Journal of Regulatory Economics; 27:2 155–175, 2005

Self-Sabotage*

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Abstract
We analyze the incentives of a vertically-integrated producer (VIP) to engage in "self-sabotage". Self-sabotage occurs when a VIP intentionally increases its upstream costs and/or reduces the quality of its upstream product. We identify conditions under which self-sabotage is profitable for the VIP even though it raises symmetrically the cost of the upstream product to all downstream producers and/or reduces symmetrically the quality of all downstream products. Under specified conditions, self-sabotage can enable a VIP to disadvantage downstream rivals differentially without violating parity requirements.

Key words: regulation, parity, sabotage

JEL Classification: L43, L51, L22

1. Introduction

A vertically-integrated producer (VIP) that sells essential inputs to competitors can have strong incentives to "sabotage" its competitors. Sabotage occurs when a VIP intentionally (and asymmetrically) disadvantages downstream rivals.[1] Sabotage

* We are grateful to David Mandy and an anonymous referee for helpful comments and suggestions.

1 See, for example, Economides (1998), Mandy (2000), Beard et al. (2001), Weisman and Kang (2001), Kondaurova and Weisman (2003), Bustos and Galetovic (2003), and Mandy and Sappington (2004). These studies, which build upon Salop and Scheffman's (1983, 1987) work on raising rivals' costs, often do not consider explicitly the costs of undertaking sabotage. Our analysis can be viewed as considering the particular costs of sabotage the VIP incurs when it attempts to disadvantage rivals without violating parity requirements.

may be implemented by raising asymmetrically the price at which inputs are sold to competitors, or reducing asymmetrically the quality of inputs sold to competitors, for example.[2] In an attempt to limit or preclude sabotage, regulators have imposed parity requirements on VIPs. In essence, parity requirements compel the VIP to provide the same services on the same terms and conditions to its retail affiliate and to competitors.[3]

The question addressed in this research is whether parity requirements are sufficient to deter a VIP from strategically disadvantaging its rivals. We find this is not necessarily the case, for the following reason. Parity requirements do not preclude a VIP from intentionally raising its own costs or reducing the quality of the inputs it supplies (i.e., engaging in "self-sabotage"), provided the ensuing higher costs or lower quality apply symmetrically to the VIP's retail affiliate and to downstream competitors. A VIP may have an incentive to engage in self-sabotage if the symmetric application of the resulting higher costs or lower quality harms competitors more than it harms the VIP. This may be the case, for instance, if a cost increase is particularly detrimental to competitors (because they face a greater risk of bankruptcy or use the more costly input more intensively than the VIP, for example) or if competitors serve customers that value service quality particularly highly.

These findings may not be entirely surprising in light of Williamson's (1968) observation that a firm might willingly concede to, or even orchestrate, a labor union's demand for a higher wage rate if the higher wage rate serves to increase a rival's marginal cost more than it increases the firm's own marginal cost.[4] Our primary contribution is to formalize and extend Williamson's important insight by specifying precisely the conditions under which a VIP will (and will not) engage in various forms of self-sabotage, and by identifying the factors that increase the attraction of self-sabotage to a VIP. We also analyze both a variety of strategic

2 Weisman (1995) and Sibley and Weisman (1998a,b), among others, demonstrate that the incentive to raise rivals' costs may be muted by upstream considerations. Higher costs for rivals reduce their downstream output, which, in turn, reduces their demand for upstream inputs supplied by the VIP. If the supply of those inputs is sufficiently profitable, the VIP may prefer not to raise its rivals' costs.

3 In the telecommunications industry, for example, many state regulatory commissions have implemented "performance measurement plans". These plans are designed to ensure that incumbent local exchange carriers do not disadvantage competitive local exchange carriers. Parity requirements are a key element of many of these plans. (The plan adopted in Texas, for example, is described in Southwestern Bell Telephone (2002). See Wood and Sappington (2004) for an analysis of one of these plans.) Furthermore, § 251 of the Telecommunications Act (1996) requires incumbent local exchange carriers to interconnect with rivals "on rates, terms, and conditions that are just, reasonable, and non-discriminatory". In addition, the Modification of Final Judgment, the agreement that facilitated the divestiture of the Bell System, required local exchange carriers to provision access to competitive long distance providers that was of the same "type, quality and price" that was provided to AT & T. See, for example, Fowler et al. (1986) and Weber (2003).

4 Also recall Seade's (1985) finding that there are conditions under which Cournot competitors can all gain simultaneously from a symmetric increase in their constant marginal cost of production.

behaviors in which a VIP might engage to disadvantage rivals without violating parity requirements and a variety of forms of downstream market competition.

Our analysis focuses on a setting in which the VIP engages in self-sabotage by intentionally increasing its upstream marginal cost of production. In this setting (described in section 2), we find that self-sabotage tends to be more profitable for the VIP the more downstream rivals it faces, the more homogeneous are its products and the products of its rivals, and the more inelastic is the demand for the VIP's downstream product. These factors become relevant when an increase in the VIP's upstream costs serves to increase the downstream marginal cost of rivals more than it increases the VIP's marginal cost of production. Absent this asymmetric effect of higher upstream costs, the VIP will not engage in cost-increasing self-sabotage in this canonical setting. These findings are reported in section 3.

Section 4 considers extensions of our basic model. We note in section 4 that a VIP may engage in cost-increasing self-sabotage even when doing so increases the VIP's downstream costs more than it increases rivals' costs. This can be the case, for example, if the regulated price for the VIP's upstream product is not compensatory,[5] or if the VIP derives non-pecuniary benefits (e.g., perquisites) from upstream cost increases. Section 4 also presents conditions under which a VIP will undertake quality-reducing self-sabotage, even though the self-sabotage serves to reduce symmetrically the quality of all downstream products. Section 5 summarizes the main implications of our research, and suggests directions for future research. The proofs of all formal conclusions are presented in Appendix A.[6]

2. Elements of the Basic Model

The VIP in our model is a monopoly supplier of an essential input that is employed in the production of a (downstream) retail product. The VIP's downstream affiliate and n symmetric rivals produce and market the retail product.[7]

For simplicity, both the upstream and downstream production technologies exhibit constant returns to scale.[8] The VIP's upstream marginal cost is c^u. The VIP sells the input to its downstream rivals at unit price w. We will write each rival's

5 See Biglaiser and DeGraba (2001), Mandy (2001), Beard et al. (2001), and Bustos and Galetovic (2003) for related insights with regard to the direct, asymmetric sabotage of rivals.

