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Successive Monopolies with Endogenous Quality*

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Abstract

This paper analyzes the impact of vertical integration on product quality. Contrary to previous findings, it is shown that integration decreases quality in many natural situations. In general, the direction of the quality change is governed by three effects that are isolated in the model. This separation allows an analysis of important special cases like the manufacturer/retailer relationship, the intermediate/final good producer relationship, the deregulation of network infrastructure, and the provision of promotional services through independent distributors.

JEL classification: L12, L15, L22, D4

Keywords: Vertical integration, double marginalization, quality

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1 Introduction

This paper addresses the impact of vertical integration on product characteristics in supply chains with market power. In particular, it tries to shed light on the question how product quality is affected by the market structure. In antitrust and regulatory contexts defendants often argue that a vertically integrated firm provides a higher level of product quality than separate entities. During the process of privatizing the German railway, for instance, Deutsche Bahn contended that a vertical separation of railway system and passenger transport should be avoided to maintain quality. Similarly, in *Hilti v. European Commission*, the Hilti Corporation, a producer of nail guns used in construction, held that its guns should only be loaded with cartridges containing its own nails because potential downstream competitors allegedly produced inferior components of a dangerous nature.

These arguments find support in the theoretical literature. Tirole (1988) argues that in the provision of retailers' services that make the manufacturer's good more attractive to consumers, there is downstream moral hazard in the sense that retailers do not take the positive externality into account that service provision exerts on producers. This suggests that independent retailers provide a lower service level than vertically integrated firms. Using a similar model Rey and Vergé (2008) propose that "[t]he distributor will choose [...] too little effort. The basic reason is that when choosing level of effort and its price, the distributor does not take into account the impact of these decisions on the producer's profit" (p. 363).

In the above models, investment occurs downstream. However, equivalent conclusions were drawn by papers that analyze upstream investment or bilateral investment. Economides (1999) finds that vertical integration of successive monopolies always increases the provision of quality. Buehler et al. (2004) largely confirm this result. While they provide two numerical examples where integration may decrease quality, they argue that these are contrived. The paper concludes that "incentives to invest are generally smaller under vertical separation than under integration" (p. 255). The main argument is the same as proposed by the previous literature: "the network owner invests less than under integration, as she does not take positive quality effects on downstream demand into account" (p. 260).

Using a general model of vertical separation that nests previous approaches as special cases, this paper will show that the above presumption that vertical integration increases quality is wrong. As it turns out, Tirole's (1988) focus on the service externality is misleading: an independent retailer actually provides a *higher* level of services than an integrated firm. This is also true in Rey and Vergé's (2008) model, if it weren't for a mistake the authors make in deriving their prediction. While Economides's (1999) and Buehler et al.'s (2004) results are valid, they rest on specific assumptions on demand, costs, and the timing of investment.[1] The particular assumptions they make are well-suited to characterize quality adjustments in the particular special case they analyze (deregulation of network infrastructure).[2] However, they are less apt to characterize more general vertical chains (like the relationships between a manufacturer and a retailer or between an intermediate good and a final good producer). This, however, is the focus of this paper and as will be shown below, quality turns out to be lower under integration in many natural situations.

The paper is organized as follows. Section 2 presents a model of successive monopolies with endogenous quality choice that improves on previous approaches by allowing general demand and cost functions and investment either at the upstream or downstream level. As in the previous literature, quality choice will be driven by the impact of double marginalization. The level of

[1] Economides (1999) assumes very particular demand and cost structures and does not allow for sequential investments. While Buehler et al. (2004) use general demand functions, they assume away variable costs and do not allow for downstream investment. As will be shown, these assumptions create a bias towards quality increasing vertical integration.

[2] See Economides (1996, p. 690) for a discussion of how his paper relates to the general literature on network externalities.

quality is shown to depend on three distinct effects which are separately analyzed in Section 3 (the demand effect), Section 4 (the commitment effect), and Section 5 (the scale effect). Section 6 contains a welfare analysis. Section 7 discusses a number of extensions and Section 8 concludes.

