the same. Hence, a higher access charge or an increase in the intensity of sabotage has the same effect on the subsidiary's revenue. Nevertheless, while a higher τ increases the margin earned by the bottleneck monopoly on sales to independent firms, sabotage does not, and a higher access charge is always better than more sabotage. Exactly the same economics explains why a slightly higher access charge always reduces the intensity of sabotage in equilibrium:

[25] See Beard et al. (2001), Bergman (2000), Kondaurova and Weisman (2003), Laffont and Tirole (2000, section 4.5), Mandy (2000), Reiffen (1998) and Sand (2004).

Result 3.7. *Let $s_o > 0$ for $\tau < \tau_M$. Then the optimal intensity of sabotage falls with τ.*

Proof. Straightforward differentiation of (3.2) or (3.5) as the case may be yields

$$\frac{\partial s_o}{\partial \tau} = -\frac{D'}{\Delta} \cdot \frac{dp_\tau}{ds} < 0,$$

with $\Delta = \frac{d^2\pi}{ds^2}$, the second order condition. ■

The general lesson of Results 3.6 and 3.7 is that sabotage is wrought by the successful regulation of the bottleneck monopoly's market power. One might be tempted to think that sometimes price regulation should be abandoned to avoid sabotage, but this is unlikely. For example, if the elasticity of demand is 1.1, τ_M will be 10 times the downstream marginal cost $c_q(q_0)$; if $\varepsilon = 3$, τ_M will still be substantial, equal to 50% the downstream marginal cost $c_q(q_0)$.[26]

Nevertheless, if the access charge is equal to marginal cost the monopolist sabotages to achieve the desired margin. Thus, unless sabotage is verifiable, some departure from marginal cost pricing is optimal; see Sand (2004).

3.3.2. The bottleneck monopoly doesn't sabotage if the subsidiary is "small"

Consider now subsidiaries who coexist with independent firms. A straightforward implication of monotonicity in m, is that at some point the subsidiary becomes too small to warrant sabotage; this is Region D in Figure 3. In particular, Lemma A.7 in Appendix A shows that for any $\eta > 0$ there exists $\underline{\mu}(\eta)$ such that for all μ in $[0, \underline{\mu}(\eta)]$

$$D\left(\mu(\eta) - \tfrac{\tau}{p_\tau(0)}\varepsilon\right)\frac{dp_\tau}{ds} - \psi'(0) \leq 0. \tag{3.6}$$

Hence (3.6) tells that sabotage will not occur if

$$\mu \leq \frac{\tau}{p_\tau}\varepsilon, \tag{3.7}$$

i.e. the subsidiary's market share must be smaller than the elasticity of the derived demand for access ((3.7) is sufficient and necessary if sabotage is costless). This no-sabotage condition is useful because it relates incentives with observable market parameters. Now for a given ratio $\frac{\tau}{p_\tau}$ and demand elasticity ε, Table 1 shows the maximum market share of the subsidiary such that condition (3.7) holds. For example, if $\frac{\tau}{p_\tau} = 0.2$ (that is, the access charge is equivalent to 20% of the price, paid by final users) and $\varepsilon = 0.7$, then the sufficient no-sabotage condition (3.7) holds for subsidiaries with market share of 14% or less.

[26] To obtain this note that $\frac{\tau_M}{c_q(q_0)} = \frac{1}{\varepsilon - 1}$ at the monopolist's optimum.

Note that when the access charge is a small percentage of the final price (say 0.15 or less) and demand is inelastic, the sufficient condition holds only for quite small market shares. Moreover, if $\tau \leq 0$ (i.e. the access charge is fixed at or below marginal cost), the bottleneck monopolist will sabotage however small its market share.

Result 3.8. *If $\frac{\tau}{p_\tau}$ is small, demand is inelastic, and $\psi'(0)$ its not too large, then only very small subsidiaries do not sabotage.*

We can now consider some applications.

Application: bottleneck monopolies with small $\frac{\tau}{p_\tau}$ First consider two examples of Chilean services with small ratios $\frac{\tau}{p_\tau}$. In Chile's Central Interconnected System, high-voltage transmission costs are about 6% of the average wholesale monomic energy price[27] and current estimates indicate that the price elasticity of the residential demand for energy in Chile is about 0.3.[28] Hence, a market share of more than $0.3 \times 6\% = 1.8\%$ is enough for condition (3.7) not to hold.

Consider now long distance. In Chile local fixed-line companies receive a per-minute access charge for originating and delivering long-distance calls, which is paid by independent carriers and currently equals Ch$5.07 per minute.[29] In turn, carriers charge on average Ch$171.10 per minute for international calls, and Ch$41.90 per minute for national calls. Hence $\frac{\tau}{p_\tau} = \frac{5.07}{171.10} \approx 0.03$ for international calls and $\frac{\tau}{p_\tau} = \frac{5.07}{41.90} \approx 0.12$ for national calls. Unfortunately, we don't have estimates for the elasticity of the demand for long distance calls. If it were similar to the 0.7 estimate by Taylor (1994) for the United States, then it would mean that only subsidiary's with a market share of at most 2.1% would meet the no-sabotage condition.

Application: downstream liberalization and sabotage Depending on initial conditions a "liberalization" may mean allowing independent firms to compete with a vertically integrated incumbent; or allowing the upstream provider to enter the downstream market with a subsidiary (as when the 1996 Telecommunications Act allowed RBOCs to enter the InterLATA market in the United States).

Incumbents often retain large market shares after liberalization and the demand for such services is likely to be inelastic. The North-East quadrant of Table 1 suggests, thus, that sabotage should be a concern when independent firms are allowed to enter to compete with a dominant vertically integrated incumbent. Consider, for example, electricity distribution, which can be unbundled

[27] See Galetovic and Muñoz (2006).

[28] The elasticity of demand and the share of distribution charges in the residential energy price is taken from Inostroza et al. (2004).

[29] We thank Patricio Cáceres of Telefónica CTC Chile for kindly sharing data on access charges. In January 2007 $1 = Ch$540.

from retailing. Current estimates indicate that the price elasticity of the residential demand for energy in Chile is about 0.3 and $\frac{\tau}{p_\tau}$ is about 0.4.[30] Thus the no-sabotage condition would hold only if the incumbents' shares would fall from 100% today to 14% or less. More generally, if the elasticity of demand is 0.5 or less, any incumbent which retains more than 50% of the market will likely have incentives to sabotage.

A similar calculation was performed by Sibley and Weisman (1998a) to analyze the likely effects on sabotage of allowing RBOCs to enter the interLATA market, and their parametrization yielded a threshold market share of 26%. Yet they concluded that sabotage would probably not be a concern, at least initially—RBOCs were new to the market and had to snatch market share from incumbents.

3.3.3. The bottleneck monopolist doesn't sabotage if the subsidiary is very efficient

Efficiency and sabotage The bottleneck monopolist will not sabotage if her subsidiary is very efficient and excludes independent firms by merely charging the unconstrained monopoly price. To see this note that such a subsidiary optimally sets $p_M < p_\tau(0) < p_\tau(s)$ for any $s > 0$. Hence

$$\pi(s;\eta,m) = p_M D(p_M) - m(1-\eta)C\left(\frac{D(p_M)}{m}\right) - \psi(s),$$

which falls with s. Hence:

Result 3.9. *The bottleneck monopoly does not sabotage if the subsidiary efficiently excludes.*

Furthermore, Figure 3 also shows that at some point economies of scope become too strong for sabotage to be profitable, regardless of the subsidiary's size m. Then even some subsidiaries who limit price in Figure 3, will optimally choose not to sabotage.

To see why fix m arbitrarily at $\overline{m}$. Note that for subsidiaries $(\overline{m},\eta)$ who limit price when sabotage is not feasible

$$\frac{d\pi}{ds}(0;\overline{m},\eta) = D\left[1 - \frac{p_\tau - (1-\eta)c_q}{p_\tau}\varepsilon\right]\frac{dp_\tau}{ds}$$

and $p_\tau \leq p_M(\overline{m},\eta)$. As η increases and economies of scope become more intense, the term

$$\frac{p_\tau - (1-\eta)c_q}{p_\tau}$$

[30] The elasticity of demand is taken from Benavente et al. (2005). The share of distribution charges in the residential energy price is taken from Galetovic et al. (2004).

increases and $d\pi/ds\ (0;\overline{m},\eta)$ falls. For $\eta = \eta'$ such that $p_M(\overline{m},\eta') = p_\tau(0)$, this fraction equals $1/\varepsilon$ and $d\pi/ds(0;\overline{m},\eta') = 0$. Thus, when $\psi'(0) > 0$, there exists some continuous interval such that $d\pi/ds(0;\overline{m},\eta') - \psi'(0) < 0$. Since $\frac{d\pi}{ds}(s;m,\eta)$ is decreasing in s, we know that the bottleneck monopoly will never sabotage. Essentially, when economies of scope are strong enough p_τ is close to p_M and sabotage is not worth its cost.

Application: efficient exclusion is unlikely In antitrust cases it is sometimes claimed that vertical integration benefits consumers, because economies of scope lower prices. Our analysis shows that this claim is suspect because prices do not fall with vertical integration unless the subsidiary (m,η) is "considerably" more efficient than independent firms. To see this, we parametrize the cost differences between the subsidiary and independent firms that are necessary for efficient exclusion.

To proceed, note that the frontier between Regions A[i] and A[ii] in Figure 3, the set of points such that $p_M = p_\tau$ is the implicit function $\eta^{EE}(m)$ obtained from

$$p_\tau - (1-\eta^{EE}(m))c_q\left(\tfrac{D}{m}\right) \equiv \frac{1}{\varepsilon}p_\tau. \tag{3.8}$$

Define $\lambda_\tau \equiv \tau/c_q(q_0)$, the mark-up above marginal cost imposed by the access charge. Because $p_\tau = c_q(q_0) + \tau$, one can manipulate (3.8) to yield

$$\frac{(1-\eta)c_q\left(\frac{D}{m}\right)}{c_q(q_0)} = (1+\lambda_\tau)(1-1/\varepsilon). \tag{3.9}$$

The ratio on the LHS is a lower bound such that efficient exclusion is an equilibrium (for points inside Region A[i] the cost difference is even higher and, since $q_M \geq q_0$, average cost is below marginal cost at q_M). Because the ratio cannot be negative, it must be the case that $\varepsilon > 1$ at the observed equilibrium price for efficient exclusion to occur.