6 Appendix A provides the proofs of all propositions and corollaries stated in the text. These formal conclusions focus on settings in which the VIP's retail affiliate sets its price before the rivals set their prices. Appendix B demonstrates that the primary conclusions continue to hold when all competitors set prices simultaneously.

7 n is exogenous in our model. We restrict attention to parameter values for which all $n+1$ competitors earn non-negative (extranormal) profit in equilibrium. Given the symmetry of the rivals in the model, we analyze the equilibrium in which all rivals set the same price for their product.

8 For simplicity, we do not model formally any economies of scope that may exist between the VIP's upstream and downstream operations. Bustos and Galetovic (2003) provide a useful analysis of the effects of scope economies.

marginal cost of production as $c(w)$, where $c'(w) > 0$. Similarly, $c^v(c^u)$ will denote the marginal cost of the VIP's downstream affiliate, where $c^{v\prime}(c^u) \geq 0$. These marginal costs can assume a variety of forms, including the following linear form

$$c(w) = \gamma w + \gamma_1 s + \gamma_2 \quad \text{and} \quad c^v(c^u) = \gamma^v c^u + \gamma_1^v s + \gamma_2^v. \tag{1}$$

The linear formulation in equation (1) admits several interpretations, including the following three. First, γ might denote the number of units of the essential input supplied by the VIP that each rival employs in producing one unit of the downstream product. In addition, γ_1 might denote the rivals' corresponding use of a complementary input that is supplied competitively at unit price s. Similarly, γ^v and γ_1^v might characterize the corresponding use of these two inputs by the VIP's downstream affiliate. If $\gamma \neq \gamma^v$ in this setting, the VIP's downstream affiliate and its rivals employ the essential input produced by the VIP in different proportions. There are many settings where different firms employ an essential input in different proportions. For instance, in the telecommunications industry, competitive local exchange carriers can be compelled by their switch locations to employ more transport (per call) than incumbent local exchange carriers employ.

Second, suppose $\gamma = \gamma_1$, $\gamma^v = \gamma_1^v$, and $\gamma_2 = \gamma_2^v = 0$. This case might represent a setting where the rivals and the VIP's downstream affiliate use the two inputs in the same proportions, but (possibly) face different costs of borrowing funds to pay for inputs or incur different costs in combining the two inputs to produce the downstream output, for example.[9]

Third, suppose $\gamma = \gamma_1 = \gamma^v = \gamma_1^v = 1$, so all firms employ one unit of the essential input produced by the VIP and one unit of another competitively-supplied input to produce one unit of the final product. Further suppose $\gamma_2 > 0$ and $\gamma_2^v > 0$, so the rivals and the VIP's downstream affiliate employ an additional input in production, and may face different unit prices (γ_2 and γ_2^v, respectively) for this input. The different unit prices might arise, for example, if different operating scales allow different firms to take differential advantage of quantity discounts, or if some firms need to purchase inputs (e.g., special marketing or customer education services) that other firms do not.

The demand for each firm's downstream product declines as the price it charges for the product increases and as the prices its competitors charge for their products decrease. In standard fashion, own price effects are assumed to exceed cross price effects. Formally, $\partial Q^j(\cdot)/\partial p^j < 0$, $\partial Q^j(\cdot)/\partial p^i > 0$, and $|\partial Q^j(\cdot)/\partial p^j| > \sum_{\substack{k=1 \\ k \neq j}}^{n,v} |\partial Q^j(\cdot)/\partial p^k|$ for all $i \neq j$, $i, j = 1, \ldots, n, v$, where $Q^v(p^v, p^1, \ldots, p^n)$ denotes

9 Differences in borrowing costs might arise, for example, if an incumbent supplier can tap accumulated profit reserves while new entrants must rely upon more costly borrowed funds to finance ongoing operations. In practice, firms face different borrowing costs because of different bankruptcy risks. However, all firms earn non-negative profit in the present analysis.

the demand for the VIP's downstream product when the VIP sets price p^v and the n rivals set prices $p^1, \ldots, p^n$, and where $Q^i\left(p^i, p^{-i}\right)$ denotes the corresponding demand for rival i's downstream product, where $p^{-i} = \left(p^1, \ldots, p^{i-1}, p^{i+1}, \ldots, p^n, p^v\right)$. At times, it will be convenient to assume these demand functions are linear, as reflected in assumption 1.

Assumption 1: $Q^i(\cdot) = a - bp^i + \tilde{d}p^v + d\sum_{\substack{k=1 \\ k \neq i}}^{n} p^k$ for $i = 1, \ldots, n$; and $Q^v(\cdot) = a^v - b^v p^v + d^v \sum_{i=1}^{n} p^i$, where a, a^v, b, b^v, d, $\tilde{d}$, and d^v are positive constants.

It will also be convenient for much of the analysis to abstract from upstream profit effects.[10] To do so, we will assume (unless otherwise noted) that the unit price of the essential input is precisely its marginal (and average) cost of production, so $w = c^u$. This equality between the input price and its cost ensures the VIP will earn zero (extranormal) profit on its upstream operations, regardless of the realized demand for the essential input.

The profit of rival firm i when it sets price p^i and its competitors set prices p^{-i} is

$$\Pi^i\left(p^i, p^{-i}\right) = [p^i - c]Q^i\left(p^i, p^{-i}\right). \tag{2}$$

The corresponding profit of the VIP is

$$\Pi^v\left(p^v, p^1, \ldots, p^n\right) = [w - c^u]\sum_{i=1}^{n} Q^i(\cdot) + [p^v - c^v]Q^v\left(p^v, p^1, \ldots, p^n\right). \tag{3}$$

The first term to the right of the equality in expression (3) is the upstream profit the VIP derives from selling the essential input to the n rivals. The second term is the profit the VIP secures from its downstream operations.

The interaction between the VIP and the n symmetric rivals proceeds as follows. First, the input price (w) is determined by regulatory fiat. Second, the VIP sets the price (p^v) for its downstream product. Third, the rivals choose prices for their products simultaneously and independently, taking w and p^v as given.[11] Finally, consumers make their

10 This abstraction is consistent with regulatory policies in the telecommunications industry that are designed to price network elements at the cost the incumbent provider incurs in supplying these elements. To illustrate, the Federal Communications Commission (2001, 4) describes the methodology it has established for pricing network elements as "providing the best approximation of an incumbent's forward-looking cost of providing network elements to itself and others". Also see Federal Communications Commission (1996). Of course, if current cost exceeds forward-looking cost, then input prices may be set below current cost under such a policy. This possibility is considered in section 4.