2 The Model

Consider the market for a vertically differentiated product which is characterized by its quality $q \geq 0$. Demand at price p is given by the function $x(p, q)$ with inverse $p(x, q)$. Assume that $p(\cdot)$ is smooth in both arguments and that $p_x(x, q) < 0$ and $p_q(x, q) > 0$ for all x and q, where subscripts denote partial derivatives. Moreover, it will be assumed that $p_{xq}(x, q) < 0$, implying that consumers with a higher willingness to pay for the product also have a larger preference for quality.[3]

The good is produced in a vertical production process which consists of a monopoly upstream firm (indexed by 1) and a monopoly downstream firm (indexed by 2), which may or may not be vertically integrated. The upstream firm first produces an intermediate good of quality $q_1 \geq 0$ which it sells at transfer price p_t to the downstream firm. The downstream firm in turn produces the final good by choosing a quality $q_2 \geq 0$ to refine the input.[4] The good is then sold to the market at price p. The final quality q is determined by the quality levels provided by the two firms, so that $q = q(q_1, q_2)$, where it is assumed that $q(\cdot)$ is weakly increasing in both q_1 and q_2. Firms $i = 1, 2$ have smooth cost functions $C^i(x, q_i)$ which are strictly increasing in both arguments. Throughout the paper, it will be assumed that second order conditions hold to guarantee the existence of a solution.

[3] For most circumstances this is a natural assumption which is routinely made in the literature on price discrimination (e.g., Mussa and Rosen, 1978). Section 7 discusses how the results of the paper change when instead $p_{xq}(x, q) \geq 0$.

[4] While the model is formulated here as an intermediate/final good producer relationship, it can equivalently be interpreted as a manufacturer/retailer relationship with wholesale price p_t.

In the general form presented here, the equilibrium of the model is determined by several interacting effects. As a consequence, stubbornly solving the firms' maximization problems yields little in the way of understanding the structure of the solution. We will therefore proceed by an alternative route, identifying the three distinct effects that govern the relationship between vertical integration and product quality. Table 1 gives a summary of the effects and whether they tend to increase or decrease quality under integration. As can be seen there, the first of the three effects is always present, while the second and the third effect only appear under specific circumstances. Section 3 will first analyze the model under the assumption that those circumstances are not fulfilled. It will be demonstrated that in this case quality under integration is always lower than with separate firms. Sections 4 and 5 then add the characteristics needed for the second and third effect, demonstrating that both tend to increase the quality under integration. As will become apparent, this separation of effects allowa studying important special cases of vertical chains like the manufacturer/retailer relationship, the intermediate/final good producer relationship, the provision of promotional services, and the deregulation of network industries.

Effects of integration	Quality change	Occurrence
Demand effect (Section 3)	Decrease	Always
Commitment effect (Section 4)	Increase	Upstream investment
Scale effect (Section 5)	Increase	Quality scale economies

Table 1: Quality Effects

3 The Demand Effect

We will first analyze the problem under conditions that ensure that the second and third effect are absent. These conditions turn out to be that the upstream firm has no impact on quality (i.e., there is downstream investment) and that the cost of quality provision does not decrease with the scale of production (i.e., there are no scale economies regarding quality provision). More formally, we will assume the following in this section.

Condition 1 *(Downstream investment)* $\partial q/\partial q_1 = 0$.

Condition 2 *(No quality scale economies)* $\frac{\partial C^i/\partial q_i}{x} \leq \frac{\partial^2 C^i}{\partial q_i \partial x}$ *for* $i = 1, 2$.

Condition 1 of course implies that $q_1 = 0$ in equilibrium so that $q = q(0, q_2)$. Without loss of generality, we let the downstream firm choose q directly, setting $q_2 = q$, so we have downstream investment. To get a clearer picture which types of cost functions satisfy Condition 2, consider the cost structures $C = F + c(q)x$ and $\tilde{C} = F(q) + cx$. Cost structure C, where quality increases variable costs, fulfills condition 2. Cost structure $\tilde{C}$, on the other hand, where quality increases fixed costs, does not.