Table 2 shows the minimum cost advantage that the subsidiary must enjoy for efficient exclusion to be profitable. If the observed elasticity of demand is close to 1, or τ is small relative to the independent firm's marginal cost, the subsidiary's cost advantage has to be very large. For example, if $\varepsilon = 1.1$ and $\lambda_\tau = 0.1$, the subsidiary's marginal cost has to be one-tenth, or 10% of an independent's firm marginal cost, for efficient exclusion to occur. And in any case, for plausible values of ε and λ_τ the monopolist's cost advantage needs to be substantial for efficient exclusion to be profitable. For example, if $\varepsilon = 2$, even if τ increases firms' costs by 50% ($\lambda_\tau = 0.5$), the subsidiary's cost would need to be 75% the cost of an independent firm. Hence:

Result 3.10. *Unless demand is very elastic, vertical integration benefits consumers only if the monopolist is substantially more efficient than independent firms.*

3.3.4. The bottleneck monopolist doesn't sabotage if the subsidiary is very *in*efficient

Many authors have noted that sabotage becomes unattractive when the subsidiary is considerably less efficient than independent firms.[31] This, of course, also appears in our model: as can be seen in Figure 3, for each m there is no sabotage if diseconomies of scope are strong enough. The economics is well known: the inefficient subsidiary substitutes production of independent firms, but earns a margin which is smaller than the access charge. Thus, substitution results in a net loss when the subsidiary's costs are high.

Yet in practice it is unlikely that a subsidiary will choose to refrain from sabotage because it is less efficient than independent firms. For one, if the bottleneck monopolist decides not to sabotage, then it should also prefer vertical separation and no subsidiary should be observed in the first place! For another, as we have already seen, an inefficient subsidiary may operate precisely *because* it can sabotage and raise rivals' costs—as far as the sabotage decision is concerned, relative inefficiencies must be assessed after sabotage has increased rival's costs.

3.4. Welfare

3.4.1. Vertical integration, sabotage and welfare

How does welfare vary with equilibrium sabotage? Because downstream firms are perfectly competitive and make zero profits, welfare equals the sum of the monopolist's profit and consumer surplus, both evaluated at s_0, viz.

$$\begin{aligned}&\int_0^{D(p_\tau(s_o))}\left[P(x)-p_\tau(s_o)\right]dx+p_\tau(s_o)D(p_\tau(s_0))\\&-m(1-\eta)C\left(q_M(s_o)\right)-\psi(s_o)\end{aligned}$$

with exclusion and

$$\begin{aligned}&\int_0^{D(p_\tau(s_o))}\left[P(x)-p_\tau(s_o)\right]dx+p_\tau(s_o)Q_M(s_o)\\&-m(1-\eta)C\left(q_M(s_o)\right)+\tau\left[D(p_\tau(s_0))-Q_M(s_o)\right]-\psi(s_o)\end{aligned}$$

with coexistence.

Now note that s_o is a function of η and m. If the bottleneck monopoly excludes, then sabotage is more intense the smaller the subsidiary or the less intense are economies of scope. Because smaller and less efficient subsidiaries make lower profits and sabotage more, the following follows:

[31] See, for example, Economides (2000), Mandy (2000), Sand (2004) and Weisman (1999).

Result 3.11. *When the bottleneck monopoly excludes welfare falls with equilibrium sabotage.*

Things are different when the subsidiary coexists. Here the bottleneck monopoly sabotages more when the subsidiary is more efficient. Hence:

Result 3.12. *When the subsidiary coexists, welfare may increase or fall with equilibrium sabotage.*

Vertical integration and welfare A related but slightly different question is how vertical integration affects welfare. The tradeoff is simple: with vertical integration economies of scope may be realized, but consumers pay more and independent firms have higher costs.

The change in welfare when the bottleneck monopolist vertically integrates and sabotages, which is depicted in Figure 4, is

$$\begin{aligned} & -\int_{D(p_\tau(s_o))}^{D(p_\tau(0))} [P(x) - c_q(q_0)]\, dx \\ & -s_0 c_q(q_0) \left[D(p_\tau(s_o) - Q_M\right] \\ & +Q_M \cdot \left[c_q(q_0) - \frac{(1-\eta)C\left(q_M(s_o)\right)}{q_M(s_o)}\right] - \psi(s_0). \end{aligned} \tag{3.10}$$

Three of these four terms indicate a welfare loss. The first term in (3.10), which is the the shaded area in the figure, is the welfare loss due to the fall of consumption—with vertical integration price increases, consumption falls and access charge revenues are lost. The second term, which is the gridded area in the figure, is the higher cost that independent firms have to bear. And sabotage has a direct cost, $\psi(s_0)$.

Figure 4 about here

But consider now the third term. We know that $q_M(s_o) \geq q_0$, so that $\frac{C(q_M(s_o))}{q_M(s_o)} \geq c_q(q_0)$. Thus, if η is small, zero or negative, welfare must fall:

Result 3.13. *If economies of scope are not too large, welfare falls with vertical integration.*

Now the checkered area in Figure 4 is positive whenever the subsidiary can realize economies of scope. With sufficiently large economies of scope, thus, welfare could increase with vertical integration, as we now show with a simulation.

A simulation with "large" sabotage costs To explore the tradeoff between economies of scope and consumer welfare we consider a simple example. Assume that the demand for the final good is $250 - 6p$; the total cost of production of a one-plant independent firm is $100 + q^2$; the access charge is fixed at $\tau = \$2$; and the cost of sabotage is $12,500 \cdot s^2$. Then 11.8 independent firms enter the market with vertical separation, $Q = 118$, $p = \$22$, consumer welfare equals \$1,160 and aggregate welfare equals \$1,396. Note that in this example sabotage costs can be called "large": to increase the cost of independent firms by 1% the bottleneck monopolist must spend $12,500 \cdot 0.01 = \$125$, or about 5% of total downstream production costs.

Table 3(a) shows the change of aggregate welfare, and Table 3(b) the change of consumer welfare, with vertical separation = 100 in both. Those pairs (η, m) such that there is efficient exclusion (Region A) are shown in *italics*; pairs (η, m) such that the bottleneck monopolist limit prices (Region B) are shown with continuous shading; Region C, those pairs (η, m) such that the subsidiary coexists and sabotages is shown in normal script; last, those pairs (η, m) such that the subsidiary coexists but does not sabotage (Region D) are shown with discontinuous shading.

Table 3(a) indicates that aggregate welfare increases when economies of scope yield cost savings of 7% or more. On the other hand, if economies of scope are 6% or less, welfare falls for most (η, m) pairs, unless the subsidiary is small. Aggregate welfare can fall up to 7.6%, which occurs when the subsidiary coexists with $\eta = 0$ and $m = 10$. Note that welfare uniformly increases with economies of scope for a given m, despite of the fact that sabotage intensifies with economies of scope in Region C.

Variations in the intensity of sabotage can be gleaned better by looking at consumer welfare in Table 3(b). We know that it must fall in regions B and C and reach its nadir along the frontier that separates both region. Then it can be seen that in this example, consumer welfare can fall up to 15% with vertical integration. Interestingly, there seem to be two types of pairs (η, m) that hurt consumers the most. On the one hand, when economies of scope are very large, but the subsidiary is small (this case, however, seems unlikely, as economies of scope need to be very large for welfare to fall a lot). On the other hand, a large subsidiary ($m \geq 7$, say) tends to sabotage more.

The price increases behind the welfare changes shown in Table 3 are significant but not very large—at most 7% . One might thus be tempted to conclude that important but yet plausible economies of scope might be enough to compensate whatever losses consumers bear with vertical integration.[32] Yet this conclusion is probably not warranted, because we have assumed that the direct cost of sabotage is quite large. A smaller cost of sabotage significantly enlarges the set of pairs (η, m) such that aggregate welfare falls and then consumer losses will be compensated only if economies of scope are much larger.

[32] The reasoning is reminiscent to Williamson's (1968). He showed that the surplus loss caused by a price increase after a merger will be compensated by efficiency gains of about an order of magnitude smaller. But the analogy is not warranted. Roughly speaking, our simulation suggests that economies of scope have to be of about the same order of magnitude of the price increases caused by sabotage.

3.4.2. Sabotage, vertical divestitures and welfare

Some recent papers have begun to analyze the costs and benefits of vertical divestitures (see Crew et al. [2005] and Sappington [2006b]). In our model, Result 3.1 implies that a vertical divestiture benefits consumers whenever the bottleneck monopoly sabotages—$p_T(0) < p_T(s)$ regardless of economies of scope. Moreover, because the subsidiary is a price taker, $p_T(0)$ is the minimum price that consumers will pay when independent firms coexist with the subsidiary. Hence:

Result 3.14. *If the subsidiary coexists, vertical divestitures do not hurt consumers.*

On the other hand, a vertical divestiture hurts consumers if it prevents efficient exclusion. But, as we saw before, that is unlikely. For example, in our simulation, efficient exclusion occurs only if the costs of the subsidiary are close to zero.

Our results are quite similar in spirit to Sappington's (2006b), who studies vertical divestitures in a model where an incumbent firm (the equivalent of the subsidiary) competes Bertrand with rivals of varying efficiency. He finds that economies of scope do not affect the price that consumers pay when either the incumbent is the lowest-cost producer or the costs of rivals are sufficiently similar. In both cases, the equilibrium price is determined by the costs of independent rivals, which are not affected by economies of scope. Consequently, a vertical divestiture benefits consumers because the price falls when sabotage ceases, just as it does in our model.

How does a vertical divestiture affect aggregate welfare? Crew et al. (2005) tackled this question with a Cournot duopoly, and found that welfare rises with a divestiture, unless economies of scope are substantial[33]. In our simulation (see table 4 (b)) a divestiture will increase aggregate welfare if, roughly speaking, economies of scope are larger in magnitude than the price increase prompted by sabotage in equilibrium.

4. Concluding remarks

The aim of this paper has been to relate the sabotage decision with observable market outcomes and parameters. This exercise yields two simple conditions which are a function of observable market parameters and tell when sabotage pays. Moreover, it shows that market outcomes are informative by themselves about the likelihood of sabotage. Yet our consolidation of the results present in the literature is incomplete, because we have built on three specific assumptions. To conclude we will comment on these assumptions and suggest some directions for further research.