11 The key conclusions drawn in section 3 continue to hold if the VIP's downstream affiliate and the rivals set prices simultaneously. See Appendix B.

purchase decisions after observing the prices set by all $n+1$ competitors. Each firm satisfies the entire demand for its product at the prevailing equilibrium prices.

3. Main Findings

Our primary concern is with the conditions under which the VIP will engage in self-sabotage. Self-sabotage occurs in the present setting when the VIP intentionally allows its upstream marginal cost (c^u) to rise above its minimum feasible level. When $w=c^u$, an increase in c^u results in a symmetric increase in w, and in this sense does not violate a (parity) requirement that inputs be sold to retail affiliates and competitors at the same price. Proposition 1 reveals how the VIP's equilibrium profit ($\Pi^{v*}(\cdot)$) varies with small changes in the VIP's upstream marginal cost of production in this setting.

Proposition 1:

$$\frac{d\Pi^{v*}(\cdot)}{dc^u} \gtreqless 0 \quad \text{as} \quad \frac{n\left[\partial Q^v/\partial p^i\right]\left[dp^i/dc\right]}{|\partial Q^v/\partial p^v| - n\left[\partial Q^v/\partial p^i\right]\left[dp^i/dp^v\right]} \gtreqless \frac{c^{v\prime}(c^u)}{c^\prime(w)}. \tag{4}$$

The comparative static conclusion presented in Proposition 1 suggests that self-sabotage is more likely to be profitable for the VIP when: (i) the marginal cost of the VIP's downstream affiliate increases slowly relative to the rate at which a rival's marginal cost increases as upstream costs (c^u) increase (so $c^{v\prime}(c^u)/c^\prime(w)$ is small);[12] (ii) the VIP faces many rivals (so n is large); (iii) the products of the VIP and the rivals are close substitutes (so $\partial Q^v/\partial p^i$ is relatively large); (iv) the demand for the VIP's product is relatively inelastic (so $|\partial Q^v/\partial p^v|$ is relatively small); and (v) the equilibrium price of each rival varies substantially with its marginal cost (so dp^i/dc is relatively large).

Absent additional structure on consumer demand, the direction of the inequality in Proposition 1 is indeterminate. However, when downstream demands are linear (that is, when Assumption 1 holds), definitive conclusions can be drawn, as Proposition 2 reveals.[13]

Proposition 2: *Suppose Assumption 1 holds and the VIP's downstream output is positive.*[14] *Then the VIP's equilibrium profit increases with c^u at a rate*

12 This ratio is γ^v/γ in the linear setting of equation (1).

13 Appendix B proves that Proposition 2, and thus Corollary 1 and Propositions 3 and 4, also hold when the VIP's downstream affiliate and the n rivals choose prices simultaneously, rather than sequentially.

14 Sufficient conditions for the VIP's downstream output to be positive are readily inferred from equation (A2.7) in Appendix A. Intuitively, the VIP's downstream output will be positive when c^u is small, when n is small, and when the VIP's downstream marginal cost is low and its demand is pronounced relative to the corresponding values for the rivals. If the VIP's downstream output is zero, the VIP's equilibrium profit does not vary with c^u when $w=c^u$.

proportional to

$$c'(w)nbd^v - c^{v\prime}(c^u)\left[b^v[2b-(n-1)d]-nd^v\tilde{d}\right]. \tag{5}$$

Proposition 2 provides the following conclusions about the determinants of self-sabotage.

Corollary 1: *Suppose Assumption 1 holds and the VIP's downstream output is positive. Then self-sabotage increases the VIP's profit more rapidly when: (i) the marginal cost of the VIP's downstream affiliate increases slowly relative to the rate at which a rival's marginal cost increases as upstream costs (c^u) increase (so $c^{v\prime}(c^u)/c'(w)$ is small); (ii) the VIP faces many rivals (so n is large); (iii) the products of the VIP and the rivals are close substitutes (so d^v and $\tilde{d}$ are relatively large); and (iv) the demand for the VIP's product is relatively inelastic (so b^v is relatively small).*

The findings reported in Corollary 1 are readily explained. When $w = c^u$, an increase in upstream costs increases the marginal cost of both the VIP's downstream affiliate and downstream rivals. The larger the relative increase in the rivals' marginal cost, the more self-sabotage induces rivals to differentially increase their prices. These higher prices increase the demand for the VIP's downstream product, and thereby increase the VIP's profit, as property (i) of Corollary 1 indicates.

The increase in the demand for the VIP's product is particularly pronounced when the products of the VIP and the rivals are close substitutes, as property (iii) of Corollary 1 reports. Furthermore as property (ii) suggests, the aggregate impact on competitors of an increase in the marginal cost of the essential input (w) is more pronounced when many rivals operate in the downstream market. In addition, the higher price (p^v) the VIP's downstream affiliate sets when its marginal cost increases does not reduce equilibrium consumption of the VIP's product substantially when the demand for the VIP's product is inelastic. Therefore, as property (iv) of Corollary 1 indicates, self-sabotage tends to be more profitable for the VIP the more inelastic is the demand for its downstream product.

While Corollary 1 describes the factors that make self-sabotage more or less attractive to the VIP, Proposition 3 provides a sufficient condition for self-sabotage not to arise in equilibrium.

Proposition 3: *Suppose Assumption 1 holds. Then the VIP will not engage in self-sabotage if $c'(w) \leq c^{v\prime}(c^u)$.*

Proposition 3 states that self-sabotage will not be profitable for the VIP in the simple setting considered to this point unless it serves to increase the marginal cost of the VIP's rivals more than it increases the VIP's own marginal cost.[15] This conclusion may not be surprising, as it indicates that the VIP will only raise its own costs intentionally if doing so serves to increase more than proportionately the (marginal) cost of competitors. Cost increases that do not serve to disadvantage rivals disproportionately simply put the VIP at a competitive disadvantage and/or reduce the total industry surplus that is shared by all competitors.[16]

The extent to which an increase in upstream costs must raise the rivals' marginal cost disproportionately in order for self-sabotage to be profitable for the VIP varies with many elements of the environment, including the degree of product homogeneity. To illustrate this relationship most simply, suppose there is a single rival (so $n = 1$) and demand curves are linear (so assumption 1 holds) and symmetric (so $d = d^v = \tilde{d}$ and $b = b^v$). In this linear, symmetric duopoly setting, $\theta \equiv [d/b] \in (0, 1)$ can be viewed as a measure of product homogeneity.[17] Proposition 4 reports how the minimum disproportionate increase in the rivals' marginal cost required to render self-sabotage profitable for the VIP varies with the degree of product homogeneity (θ) in this setting. The minimum disproportionate increase, $\underline{\Delta}$, is the smallest value of $\Delta \equiv c'(w)/c^{v\prime}(c^u)$ for which $\partial \Pi^{v*}(\cdot)/\partial c^u > 0$.