The conditions laid out in this section correspond to an intermediate/final good producer relationship in industries with large scale production. Manufacturers buy a homogeneous input from the upstream firm which is then refined to a final product. As the good is already produced at a significant scale, further increases in the volume of production do not make the provision of quality cheaper on a per unit basis. As an example, one could think of a car manufacturer that buys steel as an input.[5]

We will begin by analyzing the equilibrium under the vertically integrated structure. In that case the integrated firm's profit function is

$$\pi = xp(x, q) - C^1(x) - C^2(x, q).$$

[5] In the case where significant scale effects are present in intermediate/final good producer relationships the scale effect becomes relevant. See Proposition 4 below.

Maximizing profits with respect to x and q gives

$$\frac{\partial \pi}{\partial x} = p + x p_x - C_x^1 - C_x^2 = 0 \tag{1}$$

and

$$\frac{\partial \pi}{\partial q} = x p_q - C_q^2 = 0. \tag{2}$$

The corresponding second order conditions are

$$\frac{\partial^2 \pi}{\partial x^2} = 2p_x + x p_{xx} - C_{xx}^1 - C_{xx}^2 < 0, \tag{3}$$

$$\frac{\partial^2 \pi}{\partial q^2} = x p_{qq} - C_{qq}^2 < 0, \tag{4}$$

and

$$\begin{aligned} \frac{\partial^2 \pi}{\partial x^2}\frac{\partial^2 \pi}{\partial q^2} - \left(\frac{\partial^2 \pi}{\partial x \partial q}\right)^2 &= (2p_x + x p_{xx} - C_{xx}^1 - C_{xx}^2) \\ &\quad \times (x p_{qq} - C_{qq}^2) - (p_q + x p_{xq} - C_{xq}^2)^2 > 0. \end{aligned} \tag{5}$$

The solution is characterized by the usual equality of marginal cost and marginal revenue on the one hand, and of marginal willingness to pay for quality and marginal cost of quality on the other hand.

Next, we will turn to the disintegrated solution. Under separation, the downstream firm's profit function is

$$\pi_2 = x\,[p(x,q) - p_t] - C^2(x,q).$$

Taking the transfer price p_t as given, firm 2 maximizes its profit with respect to x and q. This yields

$$\frac{\partial \pi_2}{\partial x} = p + xp_x - p_t - C_x^2 = 0 \tag{6}$$

and

$$\frac{\partial \pi_2}{\partial q} = xp_q - C_q^2 = 0. \tag{7}$$

The corresponding second order conditions are

$$\frac{\partial^2 \pi_2}{\partial x^2} = 2p_x + xp_{xx} - C_{xx}^2 < 0, \tag{8}$$

$$\frac{\partial^2 \pi_2}{\partial q^2} = xp_{qq} - C_{qq}^2 < 0, \tag{9}$$

and

$$\begin{aligned} \frac{\partial^2 \pi_2}{\partial x^2}\frac{\partial^2 \pi_2}{\partial q^2} - \left(\frac{\partial^2 \pi_2}{\partial x \partial q}\right)^2 &= (2p_x + xp_{xx} - C_{xx}^2) \\ &\quad \times (xp_{qq} - C_{qq}^2) - (p_q + xp_{xq} - C_{xq}^2)^2 > 0. \end{aligned} \tag{10}$$

In the first stage, the upstream firm chooses the transfer price p_t, anticipating the downstream firm's marketing decision $x(p_t)$ in the second stage. Its profit function therefore is

$$\pi_1 = x(p_t)p_t - C^1(x(p_t)).$$

The optimal transfer price is then determined by the first order condition

$$\frac{\partial \pi_1}{\partial p_t} = \frac{dx}{dp_t}\left[p_t - C_x^1(x(p_t))\right] + x = 0. \tag{11}$$

Comparing the two regimes, Proposition 1 arrives at the following result.