Let us point out that assuming free entry, while not common in the literature, is not particularly restrictive. When writing regulations (either rules or statutes), a central question is: does

[33] In their simulations, and for their specific parameter values, they find that marginal costs have to be at least 28.61% higher for a divestiture to decrease welfare. See also their Table 3.

it make sense to allow bottleneck monopolies to own subsidiaries, or is it better to prohibit vertical integration? This is, essentially, a question about the long-run performance of alternative regulatory regimes which will be inevitably affected by entry. Moreover, such long-run analysis is useful because ex post regulation of sabotage is seldom effective. For example, American courts have seldom upheld claims that sabotage raises rival's cost and violates Section 2 of the Sherman Antitrust Act. As mentioned by Goetz and McChesney (2006): "For the most part, causes of action under §2 based essentially on allegations of raising rivals' costs have not fared well." In such a case the plaintiff (the FTC or the DOJ, say) not only has to prove that the defendant has engaged in activities with the intention to monopolize the market and has injured the plaintiff, but also has to prove that competition has been harmed. The first requirement is daunting by itself, as the plaintiff has to present *material* evidence that the defendant raised his costs. Expert testimony will usually not be enough because, as *City of Tuscaloosa, 877 F. Supp. 1504 (N.D. ALA. 1995)* suggest, courts are reluctant to base their decisions on economic theories unless these are completely developed and generally accepted by the profession. The second requirement is no less demanding, for if the plaintiff proves personal injury, he then must also show that the social losses wrought by sabotage outweigh the productive efficiencies realized because of vertical integration. In the few available cases (e.g. *Oahu Gas Serv., 838 F.2d 360, 368 (9th. Cir. 1988)* and *Viacom International*, *785 F. Supp 371, 376 n.12 (S.D.N.Y. 1992)*) plaintiffs failed to achieve that goal. For this reason, ex ante regulation of industry structure, a long-run decision, may be the only effective remedy against sabotage.

On the other hand, the key assumption in this paper is perfect competition. So it would be natural to extend this analysis to systematically explore how imperfect competition affects the incentives to sabotage in the long run. Imperfect competition implies a price-marginal cost margin downstream which won't disappear with free entry. Compared with perfect competition, this margin probably affects the incentive to sabotage. But the similarity of condition (3.3) on the one hand and Sibley and Weisman's (1998a) condition (6), or Sand's (2004) condition (7), which come from a Cournot model, suggests that the simple conditions of this paper can be extended to imperfectly competitive markets. Of course, one would like results and conditions that are valid for all the whole run of models between perfect competition and monopoly, not only Cournot. Mandy (2001), who models downstream competition with a conjectural variations model, suggests a promising way to proceed.

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Appendix

A. Proofs of lemmas

A.1. Productive efficiency

Lemma A.1 (Producing at MES). *For all τ and s, $q_\tau(s) = q_0$.*

Proof. >From (2.1) we know that

$$k = q_\tau(s)c_q(q_\tau(s)) - c(q_\tau(s)) \tag{A.1}$$

for all values of $q_\tau(s)$, including q_0. It is enough to show that (A.1) defines a unique $q_\tau(s)$ but that is the case because $q_\tau(s)c_q - c$ is a strictly increasing function in $q_\tau(s)$ as $\partial\left[q_\tau(s)c_q - c\right]/\partial q_\tau = q_\tau(s)c_{qq} > 0$. ■

Lemma A.2 (Producing beyond the MES). *(i) For all $j, j' \in [0, m]$, $q_j = q_{j'}$. (ii) Let q_0 be a plant's minimum efficient scale MES when $s = 0$, that is where average cost equals marginal cost. Then $\frac{Q_M}{m} \geq q_0$.*

Proof. Take any arbitrary production Q_M. (i) For a given m, costs are minimized when $c_q(q_j) = c_q(q_j')$ since the cost function is convex in q. (ii) Suppose that $q_M < q_0$. Then $c_q(q_M) < c_q(q_0)$, a contradiction. ■

REMARK: Part (i) follows from cost minimization. Part (ii) says that in the long-run the monopolist will not install so many plants to have them produce below their MES. Of course, as assumed, regulatory and antitrust restrictions restrict m and may result in plants operating beyond their MES.

A.2. An implication of Property 1

We claim in section 3.2.2 that Property 1 (a downward-sloping marginal revenue curve) and convex c is sufficient for the second-order condition to hold when the bottleneck monopoly limit-prices. We now prove this.

Proposition A.3. *If $P + P'Q$ is decreasing in Q for all Q, (Property 1), with $P(Q) \equiv D^{-1}(Q)$, and $(1-\eta)c(q)$ is convex then*

$$2D' - \tfrac{1-\eta}{m}c_{qq}\left(D'\right)^2 + \left[p - (1-\eta)c_q\right]D'' < 0 \tag{A.2}$$

for all $p \in [0, \overline{p}]$, with $\overline{p} > p_M$.

To prove the Proposition, the following lemma is useful:

Lemma A.4. *Let $P(Q) \equiv D^{-1}(Q)$. Then (i) $D'(P(Q)) = \frac{1}{P'}$; (ii) $D''(P(Q)) = -\frac{P''}{(P')^3}$.*

Proof. $P(D(p)) \equiv p$. Hence

$$P'(D(p))D' \equiv 1, \tag{A.3}$$

from which (i) follows after straightforward subsitutions. Next, totally differentiating (A.3),

$$P''(D(p))(D')^2 + P'(D(p))D'' \equiv 0,$$

from which (ii) follows. ■

Proof of Proposition A.3 The proposition is clearly true if $D'' \leq 0$. Thus assume $D' > 0$ but Property 1 holds and c is convex. Use (i) in Lemma A.4 to substitute $\frac{1}{P'}$ for D' in (A.2) and (ii) to substitute $\frac{P''}{(P')^3}$ for D'', and obtain

$$\frac{2}{P'} - \tfrac{1-\eta}{m}\frac{c_{qq}}{(P')^2} - \left[p - (1-\eta)c_q\right]\frac{P''}{(P')^3}. \tag{A.4}$$

Now note that for all $p \leq p_M$,

$$p - (1-\eta)c_q \leq \frac{p}{\varepsilon} \equiv -\frac{p}{D'(p)\frac{p}{D(p)}} = -QP',$$

where the second equality follows from Lemma A.4 (i). Hence

$$[p-(1-\eta)c_q]\,\frac{P''}{(P')^3}\leq -QP'\frac{P''}{(P')^3}.$$

But then

$$\begin{aligned} & \frac{2}{P'}-\frac{1-\eta}{m}\frac{c_{qq}}{(P'')^2}-[p-(1-\eta)c_q]\,\frac{P''}{(P')^3} \\ \leq\ & \frac{2}{P'}-\tfrac{1-\eta}{m}\frac{c_{qq}}{(P'')^2}+QP'\frac{P''}{(P')^3} \\ =\ & \frac{1}{(P')^2}\left[2P'+QP''-\tfrac{1-\eta}{m}c_{qq}\right]<0, \end{aligned}$$

where the last inequality follows directly from Property 1 and the convexity of c. Last, existence of $p>p_M$ follows directly from continuity. ■

A.3. Properties of $s_o^{\max}$

Lemma A.5 (Existence and uniqueness). *There exists a unique $s_o^{\max}$ that satisfies*

$$(1+s_o^{\max})c_q\left(q_0\right)=(1-\eta)c_q\left(\tfrac{D((1+s_o^{\max})c_q(q_0)+\tau)}{m}\right) \tag{A.5}$$

Proof. The LHS is strictly increasing in $s_o^{\max}$ converging to infinity as $s_o^{\max}$ tends to infinity, and the RHS is strictly decreasing in $s_o^{\max}$. Hence showing that when (A.5) evaluated at $s=0$,

$$c_q\left(q_0\right)<(1-\eta)c_q\left(\tfrac{D(p_\tau(0))}{m}\right),$$

is sufficient to show that both functions intersect only once. But that is direct from

$$c_q\left(q_0\right)<(1+s_o^{\max})c_q\left(q_0\right)=(1-\eta)c_q\left(\tfrac{D((1+s_o^{\max})c_q(q_0)+\tau)}{m}\right)<(1-\eta)c_q\left(\tfrac{D(p_\tau(0))}{m}\right). \blacksquare$$

Lemma A.6 (Maximum intensity of sabotage). *For all subsidiaries (m,η) $s_o^{\max}\geq s_o(m,\eta)$*

Proof. From its definition we know that when the monopolist sabotages $s_o^{\max}$ then $Q_M=D$ and all independent firms are limit priced. But then we know that inside Region C in Figure 3 (sabotage with coexistence) $s_o(m,\eta)$ is always smaller than $s_o^{\max}$ because $\frac{\partial s_o}{\partial m}>0$ and $\frac{\partial s_o}{\partial \eta}>0$. Similarly, we know that inside Region B in Figure 3 (sabotage with limit-pricing) $s_o(m,\eta)$ is always smaller than $s_o^{\max}$ this time because $\frac{\partial s_o}{\partial m}<0$ and $\frac{\partial s_o}{\partial \eta}<0$. ■

A.4. A monopolist who owns a small subsidiary does not sabotage

Lemma A.7. ***(Minimum market share)*** *For all $\eta>0$ there exists a market share $\underline{\mu}(\eta)$ such that for all $\mu\leq\underline{\mu}(\eta)$*

$$D(p_\tau(0))\left(\mu-\tfrac{\tau}{p_\tau(0)}\varepsilon\right)\frac{dp_\tau}{ds}-\psi'(0)\leq 0$$

Proof. The proof is in two parts. First, for any $\eta>0$ we identify the market share $\underline{\mu}(\eta)$ for which the optimal intensity of sabotage is 0. Second, we show that a bottleneck monopolist who owns a subsidiary with market share smaller than $\underline{\mu}(\eta)$ does not sabotage.

We know that $0>-D(p_\tau(0))\frac{\tau}{p_\tau(0)}\varepsilon\frac{dp_\tau}{ds}-\psi'(0)$ and that

$$D(p_\tau(0))\left(1-\tfrac{\tau}{p_\tau(0)}\varepsilon\right)\frac{dp_\tau}{ds}-\psi'(0)\geq D(p_\tau(s_o))\left(1-\tfrac{\tau}{p_\tau(s_o)}\varepsilon\right)\frac{dp_\tau}{ds}-\psi'(s_o)=0.$$

Hence, from a continuity argument, there exists $\underline{\mu}(\eta)\in[0,1]$ such that

$$D(p_\tau(0))\left(\underline{\mu}(\eta)-\tfrac{\tau}{p_\tau(0)}\varepsilon\right)\frac{dp_\tau}{ds}-\psi'(0)=0. \tag{A.6}$$

>From (3.3) this implies that a monopolist who owns a subsidiary (m,η) such that

$$q_M(s) = c_q^{-1}\left(\frac{p_\tau(s)-\tau}{1-\eta}\right) = D(p_\tau(0))\frac{\underline{\mu}(\eta)}{m}$$

does not sabotage. The second part of the proof is direct: clearly, for any $\mu < \underline{\mu}(\eta)$, the LHS of (A.6) is strictly negative. ■

B. Vertical integration without sabotage

In this appendix we formally derive Figure 2.