Proposition 4: $\underline{\Delta} = [2 - \theta^2]/[\theta]$ *in the linear, symmetric duopoly setting.*

The critical disproportionate increase identified in Proposition 4 is graphed in figure 1. Two features of figure 1 warrant emphasis. First, the critical disproportionate increase declines as θ increases. This is because the increase in the rival's price induced by an increase in its marginal cost produces a larger increase in the demand for the VIP's downstream product when the products are more homogeneous.[18] Second, the requisite disproportionate increase becomes arbitrarily small as the products of the VIP and the rival become sufficiently homogeneous (i.e., $\underline{\Delta}$

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15 Notice that the inequality in Proposition 3 holds when $\gamma \leq \gamma^v$ in equation (1). It can be shown that the same qualitative conclusion holds when the downstream competitors face linear demand curves and choose quantities, rather than prices. (This is the case whether the quantities are chosen simultaneously or sequentially.)

16 If consumer demand is not linear, a VIP might find cost-increasing self-sabotage to be profitable even if the sabotage increases the costs of the VIP's downstream affiliate and the rival symmetrically. This possibility reflects Seade's (1985) observation that under some conditions (which do not include linear demand), the profits of all Cournot competitors can increase when their constant marginal costs rise symmetrically. The increased profit arises when the increase in marginal cost induces such severe output contractions that the market price increases more than marginal costs rise.

17 Formally, θ is the ratio of the rate at which a firm's demand increases as its own price declines (b) to the rate at which its demand increases as a competitor's price increases (d). The closer is θ to unity, the more symmetric is the response of a firm's demand to changes in its own price and to changes in a competitor's price. The more symmetric price response could reflect greater product homogeneity.

18 Mandy and Sappington (2004) find that the incentives for sabotage may not vary monotonically with the degree of product homogeneity.

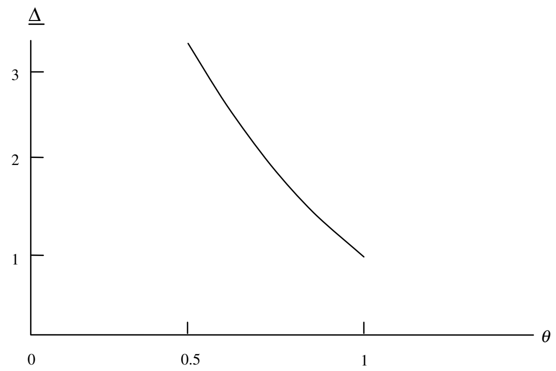

Figure 1. The minimum disproportionate increase in the rival's marginal cost

approaches unity as θ approaches unity). Therefore, although some disproportionate increase in the rivals' marginal cost is necessary to make self-sabotage profitable for the VIP in the setting analyzed to this point, the requisite increase can be very small under plausible conditions.

4. Additional Findings

The analysis to this point has incorporated two fundamental assumptions. First, neither self-sabotage nor downstream competition affects the VIP's upstream profit. Second, self-sabotage takes the form of an intentional increase in upstream costs. The implications of relaxing these assumptions are considered briefly in this section.

4.1. Upstream Price Effects

First consider the new qualitative conclusions that can emerge when the outcome of downstream competition can affect upstream profit. In particular, suppose the price (w) for the essential input produced by the VIP is set below its marginal cost of production (c^u).[19] In this case, the VIP incurs a loss on each unit of the input it sells to rivals. Therefore, the VIP will gain financially if it can reduce the rivals' downstream output, and thus their demand for the essential input.[20] One

19 Here we depart from strict parity requirements and consider a setting where the VIP is required to provide the essential input to rivals on more favorable terms than it provides the input to its downstream affiliate. Incumbent local exchange carriers in the U.S. have argued that state regulators have set the prices for unbundled network elements below cost. Lehman and Weisman (2000, chapter 6) and Tardiff (2002) provide some empirical support for this contention.

20 If self-sabotage increases the rivals' marginal cost disproportionately, self-sabotage can be profitable for the VIP even if the price of the essential input exceeds its marginal cost of production. The increase in downstream profit from self-sabotage in this case can outweigh the reduction in upstream profit. See Weisman and Kang (2001), for example, for corresponding conclusions regarding the profitability of cost-increasing sabotage.

way to reduce the rivals' output (without violating relevant parity requirements) is to engage in self-sabotage. When self-sabotage increases the rivals' costs, their output typically declines. The resulting reduction in the demand for the essential input can increase the VIP's upstream profit when $w < c^u$ more than it reduces the VIP's downstream profit, even when self-sabotage increases the marginal cost of the VIP's downstream affiliate more than it increases the rivals' marginal cost. This intuitive conclusion is recorded formally in Proposition 5.[21]

Proposition 5: *Self-sabotage that increases the marginal cost of the VIP's downstream affiliate more than it increases the rivals' marginal cost can be profitable for the VIP if the price of the essential input is set below its marginal cost of production (i.e., if $w < c^u$).*

The VIP also may undertake self-sabotage that increases its own marginal cost disproportionately if the VIP derives other benefits from the upstream cost increase. For example, the increase in upstream costs may arise because the VIP has shifted its best managers from its regulated upstream operations to unregulated operations in other markets. In this case, the additional profit the VIP derives in other markets can more than offset any losses that arise from self-sabotage in the markets on which our formal analysis is focused.[22]

4.2. Quality-Reducing Sabotage

Now consider the new conclusions that can emerge when a VIP might undertake quality-reducing self-sabotage rather than cost-increasing self-sabotage. Quality-reducing self-sabotage occurs when the VIP intentionally reduces the quality of the input it supplies below the maximum feasible level. To demonstrate how a VIP might employ quality-reducing self-sabotage to disadvantage rivals differentially even when a reduction in input quality reduces the quality of all downstream products symmetrically, consider the following *endogenous quality* setting.