Proposition 1 *Assume Conditions 1 and 2 hold. Then successive monopolies provide a higher level of quality than a vertically integrated firm. Given output, quality is such that joint profits are maximized.*

Proof. Note first that if the upstream firm were to sell her input at marginal costs ($p_t = C_x^1$), then equations (1) and (2) would be identical to equations (6) and (7) and the integrated and the disintegrated solution would fall together. As marginal cost pricing results in zero profits, however, it is straightforward to see that we must have $p_t > C_x^1$. Applying the implicit function theorem to equations (6) and (7) then yields

$$\begin{aligned} \frac{dq}{dp_t} &= -\begin{vmatrix} \frac{\partial^2 \pi_2}{\partial x^2} & \frac{\partial^2 \pi_2}{\partial x \partial p_t} \\ \frac{\partial^2 \pi_2}{\partial x \partial q} & \frac{\partial^2 \pi_2}{\partial q \partial p_t} \end{vmatrix} \Big/ \begin{vmatrix} \frac{\partial^2 \pi_2}{\partial x^2} & \frac{\partial^2 \pi_2}{\partial x \partial q} \\ \frac{\partial^2 \pi_2}{\partial x \partial q} & \frac{\partial^2 \pi_2}{\partial q^2} \end{vmatrix} \\ &= -\frac{p_q + x p_{xq} - C_{xq}^2}{(2p_x + x p_{xx} - C_{xx}^2)(x p_{qq} - C_{qq}^2) - (p_q + x p_{xq} - C_{xq}^2)^2} > 0. \end{aligned} \tag{12}$$

where (10) and the fact that by (7) $p_q - C_{xq}^2 = C_q^2/x - C_{xq}^2 \leq 0$ (this is Condition 2) have been used to determine the sign. Hence, $p_t > C_x^1$ implies that q is higher under non-integration than under integration.

For the second part of the proposition, first observe that the level of quality that maximizes joint profits for a given x is defined by (2). Noting that the actual quality choice by the independent downstream firm is given by (7) which is identical to (2) completes the proof. ■

The fact that disintegrated firms provide a higher level of quality has a simple intuition. Since the seller of the input good is an independent monopolist, he will charge a transfer price above marginal costs. The result is double marginalization which causes a restriction of output. Since a more exclusive group of consumers is served, there is an incentive to adjust the level of quality upwards.

As we have downstream investment here, the model is useful to evaluate the question whether retailers fall short of providing efficient services for the products they sell. In general, an upstream producer will worry that a retailer does not put enough effort into promotional activities. This problem has been termed downstream moral hazard by Tirole (1988, p. 178) who shows that the retailer exerts a positive externality on the producer (increased services lead to higher demand for the producer's products). As the retailer does not internalize this externality, the provided service quality is too low given the input price.

The existence of this quality-reducing externality and the term "moral hazard" suggest that independent retailers provide less services than a vertically integrated monopolist (see Rey and Vergé, 2008, p. 363, for a more recent paper drawing this conclusion). Whether this is actually the case can readily be analyzed within the scope of this section as both Tirole's and Rey and Vergé's formulations are special cases of the more general model presented here, satisfying both Conditions 1 and 2. Following Proposition 1, the surprising result is that despite the fact that they do not take the positive externality into account that they exert on producers, independent retailers provide a higher level of promotional services.

The reason for this is that there is an externality *taking the input price* p_t *as given.* However, it is of little use to take an endogenous variable in a dynamic game as exogenously given, as it is chosen strategically to affect the subsequent actions of other players. So in fact, the externality between retailer and producer is no source for downstream moral hazard as proposed by the previous literature. As Proposition 1 demonstrates, retailers really provide a level of services that maximizes joint profits of the independent firms.[6]

[6] Note, however, that in models with more than one retailer as in Mathewson and Winter (1984, 1993), retailers may exert positive externalities on each other. This happens, for instance, if one retailer's advertising for a product

Tirole's vertical externality is also Buehler et al.'s (2004) explanation why vertical integration tends to increase quality in their model. Since this externality is not a source of underinvestment, however, there must be another reason why integration increases quality in Buehler et al. (2004) and Economides (1999). As the following two sections show, there are two such reasons. First, as discussed in Section 4, upstream investment allows firms to use an underprovision of quality as a commitment to reduce excessive downstream prices. Second, as discussed in Section 5, scale effects lead to a similar result.