B.1. Characterization of equilibria

To analyze vertical integration we study the monopolist's decision, which the next proposition characterizes. Basically, the result says that, depending on η and m, the monopolist's subsidiary may exclude independent firms, limit price or coexist acting as a price taker.

Proposition B.1 (The bottleneck monopolist's decision). *Subsidiary (m,η) with $\eta \geq 0$:*

(i) sets $p_M < p_\tau$ and efficiently excludes independent firms if

$$\eta > \eta^{EE}(m); \tag{B.1}$$

(ii) limit-prices at p_τ if

$$\eta^{LP}(m) \leq \eta \leq \eta^{EE}(m); \tag{B.2}$$

(iii) coexists and sets q_M such that

$$p_\tau - (1-\eta)c_q(q_M) = \tau \tag{B.3}$$

if

$$0 \leq \eta < \eta^{LP}(m). \tag{B.4}$$

with $\eta^{EE}(m) = 1 - (p_\tau(1-1/\varepsilon))/c_q\left(\frac{D(p_\tau)}{m}\right)$ and $\eta^{LP}(m) = 1-(p_\tau - \tau)/c_q\left(\frac{D(p_\tau)}{m}\right)$.

Moreover:

(iv) If $\eta < 0$ the monopolist remains vertically separated.

Proof. The proof consists in comparing profits under different alternatives. (a) With vertical separation the monopolist makes profits equal to $\tau D(p_\tau)$. (b) With vertical integration, profits are

$$\pi = \begin{cases} p_\tau Q_M - m(1-\eta)C(q_M) + \tau[D(p_\tau) - Q_M] & \text{if } Q_M < D(p_\tau) \\ p_\tau D(p_\tau) - m(1-\eta)C(q_M) & \text{if } Q_M \geq D(p_\tau) \end{cases} \tag{B.5}$$

The kink in π occurs exactly where the subsidiary's market share is 100%.

The FOC for maximizing (B.5) are

$$\begin{aligned} p_\tau - (1-\eta)c_q(q_M) - \tau &= 0 \text{ if } Q_M < D(p_\tau) \\ p_\tau - (1-\eta)c_q\left(\frac{D(p_\tau)}{m}\right) - \tau &\geq 0 \text{ if } Q_M \geq D(p_\tau) \end{aligned}$$

Proof of part (i) We can rewrite (B.1) as follows

$$\frac{(1-\eta)c_q\left(\frac{D(p_\tau)}{m}\right)}{(1-1/\varepsilon)} < p_\tau$$

which means that if (B.1) holds then, profit maximization implies that the monopolist wants to set a price $p_M = (1-\eta)c_q[D(p_\tau)/m]/(1-1/\varepsilon)$ which is smaller than p_τ. Consequently, the subsidiary efficiently excludes independent firms. We only have to show that the monopolist is better-off integrating into the downstream market, that is

$$p_M D(p_M) - m(1-\eta)C(q_M) > \tau D(p_\tau).$$

To see that that this is indeed the case note that

$$\left[p_M - (1-\eta)\tfrac{C(q_M)}{q_M}\right] D(p_M) \quad > \quad \left[p_\tau - (1-\eta)\frac{C\left(\frac{D(p_\tau)}{m}\right)}{\frac{D(p_\tau)}{m}}\right] D(p_\tau) \tag{B.6}$$

$$> \quad p_\tau - (1-\eta)c_q\left(\tfrac{D(p_\tau)}{m}\right) D(p_\tau),$$

where the first inequality follows from profit-maximization and the second from $c_q\left(\frac{D(p_\tau)}{m}\right) > \frac{C(D(p_\tau)/m)}{D(p_\tau)/m}$. In addition, $p_\tau - (1-\eta)c_q\left(\frac{D(p_\tau)}{m}\right) \geq \tau$, because for all $\tau \in [0, \tau_M]$ there exists $m = n_\tau = D(p_\tau)/q_0$ and $\eta_\tau \geq 0$ such that $p_\tau - (1-\eta_\tau)c_q(q_0) = p_\tau/\varepsilon$, i.e. $p_M = p_\tau$. Since $p_\tau = p_0 + \tau = c_q(q_0) + \tau$, it follows that $p_\tau - (1-\eta_\tau)c_q(q_0) = \eta_\tau p_\tau + \tau \geq \tau$. Hence, $p_\tau/\varepsilon = p_\tau - (1-\eta_\tau)c_q(q_0) \geq \tau$. This establishes the result.

Proof of part (ii) We can rewrite (B.2) as

$$\tau \leq p_\tau - (1-\eta)c_q\left(\tfrac{D(p_\tau)}{m}\right) \leq \frac{1}{\varepsilon}p_\tau.$$

Then, we have that $p_M > p_\tau$ which means that the monopolist cannot efficiently exclude and must take price p_τ. But the subsidiary grabs the whole market because the necessary FOC condition to maximize (B.5) holds at $Q_M = D(p_\tau)$. To see that vertical integration is profitable, note that the FOC implies that

$$p_\tau - (1-\eta)c_q\left(\tfrac{D(p_\tau)}{m}\right) \geq \tau;$$

but because $c_q\left(\frac{D(p_\tau)}{m}\right) = C\left(\frac{D(p_\tau)}{m}\right)/\frac{D(p_\tau)}{m}$,

$$p_\tau - \frac{(1-\eta)c_q}{\frac{D(p_\tau)}{m}} \geq \tau$$

$$\Longleftrightarrow p_\tau D(p_\tau) - (1-\eta)\cdot m \cdot C\left(\tfrac{D(p_\tau)}{m}\right) \geq \tau D(p_\tau)$$

which completes the proof.

Proof of part (iii) We can rewrite (B.3) as $p_\tau - (1-\eta)c_q(D(p_\tau)/m) < \tau$, which implies that $p_M > p_\tau$. In addition, $p_\tau - (1-\eta)c_q(q_M) = \tau$ satisfies the FOC, hence the subsidiary coexists with independent firms and $Q_M < D(p_\tau)$. Now note that a subsidiary with $\eta = 0$ and $m < n_\tau$ sets $q_M = q_0$, and earns $p_\tau - c_q(q_0) = \tau$ per unit sold. Hence, the monopolist is indifferent between integrating and not. For any subsidiary with $\eta > 0$, the price–cost margin is τ for the last unit sold, and greater than τ for the inframarginal units. Hence, on average the monopolist earns higher profits with vertical integration.

Proof of part (iv) Last, note that with diseconomies of scope ($\eta < 0$), $p_\tau - (1-\eta)c_q(q_M) = \tau$ if and only if $q_M < q_0$. Hence the monopolist is better off by not integrating into the downstream market. ■

B.2. Intuition

Before moving on, here we discuss the economics behind Proposition B.1.

Figure B1 about here

Figure B1 shows the demand curve confronted by the subsidiary for a given τ. Free entry implies that firms are willing to produce any quantity demanded at price p_τ. Thus the relevant demand curve is kinked with the traditional discontinuity of its marginal revenue curve, and the four types of equilibria summarized in the Proposition emerge.

To begin, assume that the subsidiary is very efficient and its marginal cost curve is, say, MC_1. Then the subsidiary ignores independent firms and sets $p = p_M < p_\tau$. Consequently, Figure 2 indicates that for (m, η) in Region I independent firms are efficiently excluded.

Clearly, the access charge τ is irrelevant inside Region I. On the other hand, τ is relevant for a subsidiary with marginal cost curve $\text{MC}_2 + \tau$, who limit-prices firms. In this case the subsidiary enjoys of economies of scope and collects a unit margin higher than τ which increases with τ. Subsidiaries (m, η) who limit-price are in Region II of Figure 2.

Next, as the proposition indicates, any monopolist with $\eta > 0$ will at least coexist with firms. Consider a monopolist with marginal cost curve $\text{MC}_3 + \tau$. Initially η yields a cost advantage over firms, and it always pays to take advantage of this margin until diminishing returns set in. After marginal costs reach p_τ, the monopolist earns more by selling the input to downstream firms and collecting τ per unit sold.

Last, in Region IV, where $\eta < 0$, the bottleneck monopoly does not integrate into the downstream market because it would obtain a smaller margin than τ at any scale of production, even when $\tau = 0$. This again highlights the importance of entry. If firms were price takers but their number fixed, then an inefficient monopolist would find it profitable to set up a subsidiary and restrict production. But, as we have seen, entry effectively transforms the subsidiary into a price taker in the downstream market and erodes any rents that could be appropriated by vertically integrating and restricting output.

C. Vertical integration with sabotage

We now show that if τ is low enough, the sabotage decision is characterized by Figure 3. We proceed as follows. Lemma C.1 shows that there exist downward-sloping functions $\eta^A(m)$, $\eta^B(m)$ and $\eta^C(m)$ like those depicted in Figure 3. Then Lemma C.2 shows that they are ordered such as in the figure. Last, we state a corollary that completes the characterization. In what follows it will be useful to define function Π as

$$\pi(s; m, \eta) \equiv \Pi(s; m, \eta) - \psi(s).$$

That is, function Π is the profit function gross of direct sabotage costs.