There is a single downstream rival (so $n = 1$) in this setting. The quality (q) of the input produced by the VIP determines the quality (q^v) of its own downstream product and the quality (q^r) of the rival's product. The input quality affects the

21 This conclusion parallels the insights provided in Biglaiser and DeGraba (2001), Mandy (2001), Beard et al. (2001), and Bustos and Galetovic (2003).

22 This conclusion might be viewed as a corollary of Reiffen's (1998) observation that the sabotage of rivals can be associated with lower operating costs for the VIP. Also see Weisman (1998). Notice that non-pecuniary benefits of self-sabotage can induce the VIP to undertake self-sabotage that raises disproportionately the costs of the VIP's downstream affiliate even if the VIP does not operate in other markets. These non-pecuniary benefits may arise, for example, when higher upstream costs are the result of reduced managerial effort and/or tangible perquisites for the firms' owners/managers.

quality of the two downstream products symmetrically and, for simplicity, linearly, so $q^r = q^v = zq$, where $z > 0$ is a constant. After the VIP sets the input quality, the VIP (or, equivalently in this case, the VIP's downstream affiliate) determines the level of output (x^v) it will produce.[23] The rival then chooses its preferred output level (x^r), given x^v and q. Outputs and qualities determine the market-clearing prices for the firms' outputs according to equation (6).

$$P^j(\cdot) = A - Bx^j - Dx^i + E^j q^j - F^j q^i \quad \text{for} \quad i \neq j, \;\; i, j = r, v, \tag{6}$$

where $P^j(\cdot)$ denotes the market-clearing price for firm *j*'s downstream product. The firms' products are gross substitutes, so $D > 0$. Furthermore, each firm's price is more responsive to its own output and quality than to the output and quality of its competitor (so $B > D$ and $E^j > F^j > 0$, for $j = r, v$).

Each downstream competitor produces with a constant marginal cost that does not vary with quality. For simplicity, we abstract from any upstream costs associated with input quality, and investigate when the VIP will undertake quality-reducing self-sabotage.[24]

Proposition 6: *The VIP will undertake quality-reducing sabotage in the endogenous quality setting if and only if* $E^r - F^r > [E^v - F^v][2B/D]$ [25]

Proposition 6 reveals that the VIP will undertake quality-reducing self-sabotage when the rival's demand is sufficiently more sensitive to symmetric changes in the firms' product qualities than is the demand for the VIP's downstream product.[26] In the presence of such asymmetric sensitivity to quality changes, the predominant effect of a reduction in input quality is to shift the rival's demand curve inward, and thereby to induce the rival to reduce its output. The reduced output increases the market-clearing price for the VIP's downstream product, and thereby increases the VIP's profit.[27]

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23 This timing is relevant when output levels can be changed more quickly than product quality can be altered, as is often the case in practice.

24 Formally, the VIP will engage in quality-reducing self-sabotage when its equilibrium profit increases as input quality (q) declines. If the VIP's upstream costs declines as the quality of the input declines, the VIP's incentive to engage in quality-reducing self-sabotage typically will be more pronounced than it is in the present setting.

25 It can be shown that the identical sufficient condition for self-sabotage holds in a Cournot setting, where output levels are determined simultaneously rather than sequentially.

26 For simplicity, we have focused on the case where changes in the quality of the input affect the quality of all downstream products symmetrically. If the rival's demand is sufficiently more sensitive to changes in quality than is the demand for the VIP's downstream product, the VIP will even undertake quality-reducing self-sabotage that serves to reduce disproportionately the quality of the VIP's downstream product. An incumbent supplier's demand might be relatively insensitive to changes in quality because of lasting reputation effects, for example.

27 Quality-reducing self-sabotage is profitable for the VIP under the specified condition because quantities are strategic substitutes in the endogenous quality setting (see Bulow et al. 1985). When

In summary, some of the key qualitative conclusions drawn in section 3 require modification in different settings. In particular, the VIP may engage in cost-increasing self-sabotage that produces a larger increase in the VIP's downstream marginal cost than in the rivals' marginal cost. In addition, the VIP may undertake quality-reducing self-sabotage that reduces the quality of its downstream product as much as (or more than) it reduces the quality of the rivals' product.

5. Conclusions

Our findings suggest that although parity requirements can play a useful role in preventing a VIP from directly sabotaging its downstream rivals, parity requirements do not always preclude the more indirect disadvantaging of rivals that self-sabotage can admit. We have analyzed different forms of self-sabotage and identified conditions under which self-sabotage will, and will not, arise. In the simple environment on which this research focused, a VIP will not engage in cost-increasing self-sabotage unless it serves to increase disproportionately the marginal cost of downstream rivals. However, as the analysis in section 4 revealed, self-sabotage may arise more generally in other environments. For example, a VIP may engage in quality-reducing sabotage even when a reduction in input quality reduces the quality of all downstream products symmetrically.

In addition to our primary finding that parity restrictions may not prevent VIPs from disadvantaging rivals, our analysis suggests the following three conclusions that may be of interest to policymakers. First, as noted immediately above, cost-increasing self-sabotage may be of limited practical concern if upstream cost increases do not differentially raise the costs of rivals, as when the rivals use less of the essential input (on a per unit basis), for example.

Second, even though cost-based pricing of a VIP's upstream products can help to ensure the VIP's economic viability, the corresponding full pass-through of upstream costs could encourage a VIP to undertake anticompetitive cost-increasing self-sabotage under some conditions. On the other hand, input prices below cost can encourage anticompetitive self-sabotage (as demonstrated in Proposition 5). Ideally, the regulator would like to be able to distinguish between essential and

downstream competitors set prices rather than quantities, a reduction in the rival's quality induces the rival to reduce its price, which reduces the demand for the VIP's downstream product, and thus the VIP's profit. Consequently, the VIP typically will not engage in quality-reducing self-sabotage when the downstream competitors set prices rather than quantities. See Mandy and Sappington (2004) for a detailed analysis of the different effects of demand-reducing sabotage under Cournot and Bertrand competition. Notice that, in practice, the rival might be able to undertake costly activities to ameliorate the effects of the reduced input quality on consumer demand. The VIP might continue to find quality-reducing sabotage to be profitable in this setting if the equilibrium reduction in the demand for the rival's product and the rival's amelioration costs together are sufficiently pronounced.

avoidable upstream costs. In practice, this distinction can sometimes be difficult to draw.