4 The Commitment Effect

We will now relax Condition 1 to show that if it does not hold, a second effect appears that influences the quality provision of independent monopolists. For simplicity, we will consider a situation where only the upstream firm's investment is relevant for the overall level of quality. Corresponding to last section's procedure, it will therefore be assumed that $q = q(q_1, 0) = q_1$. As will become clear below, the results carry over to the general case where q_2 is also relevant. In addition to tractability, this approach has the advantage that it represents an important special case, namely the situation where a manufacturer sells its products via a retailer (who does not provide extensive services).

The vertically integrated solution is again given by equations (1) to (5), with the cost functions' indices exchanged as the quality investment is now made by firm one instead of firms two.[7]

increases another retailer's demand for the product. In this case, of course, retailers may underprovide promotional activities.

[7] The correspondingly altered equations will be referred to as equations (1a) to (5a) in what follows.

If the two firms are independent, the downstream firm's profit function is

$$\pi_2 = x\left[p(x,q) - p_t\right] - C^2(x).$$

Given an input good of price p_t and quality q, it will therefore set the quantity such that

$$\frac{\partial \pi_2}{\partial x} = p + xp_x - p_t - C_x^2 = 0. \tag{13}$$

The corresponding second order condition is

$$\frac{\partial^2 \pi_2}{\partial x^2} = 2p_x + xp_{xx} - C_{xx}^2 < 0. \tag{14}$$

The upstream firm's profit function is

$$\pi_1 = x(p_t,q)p_t - C^1(x(p_t,q),q).$$

The optimal choice of p_t and q is then given by

$$\frac{\partial \pi_1}{\partial p_t} = \frac{dx}{dp_t}\left[p_t - C_x^1(x(p_t,q),q)\right] + x = 0 \tag{15}$$

and

$$\frac{\partial \pi_1}{\partial q} = \frac{dx}{dq}\left[p_t - C_x^1(x(p_t,q),q)\right] - C_q^1(x(p_t,q),q) = 0. \tag{16}$$

Comparing these two solution we arrive at the following proposition.

Proposition 2 *Assume Condition 2 holds. Then successive monopolies provide a higher level of quality (if the demand effect is sufficiently strong) or a lower level of quality (if the commitment* *effect is sufficiently strong) than a vertically integrated firm. Given output, quality is below the level that maximizes joint profits.*

Proof. The most convenient way of proving this proposition is by way of graphical representation of the equilibrium. We will first depict the vertically integrated equilibrium in (x, q) space. The equilibrium point is represented by the intersection of the two curves that are defined by equations (1.1a) and (1.2a). Using the implicit function theorem, the curve $\partial\pi/\partial x = 0$ is found to have the slope

$$\left.\frac{dq}{dx}\right|_{\partial\pi/\partial x=0} = -\frac{\frac{\partial^2\pi}{\partial x^2}}{\frac{\partial^2\pi}{\partial x\partial q}} = -\frac{2p_x + xp_{xx} - C^1_{xx} - C^2_{xx}}{p_q + xp_{xq} - C^1_{xq}}. \tag{17}$$

Likewise, the curve $\partial\pi/\partial q = 0$ has slope

$$\left.\frac{dq}{dx}\right|_{\partial\pi/\partial q=0} = -\frac{\frac{\partial^2\pi}{\partial x\partial q}}{\frac{\partial^2\pi}{\partial q^2}} = -\frac{p_q + xp_{xq} - C^1_{xq}}{xp_{qq} - C^1_{qq}}. \tag{18}$$

By (1.3a), the numerator of (17) is negative and by (1.4a) the denominator of (18) is also smaller than zero at the equilibrium point. Hence, around the equilibrium, the slope of both curves has the same sign as $\partial^2\pi/(\partial x\partial q)$. By (1.2a), $p_q - C^1_{xq} = C^1_q/x - C^1_{xq} \leq 0$, where the inequality follows from Condition 2. Therefore, we must have $\partial^2\pi/(\partial x\partial q) < 0$ so both curves are downward sloping. Comparing (17) and (18), one finds that the curve $\partial\pi/\partial x = 0$ is strictly steeper than the curve $\partial\pi/\partial q = 0$ if and only if

$$\frac{\partial^2\pi}{\partial x^2}\frac{\partial^2\pi}{\partial q^2} > \left(\frac{\partial^2\pi}{\partial x\partial q}\right)^2.$$