Lemma C.1. *There exist the following continuous downward-sloping functions defined on* $(0, n_\tau]$*:*

(i) $\eta^A(m)$ *defined by*

$$\frac{d\Pi}{ds}(0; m, \eta^A(m)) - \psi'(0) \equiv 0 \tag{C.1}$$

with $\frac{d\Pi}{ds}(s; m, \eta) = D(p_\tau(s)) \left[1 - \frac{p_\tau(s) - (1-\eta)c_q(q_M)}{p_\tau(s)} \varepsilon\right] \frac{dp_\tau}{ds}$. *This characterizes limit-pricers who set* $s_o = 0$ *but satisfy the FOC;*

(ii) $\eta^B(m)$ *defined by*

$$p_\tau(s_o^{\max}) - \tau = [1 - \eta^B(m)] c_q \left(\frac{D(p_\tau(s_o^{\max}))}{m}\right); \tag{C.2}$$

(iii) $\eta^C(m)$ *defined by*

$$\Pi[s_o; m, \eta^C(m)] - \psi(s_o) = \begin{cases} \Pi(0; m, \eta^C(m)) & \text{if } m \le m^C; \\ \tau D(p_\tau(0)) & \text{if } m \ge m^C, \end{cases} \tag{C.3}$$

with m^C *defined by*

$$\Pi(s_o; m^C, 0) - \psi(s_o) = \Pi(0; m^C, 0) = \tau D(p_\tau(0))$$

and

$$\Pi(s; m, \eta)) = p_\tau(s) Q_M(p_\tau(s)) - m(1-\eta) C\left(q_M(p_\tau(s))\right) + \tau\left[D(p_\tau(s)) - Q_M(p_\tau(s))\right].$$

REMARK Note that two different cases can occur for monopolists who coexist and are indifferent between sabotaging and not. First, the marginal cost function ψ' may intersect the marginal benefit function $\frac{d\Pi}{ds}$ only once. In that case equation (C.3) does not define an implicit function when $\eta > 0$ because it is not only satisfied for those who are just indifferent, but for all monopolists with subsidiaries that coexist without sabotage. Additionally, the implicit function is obtained from $\frac{d\Pi}{ds}(0; m, \eta^C(m)) - \psi'(0) = 0$, a case that can be treated like (i) changing the marginal utility function. Given that, we only consider the case where ψ' and $\frac{d\Pi}{ds}$ intersect either twice or don't intersect at all. Then $\Pi(s_o; m, \eta) - \psi(s_o) = \Pi(0; m, \eta)$ does indeed define an implicit function. ■

Proof. The proof is an application of the Implicit Function Theorem. In each case we have an expression of the form $F(m, \eta(m)) = 0$ which defines implicitly η as a function of m. The slope of this function is $\frac{d\eta}{dm} = -\frac{F_m}{F_\eta}$ (when $F_\eta \neq 0$) with F_m and F_η the respective partial derivatives.

Proof of part (i) $F(m,\eta) \equiv \frac{d\Pi}{ds}(0;m,\eta) - \psi'(0)$. Then

$$\begin{aligned} F_m &= \frac{\partial}{\partial m}\left[\frac{d\Pi}{ds}(0;m,\eta)\right] < 0, \\ F_\eta &= \frac{\partial}{\partial \eta}\left[\frac{d\Pi}{ds}(0;m,\eta)\right] < 0 \end{aligned}$$

because, for subsidiaries (m,η) who limit price, marginal profit falls at 0 as the subsidiary becomes larger or more efficient. Hence $-\frac{F_m}{F_\eta} < 0$.

Proof of part (ii) $F(m,\eta) \equiv p_\tau(s_o^{\max}) - \tau - [1-\eta]c_q\left(\frac{D(p_\tau(s_o^{\max}))}{m}\right)$. Then

$$\begin{aligned} F_m &= (1-\eta)c_{qq}\tfrac{D}{m^2}; \\ F_\eta &= c_q. \end{aligned}$$

Thus

$$\frac{d\eta^B}{dm} = -\frac{(1-\eta)D}{m^2}\frac{c_{qq}}{c_q} < 0,$$

because c_q and c_{qq} are positive.

Proof of part (iii) When $m \le m^C$, $F(m,\eta) \equiv \Pi(s_o;m,\eta) - \psi(s_o) - \Pi(0;m,\eta)$. Then

$$\begin{aligned} F_m &= \left(\frac{d\Pi}{ds} - \frac{d\psi}{ds}\right)\frac{\partial s}{\partial m} + \frac{\partial \Pi}{\partial m}(s_o) - \frac{\partial \Pi}{\partial m}(0) \\ &= \frac{\partial \Pi}{\partial m}(s_o) - \frac{\partial \Pi}{\partial m}(0) \end{aligned}$$

because s_o satisfies the first order condition $\frac{d\Pi}{ds}(s_o) - \psi'(s_o) = 0$. Similarly

$$F_\eta = \frac{\partial \Pi}{\partial \eta}(s_o) - \frac{\partial \Pi}{\partial \eta}(0).$$

Now, the partial derivatives $\frac{\partial \Pi}{\partial m}(s)$ and $\frac{\partial \Pi}{\partial \eta}(s)$ are

$$\begin{aligned} \frac{\partial \Pi}{\partial m}(s) &= (1-\eta)\left[q_M \cdot c_q - C\right], \\ \frac{\partial \Pi}{\partial \eta}(s) &= m \cdot C, \end{aligned}$$

with, as always, $q_M \equiv Q_M[p_\tau(s);m,\eta]/m$. Both derivatives are increasing in s because

$$\begin{aligned} \frac{d}{ds}\left(\frac{\partial \Pi}{\partial m}\right) &= (1-\eta)\left(c_q + q_M c_{qq} - c_q\right)\tfrac{dq_M}{ds} \\ &= (1-\eta)\cdot q_M \cdot c_{qq}\frac{dq_M}{ds} > 0, \\ \frac{d}{ds}\left(\frac{\partial \Pi}{\partial \eta}\right) &= m \cdot c_q \tfrac{dq_M}{ds} > 0 \end{aligned}$$

because $\frac{dq_M}{ds}$ is positive for all subsidiaries who optimally coexist. Thus F_m and F_η have the same sign and we conclude that

$$\frac{d\eta^A}{dm} = -\frac{F_m}{F_\eta} < 0.$$

When $m \ge m^C$, $\Pi(0;m,\eta)$ is replaced by $\tau D[p_\tau(0)]$ which does not depend on m nor η. Thus, in this case we have

$$\frac{d\eta^A}{dm} = -\frac{\frac{\partial \Pi}{\partial m}(s_o)}{\frac{\partial \Pi}{\partial \eta}(s_o)},$$

which is clearly negative because, for a given s, Π increases with size and economies of scope. ■

Lemma C.2. *(i)* $\lim_{m\to 0}\eta^A = \lim_{m\to 0}\eta^B = \lim_{m\to 0}\eta^C = 1$; *(ii)* $\eta^A(n_\tau) > 0$; *(iii)* $\eta^B(n_\tau) < \eta^C(n_\tau) < 0$; *(iv) for all* $m \in (0, n_\tau]$, $\eta^A(m) > \eta^B(m)$; *(v)* $\eta^B(m) > \eta^C(m)$ *iff* $m \in (0, m^*)$ *and* $\eta^B(m) < \eta^C(m)$ *iff* $m \in (m^*, n_\tau]$ *with* $m^* > m^C$.

Proof of part (i) We show that for η arbitrarily close to 1 there always exists an m such that $\eta^A(m) = \eta$, that is, η^A gets as close as possible to 1 and the pair (m, η) satisfies equation (C.1). First note that equation (C.1) can be rewritten as

$$(1-\eta)c_q\left(\tfrac{D(p_\tau(0))}{m}\right) = p_\tau(0)\left[1 - \frac{1}{\varepsilon} + \frac{\psi'(0)}{\varepsilon D(p_\tau(0))\frac{dp_\tau}{ds}}\right] \tag{C.4}$$

In this equation only $(1-\eta)c_q\left(\frac{D(p_\tau(0))}{m}\right)$ depends on η and m. Now we can rewrite (C.4) as

$$\eta^A(m) = 1 - \frac{p_\tau(0)}{c_q\left(\frac{D(p_\tau(0))}{m}\right)}\left[1 - \frac{1}{\varepsilon} + \frac{\psi'(0)}{\varepsilon D(p_\tau(0))\frac{dp_\tau}{ds}}\right]$$

which implies that

$$\lim_{m\to 0}\eta^A(m) = 1 - \lim_{m\to 0}\frac{H}{c_q\left(\frac{D(p_\tau(0))}{m}\right)} = 1$$

where H is a bounded constant and $\lim_{m\to 0} c_q(D(p_\tau(0))/m = \infty$.

Next consider the equation satisfied by $(m, \eta^B(m))$

$$p_\tau(s_o^{\max}) - \tau = (1-\eta)c_q\left(\frac{D\left(p_\tau(s_o^{\max})\right)}{m}\right)$$

which can be rewritten as

$$\eta^B(m) = 1 - \frac{p_\tau(s_o^{\max}) - \tau}{c_q\left(\frac{D\left(p_\tau(s_o^{\max})\right)}{m}\right)}$$

which as before means that $\lim_{m\to 0}\eta^B(m) = 1$.

Finally consider the equation satisfied by $(m, \eta^C(m))$ when $m \le m^C$

$$p_\tau(s_o)Q_M(p_\tau(s_o)) - m(1-\eta^C(m))C\left(\tfrac{Q_M(p_\tau(s_o))}{m}\right) + \tau\left[D(p_\tau(s_o)) - Q_M(p_\tau(s_o))\right] - \psi(s_o) =$$
$$p_\tau(0)Q_M(p_\tau(0)) - m(1-\eta^C(m))C\left(\tfrac{Q_M(p_\tau(0))}{m}\right) + \tau\left[D(p_\tau(0)) - Q_M(p_\tau(0))\right]$$

which implies that

$$\eta^C(m) = 1 - \frac{\left\{\begin{array}{c}\tau\left[D(p_\tau(s_o)) - D(p_\tau(0)\right] + Q_M(p_\tau(0)) - Q_M(p_\tau(s_o)) \\ +p_\tau(s_o)Q_M(p_\tau(s_o)) - p_\tau(0)Q_M(p_\tau(0)) - \psi(s_o)\end{array}\right\}}{m\left[C\left(\frac{Q_M(p_\tau(0))}{m}\right) - C\left(\frac{Q_M(p_\tau(s_o))}{m}\right)\right]}$$

and $\lim_{m\to 0}\eta^C(m) = 1$ as $\lim_{m\to 0} s_o(m) = 0$.

Proof of part (ii) All subsidiaries $(m, \eta^A(m))$ limit price with $s_o = 0$ and the bottleneck monopoly always prefers to integrate. Then all such subsidiaries must have $\eta > 0$, otherwise the bottleneck monopoly would rather remain vertically separated.

Proof of part (iii) With subsidiary $(n_\tau, \eta^B(n_\tau))$ the bottleneck monopoly loses money with vertical integration and does not satisfy the participation constraint. Then $\eta^B(n_\tau)$ must lie below $\eta^C(n_\tau)$, which defines that participation constraint.

Proof of part (iv) Fix m and consider subsidiary $(m, \eta^B(m))$. Then the bottleneck monopolist sabotages just enough to prompt the subsidiary to limit price and grab the whole market. Now subsidiary $(m, \eta^A(m))$ also grabs the whole market, but then the bottleneck monopoly is indifferent between sabotaging and not. That subsidiary must be more efficient than the one that prompts the monopolist to sabotage just enough to limit price, that is, $\eta^A(m) > \eta^B(m)$; otherwise the subsidiary would only coexist.