Third, the more differentiated are the retail products of the rival and the VIP, the less likely is the VIP to find cost-increasing self-sabotage profitable, *ceteris paribus*. Consequently, competition policies that foster product innovation rather than product imitation may be less likely to encourage certain types of anticompetitive behavior that are particularly difficult to observe and preclude.[28]

Because self-sabotage can have varied and subtle effects, it merits additional investigation in alternative settings. For example, non-linear cost structures might be analyzed. We conjecture that additional incentives for self-sabotage (that increases upstream fixed costs) can arise when fixed costs are allocated using common cost-allocation methodologies (such as the relative output methodology). A more complete assessment of the upstream effects of self-sabotage also is warranted. Models in which downstream competitors choose both price and quality also merit investigation, as do models in which the upstream supplier faces meaningful competition.[29]

This research has taken as given the prevailing regulatory policy and analyzed the behavior of a VIP under the specified policy. Future research might consider the optimal design of regulations for a vertically-integrated supplier of an essential input. Such research should account for the fact that production costs and input quality are endogenous, and that regulators seldom have perfect knowledge of production technologies. It would be interesting to know whether parity requirements generally are an element of an optimal regulatory policy, and whether (self-) sabotage arises in equilibrium under an optimal regulatory policy.[30]

Appendix A

Proof of Proposition 1: From expression (3), the profit-maximizing price for the VIP (the Stackelberg leader) when $w = c^u$ is characterized by

$$\frac{\partial \Pi^v(\cdot)}{\partial p^v} = Q^v(\cdot) + [p^v - c^v]\left[\frac{\partial Q^v}{\partial p^v} + \sum_{j=1}^{n} \frac{\partial Q^v}{\partial p^j}\frac{dp^j}{dp^v}\right] = 0. \tag{A1.1}$$

28 More precise policy recommendations along these lines must await the findings of a formal analysis in which the degree of product differentiation is determined endogenously.

29 Beard et al. (2001) find that upstream competition often reduces, but does not eliminate, cost-increasing sabotage of downstream rivals. Upstream competition that increases the cost of self-sabotage for the VIP also will tend to reduce, but not necessarily eliminate, self-sabotage.

30 As the referee has noted, parity regulation could reduce welfare in some settings. For example, Pareto gains might be available if a VIP were permitted to differentially reduce the quality of the inputs sold to competitors in return for lower input prices. Beard et al. (2001) note that because of the sabotage it can induce, stringent input price regulation can reduce welfare below the level achieved in the absence of input price regulation.

Similarly, from expression (2), the profit-maximizing price for the jth competitor is characterized by

$$\frac{\partial \Pi^j(\cdot)}{\partial p^j} = Q^j(\cdot) + \left[p^j - c\right] \frac{\partial Q^j}{\partial p^j} = 0. \tag{A1.2}$$

Also notice from expression (3), using equation (A1.1), that when $w = c^u$

$$\frac{d\Pi^v(\cdot)}{dc^u} = -Q^v(\cdot)c^{v\prime}(c^u) + [p^v - c^v] \sum_{j=1}^{n} \frac{\partial Q^j}{\partial p^j} \frac{dp^j}{dc} c'(w). \tag{A1.3}$$

Solving equation (A1.1) for $p^v - c^v$ yields

$$p^v - c^v = \frac{-Q^v(\cdot)}{H}, \tag{A1.4}$$

where $H = \frac{\partial Q^v}{\partial p^v} + \sum_{j=1}^{n} \frac{\partial Q^v}{\partial p^j} \frac{dp^j}{dp^v} = \frac{\partial Q^v}{\partial p^v} + n \left[\frac{\partial Q^v}{\partial p^j} \frac{dp^j}{dp^v}\right] < 0.$

Substituting expression (A1.4) into expression (A1.3) yields

$$\frac{d\Pi^v(\cdot)}{dc^u} = -Q^v(\cdot)c^{v\prime}(c^u) + \frac{Q^v(\cdot)}{|H|} n \left[\frac{\partial Q^v}{\partial p^j}\right] \left[\frac{dp^j}{dc}\right] c'(w). \tag{A1.5}$$

Equation (A1.5) implies

$$\frac{d\Pi^{v*}(\cdot)}{dc^u} \gtreqless 0 \quad \text{as} \frac{n}{|H|} \left[\frac{\partial Q^v}{\partial p^j}\right] \left[\frac{dp^j}{dc}\right] \gtreqless \frac{c^{v\prime}(c^u)}{c'(w)} \tag{A1.6}$$

■

Proof of Proposition 2: When assumption 1 holds, equality (A1.2) can be rewritten as

$$a - bp^j + \tilde{d}p^v + d \sum_{\substack{k=1 \\ k \neq j}}^{n} p^k - b\left[p^j - c\right] = 0. \tag{A2.1}$$

When each of the symmetric rivals sets the same price in equilibrium, equation (A2.1) implies

$$p^j = \frac{a + \tilde{d}p^v + bc}{2b - [n-1]d}. \tag{A2.2}$$

Equations (A1.1) and (A2.2) together reveal

$$p^v = \frac{1}{2M} \left[[nd^v]a + Sa^v + [nbd^v]c + Mc^v\right], \tag{A2.3}$$

where $S = 2b - [n-1]d$ and $M = b^v S - nd^v \tilde{d}$. (A.24)

Equations (A2.2) and (A2.3) together imply

$$p^j = \frac{1}{2MS}\Big[[2b^v S - nd^v \tilde{d}]a + [\tilde{d}S]a^v + [2bb^v S - nbd^v \tilde{d}]c + [b^v \tilde{d}S - n\tilde{d}^2 d^v]c^v\Big]. \tag{A2.4}$$

Equation (A2.3) implies

$$p^v - c^v = \frac{1}{2M}[nd^v a + Sa^v + nbd^v c - Mc^v]. \tag{A2.5}$$

Assumption 1 and equations (A2.3) and (A2.5) imply

$$Q^v(\cdot) = \frac{1}{2S}[nd^v a + Sa^v + nbd^v c - Mc^v]. \tag{A2.6}$$

Since $\Pi^v(\cdot) = [p^v - c^v] \cdot Q^v(\cdot)$ when $w = c^u$, equalities (A2.6) and (A2.7) imply

$$\Pi^{v^*}(\cdot) = \frac{1}{4MS}[nd^v a + Sa^v + nbd^v c - Mc^v]^2. \tag{A2.7}$$