Proof of part (v) First, when $m < m^C$ we apply a similar argument as in (iv). Fix m and consider subsidiary $(m, \eta^B(m))$. This subsidiary must coexist with a market share strictly less than one and must be more efficient than subsidiary $(m, \eta^C(m))$. Now, when $m > m^C$, we know that: $\eta^C(m) < 0$; $\eta^B(m^C) > \eta^C(m^C) = 0$; and $\eta^B(n_\tau) < \eta^C(n_\tau) < 0$. By continuity they must intersect at some point m^*, and the intersection is unique because on $\eta^B(m)$ profits monotonically fall as m increases and along $\eta^C(m)$ profits are zero by definition. Obviously $\eta^B(m^*) = \eta^C(m^*) < 0$. This completes the proof. ■

Corollary C.3. *Functions $\eta^A(m)$, $\eta^B(m)$ and $\eta^C(m)$ split the (m, η) space in open sets A, B, C, D and E, where*

(i) A is the open set of all subsidiaries (m, η) with $\eta > \eta^A(m)$ such that the bottleneck monopoly strictly prefers to vertically integrate, does not sabotage and has $\mu = 1$.

(ii) B is the open set of all subsidiaries (m, η) with $\eta^A(m) \geq \eta > \eta^B(m)$ for all $m < m^*$ and $\eta^A(m) \geq \eta > \eta^C(m)$ for all $m \geq m^*$ such that the bottleneck monopoly strictly prefers to vertically integrate, sabotage and has $\mu = 1$.

(iii) C is the open set of all subsidiaries (m, η) with $\eta^B(m) \geq \eta > \eta^C(m)$ such that the bottleneck monopolist strictly prefers to vertically integrate, sabotage and has $\mu < 1$.

(iv) D is the open set of all subsidiaries (m, η) with $\eta^C(m) \geq \eta > 0$ such that the bottleneck monopolist strictly prefers to vertically integrate, does not sabotage and has $\mu < 1$.

(v) E is the open set of all subsidiaries (m, η) with $\min(0, \eta^C(m)) \geq \eta$ such that the bottleneck monopolist strictly prefers to remain vertically separated.

Proof. The proof follows directly from the former analysis. ■

Table 1
Largest market share such that the bottleneck monopoly doesn't sabotage (in percentage)

$\varepsilon \downarrow$ / $\frac{\tau}{p_\tau} \rightarrow$	**0.05**	**0.1**	**0.15**	**0.2**	**0.25**	**0.3**	**0.35**	**0.4**	**0.45**	**0.5**	**0.55**	**0.6**	**0.65**	**0.7**	**0.75**	**0.8**	**0.85**	**0.9**	**0.95**	**1.0**
0.1	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	10.0
0.2	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
0.3	1.5	3.0	4.5	6.0	7.5	9.0	10.5	12.0	13.5	15.0	16.5	18.0	19.5	21.0	22.5	24.0	25.5	27.0	28.5	30.0
0.4	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0	24.0	26.0	28.0	30.0	32.0	34.0	36.0	38.0	40.0
0.5	2.5	5.0	7.5	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0	32.5	35.0	37.5	40.0	42.5	45.0	47.5	50.0
0.6	3.0	6.0	9.0	12.0	15.0	18.0	21.0	24.0	27.0	30.0	33.0	36.0	39.0	42.0	45.0	48.0	51.0	54.0	57.0	60.0
0.7	3.5	7.0	10.5	14.0	17.5	21.0	24.5	28.0	31.5	35.0	38.5	42.0	45.5	49.0	52.5	56.0	59.5	63.0	66.5	70.0
0.8	4.0	8.0	12.0	16.0	20.0	24.0	28.0	32.0	36.0	40.0	44.0	48.0	52.0	56.0	60.0	64.0	68.0	72.0	76.0	80.0
0.9	4.5	9.0	13.5	18.0	22.5	27.0	31.5	36.0	40.5	45.0	49.5	54.0	58.5	63.0	67.5	72.0	76.5	81.0	85.5	90.0
1.0	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100
1.5	7.5	15.0	22.5	30.0	37.5	45.0	52.5	60.0	67.5	75.0	82.5	90.0	97.5	100	100	100	100	100	100	100
2.0	10.0	20.0	30.0	40.0	50.0	60.0	70.0	80.0	90.0	100	100	100	100	100	100	100	100	100	100	100
3.0	15.0	30.0	45.0	60.0	75.0	90.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100
5.0	25.0	50.0	75.0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Note: For a given ratio τ / p_τ and demand elasticity ε, the table shows the maximum market share μ of the subsidiary such that the bottleneck monopoly has no incentive to sabotage. For example, if $\tau / p_\tau = 0.2$ and $\varepsilon = 0.7$, then the sufficient no-sabotage condition (3.6) will hold only for subsidiaries with a market share of less than 14.0%.

Table 2
Subsidiary's marginal cost
such that efficient exclusion is profitable
(as percentage of an independent's firm marginal cost)

$\varepsilon \downarrow$	$\lambda_\tau \equiv \frac{\tau}{c_q(q_0)} \rightarrow$											$\frac{\tau_M}{c_q(q_0)}$
	0.0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**	
1.1	9.1	10.0	10.9	11.8	12.7	13.6	14.5	15.5	16.4	17.3	18.2	10.0
1.2	16.7	18.3	20.0	21.7	23.3	25.0	26.7	28.3	30.0	31.7	33.3	5.00
1.3	23.1	25.4	27.7	30.0	32.3	34.6	36.9	39.2	41.5	43.8	46.2	3.33
1.4	28.6	31.4	34.3	37.1	40.0	42.9	45.7	48.6	51.4	54.3	57.1	2.50
1.5	33.3	36.7	40.0	43.3	46.7	50.0	53.3	56.7	60.0	63.3	66.7	2.00
2	50.0	55.0	60.0	65.0	70.0	75.0	80.0	85.0	90.0	95.0	100	1.00
3	66.7	73.3	80.0	86.7	93.3	100	-	-	-	-	-	0.50
4	75.0	82.5	90.0	97.5	-	-	-	-	-	-	-	0.33
5	80.0	88.0	96.0	-	-	-	-	-	-	-	-	0.25
10	90.0	99.0	-	-	-	-	-	-	-	-	-	0.11

Note: For a given ratio $\tau / c_q(q_0)$ and demand elasticity ε the table shows the subsidiary's marginal cost, as a percentage of an independent firm's marginal cost, such that $p_M = p_\tau(0)$. For example, if $\lambda_\tau = 0.2$ and $\varepsilon = 1.2$, then for the subsidiary to set $p_M = p_\tau(0)$, its marginal cost would have to be 20.0% of an independent's firm marginal cost. The last column shows the maximum λ_τ that could possibly be observed for the respective elasticity─when $\tau = \tau_M$ and the access charge maximizes the bottleneck monopolist's profits.

Table 3
Simulation results

(a)
Aggregate welfare and sabotage (vertical separation = 100)

$\eta\downarrow$ $m\rightarrow$	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*	*279,8*
0,90	163,3	213,2	230,5	239,1	244,0	247,1	249,1	250,4	251,3	251,9	*252,9*
0,80	130,0	161,1	192,8	208,9	218,2	224,1	227,9	230,5	232,2	233,3	233,9
0,70	119,1	137,6	157,6	180,0	193,3	201,7	207,2	210,9	213,3	214,9	215,8
0,60	113,4	125,7	138,7	152,6	169,2	179,9	187,0	191,7	194,8	196,7	197,8
0,50	109,7	118,1	126,9	136,3	146,1	158,7	167,1	172,8	176,5	178,8	180,1
0,40	107,0	112,6	118,5	124,7	131,3	138,2	147,7	154,2	158,4	161,1	162,5
0,30	104,9	108,3	112,0	115,8	119,9	124,3	128,9	135,9	140,6	143,5	145,1
0,20	103,2	104,8	106,5	108,5	110,6	112,9	115,5	118,2	123,1	126,2	127,9
0,10	101,6	101,7	101,9	102,2	102,6	103,3	104,0	104,9	106,0	109,1	110,8
0,09	101,5	101,4	101,4	101,6	101,9	102,4	103,0	103,7	104,6	107,4	109,1
0,08	101,4	101,1	101,0	101,0	101,2	101,5	101,9	102,5	103,2	105,7	107,4
0,07	101,2	100,8	100,6	100,4	100,5	100,6	100,9	101,3	101,9	104,0	105,7
0,06	101,1	100,6	100,2	99,9	99,7	99,7	99,8	100,1	100,5	102,3	104,0
0,05	100,9	100,3	99,7	99,3	99,0	98,9	98,8	98,9	99,2	100,6	102,3
0,04	100,8	100,0	99,3	98,8	98,3	98,0	97,8	97,8	97,9	98,9	100,6
0,03	100,7	99,7	98,9	98,2	97,6	97,2	96,8	96,6	96,6	97,2	98,9
0,02	100,5	99,5	98,5	97,7	96,9	96,3	95,9	95,5	95,3	95,5	97,2
0,01	100,4	99,2	98,1	97,1	96,3	95,5	94,9	94,4	94,0	93,8	95,6
0	100	98,9	97,7	96,6	95,6	94,7	93,9	93,3	92,8	92,4	93,9

(b)
Consumer welfare and sabotage: (vertical separation = 100)

$\eta\downarrow$ $m\rightarrow$	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*	*112.2*
0,90	85.0	92.7	95.7	97.2	98.1	98.7	99.2	99.5	99.8	100.0	*101.0*
0,80	93.7	85.0	90.0	92.7	94.5	95.7	96.5	97.2	97.7	98.1	98.4
0,70	96.5	90.8	85.0	88.6	91.1	92.7	94.0	94.9	95.7	96.3	96.8
0,60	97.9	93.7	89.4	85.0	87.8	90.0	91.5	92.7	93.7	94.5	95.1
0,50	98.7	95.3	92.0	88.5	85.0	87.3	89.2	90.6	91.8	92.7	93.5
0,40	99.2	96.5	93.7	90.8	88.0	85.0	86.9	88.6	90.0	91.1	92.0
0,30	99.6	97.3	94.9	92.5	90.0	87.5	85.0	86.6	88.2	89.4	90.5
0,20	99.9	97.9	95.8	93.7	91.5	89.4	87.2	85.0	86.4	87.8	89.0
0,10	100	98.4	96.5	94.7	92.8	91.0	89.1	87.2	85.2	86.3	87.5
0,09	100	98.4	96.5	94.7	92.8	91.0	89.1	87.2	85.2	86.1	87.4
0,08	100	98.4	96.6	94.8	92.9	91.1	89.2	87.3	85.4	86.0	87.2
0,07	100	98.4	96.6	94.8	93.0	91.2	89.3	87.5	85.6	85.8	87.1
0,06	100	98.5	96.7	94.9	93.1	91.3	89.5	87.6	85.8	85.7	87.0
0,05	100	98.5	96.8	95.0	93.2	91.4	89.6	87.8	86.0	85.5	86.8
0,04	100	98.5	96.8	95.1	93.3	91.5	89.8	88.0	86.1	85.3	86.7
0,03	100	98.6	96.9	95.1	93.4	91.6	89.9	88.1	86.3	85.2	86.5
0,02	100	98.6	96.9	95.2	93.5	91.8	90.0	88.2	86.5	85.0	86.4
0,01	100	98.6	97.0	95.3	93.6	91.9	90.1	88.4	86.6	84.9	86.3
0	100	98.7	97.0	95.3	93.7	92.0	90.3	88.5	86.8	85.0	86.1