Differentiating equation (A2.8) with respect to c^u provides:

$$\begin{aligned}\frac{d\Pi^{v^*}(\cdot)}{dc^u} &= \frac{1}{2MS}[nd^v a + Sa^v + nbd^v c - Mc^v]\big[c'(w)nbd^v - c^{v\prime}(c^u)M\big] \\ &= \frac{Q^v(\cdot)}{M}\big[c'(w)nbd^v - c^{v\prime}(c^u)M\big].\end{aligned} \tag{A2.8}$$

The statement in the proposition follows from equations (A2.4) and (A2.9). ■
The proof of Corollary 1 is immediate upon examination of expression (5), and so is omitted. ■

Proof of Proposition 3: From equations (A2.4) and (A2.9), the VIP's equilibrium profit (when $w = c^u$ and the VIP's downstream output is positive) varies with c^u at a rate that is proportional to

$$c'(w)nbd^v - c^{v\prime}(c^u)\Big[b^v[2b - (n-1)d] - nd^v \tilde{d}\Big]. \tag{A3.1}$$

The assumption that own-demand effects dominate cross-demand effects implies that

$$b^v > nd^v \quad \text{and} \tag{A3.2}$$

$$b > \tilde{d} + [n-1]d. \tag{A3.3}$$

Inequalities (A3.2) and (A3.3) imply that $b^v[2b - (n-1)d] - nd^v \tilde{d} > 0$. Therefore, expression (A3.1) will be negative when $c'(w)c^{v\prime}(c^u)$ if

$$nbd^v < b^v[2b - (n-1)d] - nd^v \tilde{d} \text{ or } nd^v[b + \tilde{d}] < b^v[2b - (n-1)d]. \tag{A3.4}$$

Since $b^v > nd^v$ from inequality (A3.2), the second inequality in expression (A3.4) will hold if

$$b + \tilde{d} < 2b - [n-1]d. \tag{A3.5}$$

Inequality (A3.2) ensures that inequality (A3.5) holds.

Therefore, when $c'(w) \leq c^{v\prime}(c^u)$ and $w = c^u$, the VIP's equilibrium profit declines as c^u increases whenever the VIP's downstream output is positive, and does not vary with c^u when the VIP's downstream output is zero. Consequently, self-sabotage will not increase the VIP's equilibrium profit under the specified conditions.

■

Proof of Proposition 4: When $n = 1$, $b = b^v$, and $d^v = \tilde{d} = d$, expression (5) implies that self sabotage is profitable for the VIP if and only if

$$\frac{bd}{2b^2 - d^2} = \frac{\theta}{2 - \theta^2} > \frac{1}{\Delta}. \tag{A4.1}$$

Inequality (A4.1) implies that $\underline{\Delta} = \dfrac{2 - \theta^2}{\theta}$. (A4.2)

■

Proof of Proposition 5: An example is sufficient to prove the proposition. To this end, suppose $n = 1$ so the VIP faces a single rival downstream. Also suppose the downstream marginal costs of the VIP and the rival are $c^v = c^u + c^{vd}$ and $c^r = w(c^u) + c^{rd}$, respectively, where $c^{vd} > 0, c^{rd} > 0$, and

$$w(c^u) = \alpha c^u - \beta \text{ for some } \alpha \in (0,1) \text{ and } \beta > 0. \tag{A5.1}$$

Expression (A5.1) implies that the essential input is sold to the rival at a price below the VIP's marginal cost of producing the input (since $\beta > 0$ and $\alpha < 1$), and that self-sabotage increases the VIP's downstream marginal cost more than it increases the rival's marginal cost (since $\alpha < 1$).

The statement in the proposition is proved most simply by assuming that downstream demands are independent and perfectly inelastic up to a reservation price. Suppose N^v customers are willing to buy exactly one unit of the VIP's downstream product at any price below R^v, and N^r customers are willing to buy exactly one unit of the rival's product at any price below R^r. Let

$$m \equiv R^r - \alpha \underline{c}^u + \beta - c^{rd} > 0, \tag{A5.2}$$

where $\underline{c}^u$ is the smallest feasible value of the VIP's upstream marginal cost, c^u. Expression (A5.2) reveals that m is the minimum level of self-sabotage required to ensure the rival cannot operate profitably when it pays unit price $\alpha[\underline{c}^u + m] - \beta$ for the essential input.

The VIP's profit when it undertakes no self-sabotage in this setting is

$$\Pi^{vo} = -[\beta + (1-\alpha)\underline{c}^u]N^r + [R^v - \underline{c}^u - c^{vd}]N^v. \tag{A5.3}$$

The VIP's profit when it intentionally increases its upstream marginal cost to $\underline{c}^u + m$ is

$$\Pi^{vm} = N^v \left[\max\left\{0, R^v - \underline{c}^u - m - c^{vd}\right\}\right]. \tag{A5.4}$$

The VIP will strictly prefer to engage in self-sabotage (at the profit-maximizing level, m) than to refrain from self-sabotage if $\Pi^{vm} > \Pi^{vo}$ when, from expression (A5.4),

$$R^v - \underline{c}^u - m - c^{vd} > 0. \tag{A5.5}$$

Straightforward manipulation of expressions (A5.2)–(A5.5) reveals that the VIP will undertake self-sabotage (at level m) whenever $N^r > N^v$ and

$$\frac{N^v[R^r - \alpha\underline{c}^u - c^{rd}] - N^r[1-\alpha]\underline{c}^u}{N^r - N^v} < \beta$$
$$< \left[R^v - \underline{c}^u - c^{vd}\right] - \left[R^r - \alpha\underline{c}^u - c^{rd}\right]. \tag{A5.6}$$

It is readily verified that inequality (A5.6) holds for a wide range of plausible parameter values. ■

Proof of Proposition 6: The profit functions for the VIP and its rival, respectively, are

$$\pi^v(\cdot) = x^v[p^v - c^v], \quad \text{and} \quad \pi^r(\cdot) = x^r[p^r - c^r]. \tag{A6.1}$$

Differentiating the terms in expression (A6.1) provides the following necessary conditions for an interior optimum

$$p^v - c^v + x^v\left[\frac{\partial p^v}{\partial x^v} + \frac{\partial p^v}{\partial x^r}\frac{\partial x^r}{\partial x^v}\right] = 0 \tag{A6.2}$$

and

$$p^r - c^r + x^r\frac{\partial p^r}{\partial x^r} = 0. \tag{A6.3}$$

Using equation (A6.2), it is readily shown that:

$$\frac{d\pi^v(\cdot)}{dq} = x^v\left[\frac{\partial p^v}{\partial x^r}\frac{\partial x^r}{\partial q^r}\frac{\partial q^r}{\partial q} + \frac{\partial p^v}{\partial x^r}\frac{\partial x^r}{\partial q^v}\frac{\partial q^v}{\partial q} + \frac{\partial p^v}{\partial q^v}\frac{\partial q^v}{\partial q} + \frac{\partial p^v}{\partial q^r}\frac{\partial q^r}{\partial q}\right]. \tag{A6.4}$$

By assumption, $q^r = q^v = z \cdot q$. Therefore, $\partial q^r/\partial q = \partial q^v/\partial q = z$. Consequently, equality (A6.4) can be rewritten as

$$\frac{d\pi^v(\cdot)}{dq} = z \cdot x^v\left[\frac{\partial p^v}{\partial x^r}\frac{\partial x^r}{\partial q^r} + \frac{\partial p^v}{\partial x^r}\frac{\partial x^r}{\partial q^v} + \frac{\partial p^v}{\partial q^v} + \frac{\partial p^v}{\partial q^r}\right]. \tag{A6.5}$$

From equation (6), equality (A6.3) can be rewritten as

$$A - Bx^r - Dx^v + E^r q^r - F^r q^v - c^r - Bx^r = 0. \tag{A6.6}$$

Equality (A6.6) implies

$$x^r = \frac{A - Dx^v + E^r q^r - F^r q^v - c^r}{2B}. \tag{A6.7}$$

Equality (A6.7) implies

$$\frac{\partial x^r}{\partial q^r} = \frac{E^r}{2B} \quad \text{and} \quad \frac{\partial x^r}{\partial q^v} = \frac{-F^r}{2B}. \tag{A6.8}$$

Substituting from expression (A6.8) into equation (A6.5) reveals that when equation (6) holds

$$\frac{d\pi^v(\cdot)}{dq} = z \cdot x^v \left[\frac{-DE^r}{2B} + \frac{DF^r}{2B} + E^v - F^v \right]. \tag{A6.9}$$

Equation (A6.9) implies that $\frac{d\pi^v(\cdot)}{dq} < 0$ when

$$\frac{D[F^r - E^r]}{2B} < F^v - E^v, \text{ or } E^r - F^r > [E^v - F^v]\left[\frac{2B}{D}\right]. \tag{A6.10}$$

■

Appendix B

This appendix proves that the key conclusions reported in section 3 continue to hold when the VIP's downstream affiliate and the n rivals engage in Bertrand, rather than Stackelberg, competition. Formally, this appendix proves that when $w = c^u$, when assumption (1) holds, when the VIP and the n rivals set prices simultaneously and independently, and when the VIP's downstream output is positive, the VIP's equilibrium profit increases with c^u at a rate that is proportional to

$$c'(w)nbd^v - c^{v\prime}(c^u)\left[b^v[2b - (n-1)d] - nd^v\tilde{d}\right]. \tag{B1}$$

Thus, Proposition 2 holds (and hence Corollary 1 and Propositions 3 and 4 hold) when the firms engage in Bertrand competition downstream.

The proof employs techniques analogous to those employed in the proof of Proposition 2. These techniques reveal that when assumption 1 holds and when each of the symmetric rivals sets the same price in equilibrium, this price is

$$p^j = \frac{a + \tilde{d}p^v + bc}{2b - [n-1]d}, \tag{B2}$$

where p^v is the VIP's downstream price.

From equation (3), the profit-maximizing price for the VIP's downstream affiliate under Bertrand competition is characterized by

$$Q^v(\cdot) + [p^v - c^v]\left[\frac{\partial Q^v}{\partial p^v}\right] = 0. \tag{B3}$$

Assumption 1 and equations (B2) and (B3) together imply that

$$p^v = \frac{1}{Y}\,[[nd^v]a + Sa^v + [nbd^v]c + [b^v S]c^v], \tag{B4}$$

where

$$S = 2b - [n-1]d \quad \text{and} \quad Y = 2b^v S - nd^v \tilde{d}. \tag{B5}$$

Equations (B2) and (B4) together imply that each rival's equilibrium price is

$$p^j = \frac{1}{Y}\left[[2b^v]a + [\tilde{d}]a^v + [2bb^v]c + [b^v \tilde{d}]c^v\right]. \tag{B6}$$

Equation (B4) implies

$$p^v - c^v = \frac{1}{Y}\,[[nd^v]a + Sa^v + [nbd^v]c - Mc^v], \tag{B7}$$

where

$$M = b^v S - nd^v \tilde{d}. \tag{B8}$$

Assumption 1 and equations (B4) and (B6) imply

$$Q^v(\cdot) = \frac{b^v}{Y}\,[[nd^v]a + Sa^v + [nbd^v]c - Mc^v]. \tag{B9}$$

Since the VIP's profit when $w = c^u$ is $[p^v - c^v]Q^v(\cdot)$, equalities (B7) and (B9) imply that the VIP's equilibrium profit under downstream Bertrand competition is

$$\frac{b^v}{Y^2}\,[[nd^v]a + Sa^v + [nbd^v]c - Mc^v]^2. \tag{B10}$$

Differentiating expression (B10) with respect to c^u provides the rate at which the VIP's equilibrium profit increases as c^u increases. This rate is

$$\begin{aligned}\frac{2b^v}{Y^2}&\left[[nd^v]a + Sa^v + [nbd^v]c - Mc^v\right]\left[c'(w)nbd^v - c^{v\prime}(c^u)M\right]\\ &= \frac{2Q^v(\cdot)}{Y}\left[c'(w)nbd^v - c^{v\prime}(c^u)M\right].\end{aligned} \tag{B11}$$

Equations (B5), (B8) and (B11) reveal that when the VIP's downstream output is positive, the VIP's equilibrium profit under downstream Bertrand competition varies with c^u at a rate that is proportional to the term in expression (B1). ■

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