Figure 1
Sabotage and the subsidiary's market share

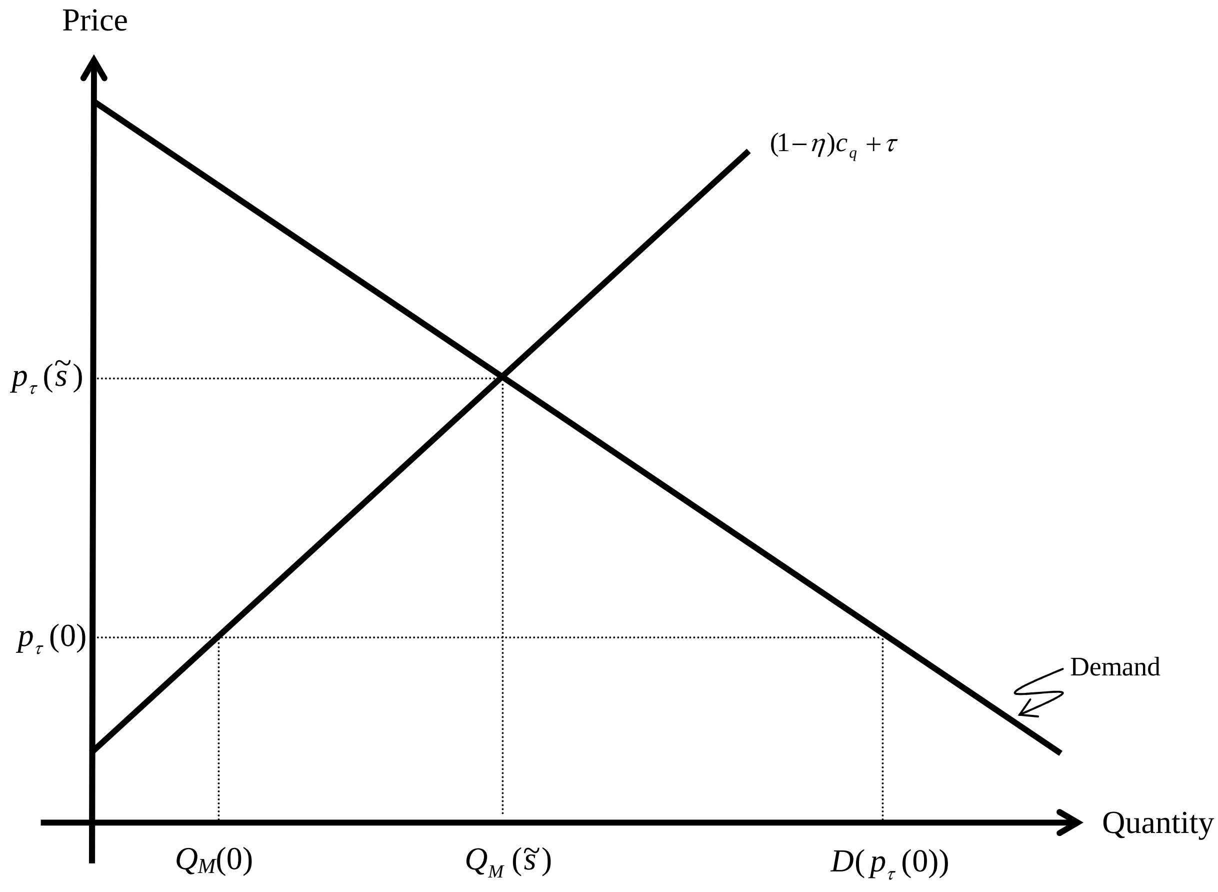

Figure 1 shows how the subsidiary's sales depend on the intensity of sabotage. As the intensity of sabotage increases, so does the equilibrium price. The subsidiary moves up its marginal cost curve and its market share increases. When the intensity of sabotage reaches $\tilde{s}$, the subsidiary grabs the whole market.
Note that the subsidiary's marginal cost includes the access charge τ ---when increasing sales the subsidiary sells less access to independent firms and incurs an opportunity cost.

Figure 2
Vertical integration with no sabotage

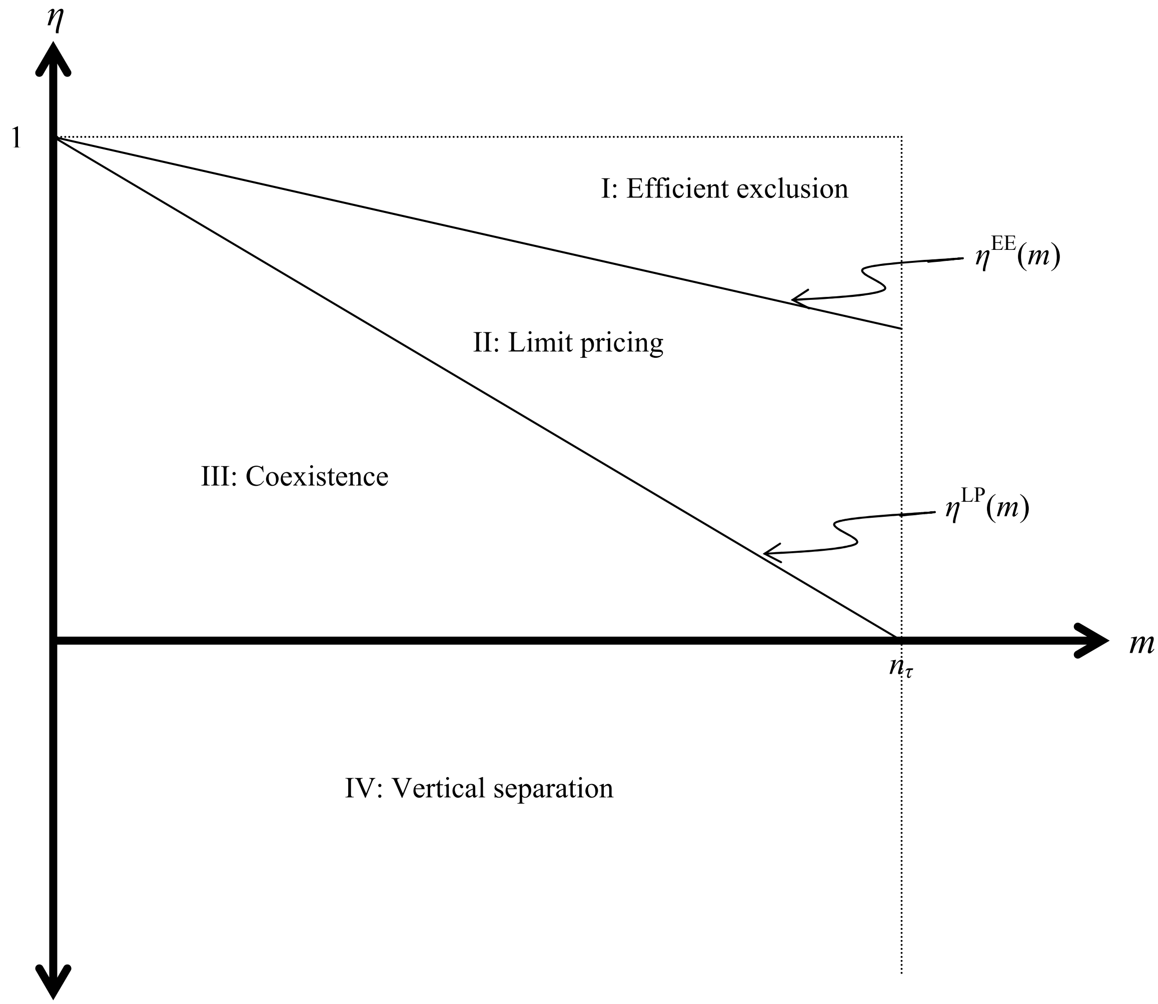

Figure 2 shows the types of equilibria and incentives to vertically integrate as a function of economies of scope (η) and the size of the monopolist's subsidiary (*m*).

The monopolist vertically integrates if there are some economies of scope ($0 < \eta \leq 1$), which occurs in regions I, II and III; it does not integrate if there are diseconomies of scope $\eta < 0$, which occurs in Region IV.

A very efficient subsidiary excludes all independent firms simply by setting its unconstrained monopoly price; this is Region I, where economies of scope are large. In Region II the subsidiary limit prices competitors. All sales are made by the subsidiary, but the price is set by the minimum average cost of a potential entrant. Finally, in Region III the subsidiary coexists with independent firms, which set the price (see Figure 1).

Note that all lines stop when $m = n_\tau$, where n_τ is the number of independent firms that would enter the market when the access charge is τ and the monopolist does not establish a subsidiary. This is the maximum number of independent firms that will ever enter the market in equilibrium.

Figure 3
Vertical integration with sabotage

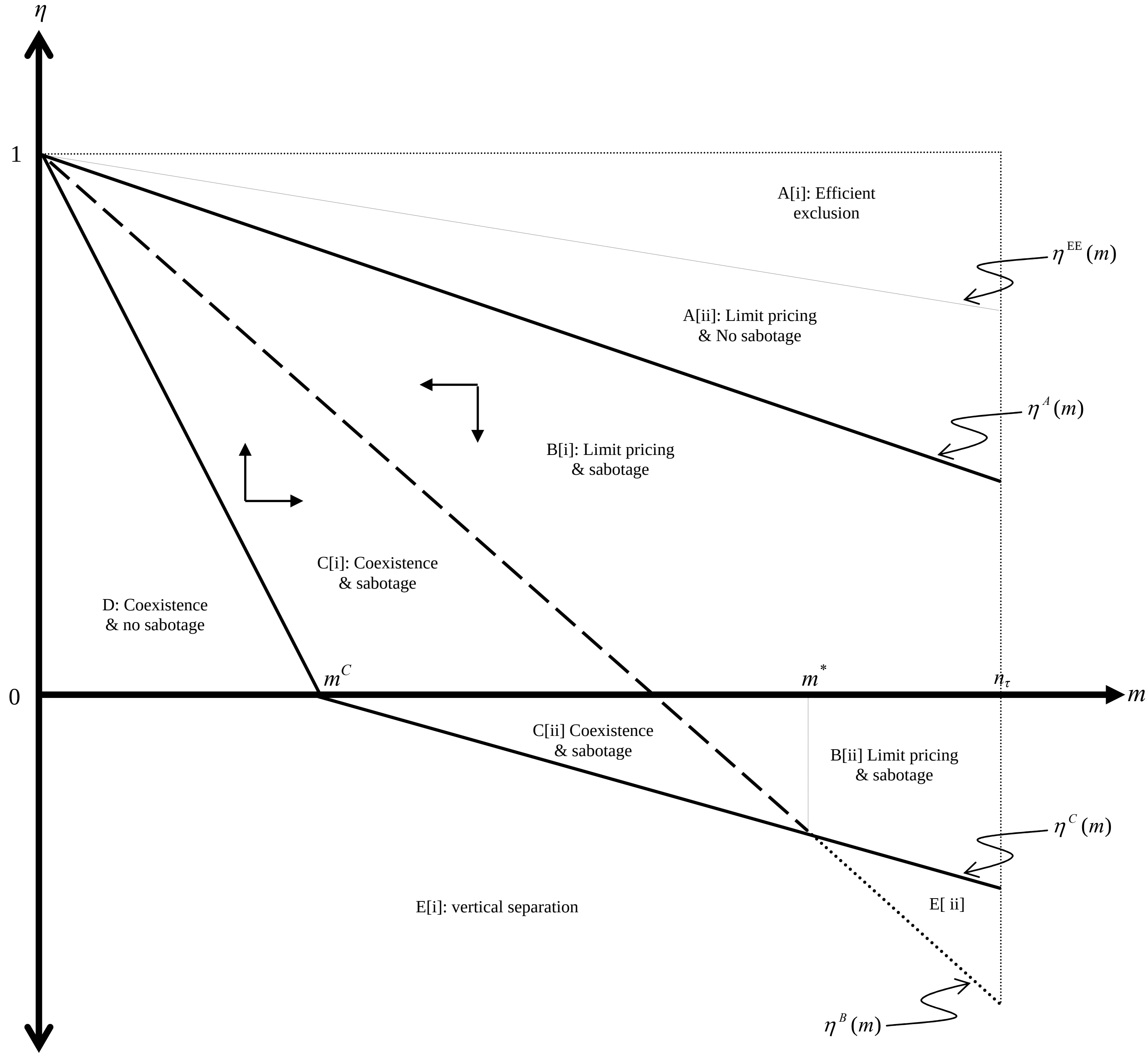

Figure 4
Welfare and vertical integration

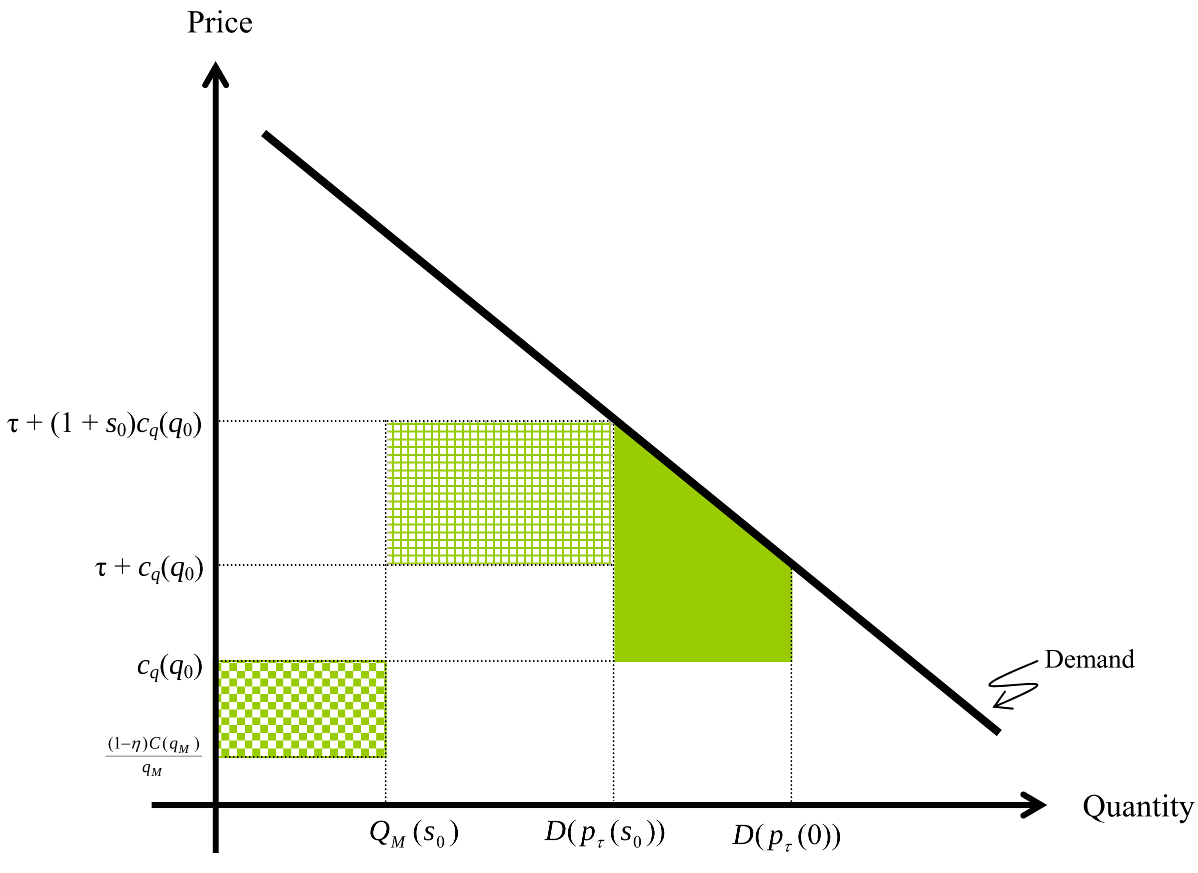

Figure 4 shows the change in welfare wrought by vertical integration when the subsidiary and independent firms coexist. The shaded area is the welfare loss due to the fall of consumption. The gridded area is the welfare loss due to the increase in the independent firms' cost preoduced by sabotage. Last, the checkered area is the welfare gain produced by the subsidiary's economies of scope. Note that the direct cost of sabotage incurred by the bottleneck monopolist is not shown in the figure.

Figure B1
Vertical integration with no sabotage

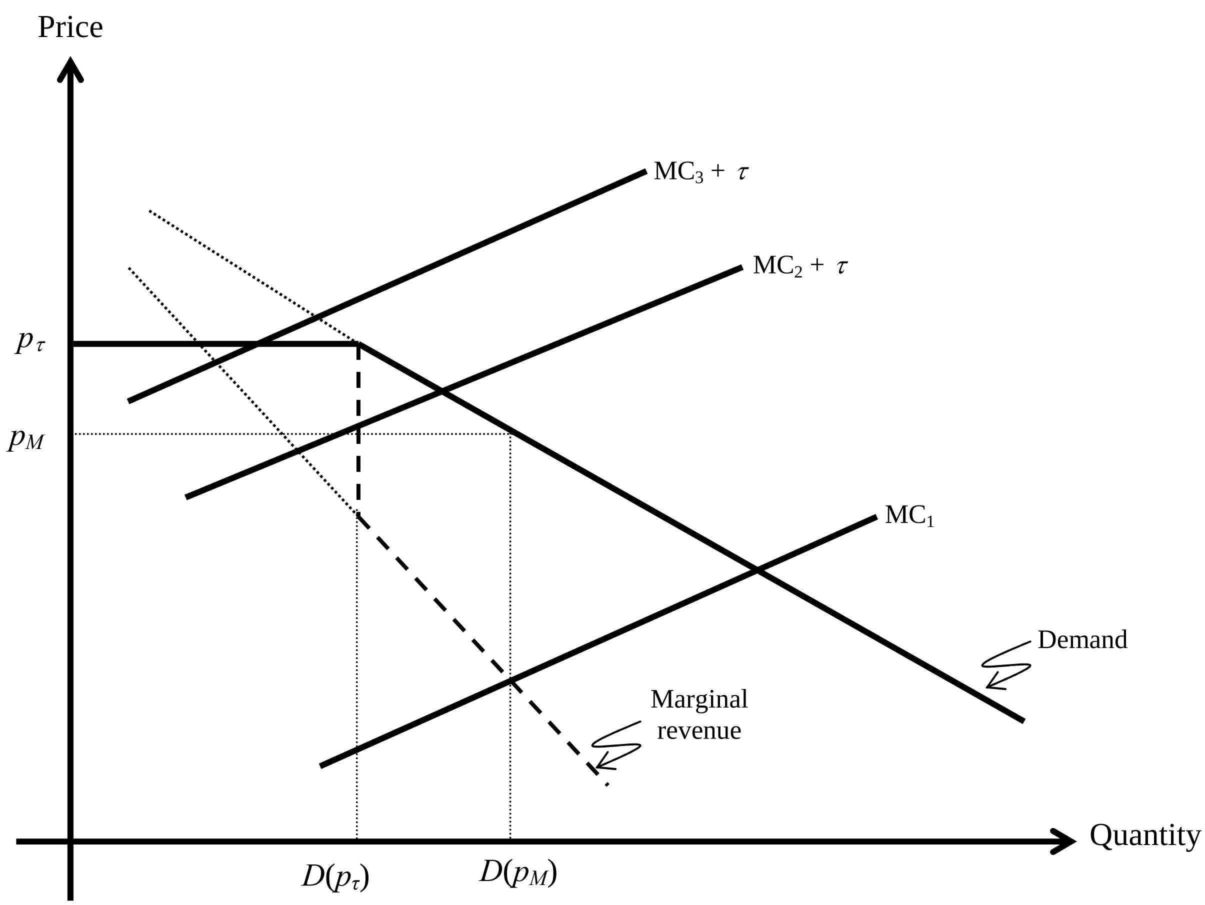

Figure B1 shows how the vertical integration decision depends on the subsidiary's cost. A low-cost subsidiary with marginal cost curve MC_1 will set a monopoly price below p_τ; this is efficient exclusion, Region I en Figure 2. A subsidiary with a marginal cost curve like MC_2 will limit price independent firms by charging p_τ; this is region 2 in Figure 2. Subsidiaries with still higher costs, like MC_3 will, coexist; this is Region III in Figure 2.