Around the equilibrium we know this to be the case from (1.5a). Accordingly, Figure 1 represents the solution with the curve $\partial\pi/\partial x = 0$ falling steeper than the curve $\partial\pi/\partial q = 0$. Next we will

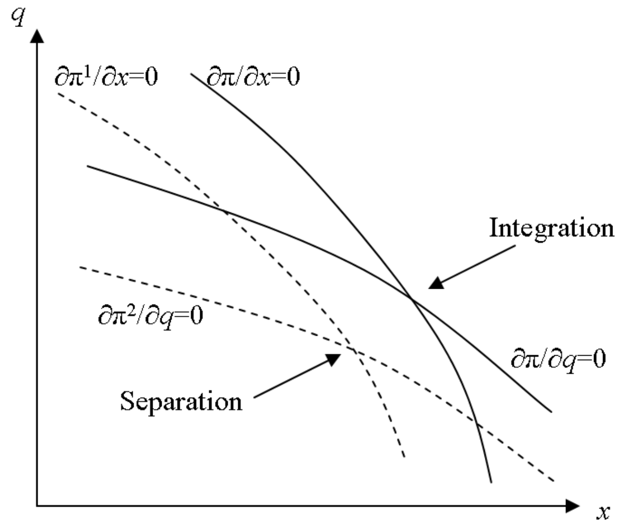

Figure 1: Equilibrium with upstream investment

determine how the curves shift under independent pricing. From (15) we first obtain

$$p_t = -\frac{x}{\frac{dx}{dp_t}} + C_x^1. \tag{19}$$

Substituting (19) into (13) gives

$$\frac{\partial \pi_2}{\partial x} = p + xp_x - C_x^1 - C_x^2 + \frac{x}{\frac{dx}{dp_t}} = 0 \tag{20}$$

which is the curve $\partial \pi_2 / \partial x = 0$ that describes the choice of x under disintegration. Note that (20) is exactly equal to (1.1a) with $x/(dx/dp_t)$ added. The sign of this expression is equal to the sign of

$$\frac{dx}{dp_t} = -\frac{\frac{\partial^2 \pi_2}{\partial x \partial p_t}}{\frac{\partial^2 \pi_2}{\partial x^2}} = \frac{1}{2p_x + xp_{xx} - C_{xx}^2} < 0 \tag{21}$$

which is derived by applying the implicit function theorem to (13). In view of (20) the question is: given some value of q, how must x be changed in equation (1.1a) to yields a positive expression such that (20) is fulfilled? As $\partial^2 \pi / \partial x^2 < 0$ by (1.3a), it turns out that x must be decreased.

Hence, the curve $\partial\pi_2/\partial x = 0$ lies to the left of the curve $\partial\pi/\partial x = 0$ as depicted in Figure 1. This is the demand effect of independent quality provision: as is apparent from the graphical representation, it increases q and decreases x. The curve that describes the choice of q under disintegration is found by substituting (19) in (16) which yields

$$\frac{\partial\pi_1}{\partial q} = -\frac{dx}{dq}\frac{x}{\frac{dx}{dp_t}} - C_q^1 = 0. \tag{22}$$

Applying the implicit function theorem to (13) again we find that

$$\frac{dx}{dq} = -\frac{\frac{\partial^2\pi_2}{\partial x\partial q}}{\frac{\partial^2\pi_2}{\partial x^2}} = -\frac{p_q + xp_{xq}}{2p_x + xp_{xx} - C_{xx}^2}.$$

Noting that this expression is equal to $-(p_q + xp_{xq})\frac{dx}{dp_t}$ and substituting it into (22) then gives

$$\frac{\partial\pi_1}{\partial q} = xp_q - C_q^1 + x^2 p_{xq} = 0. \tag{23}$$

Note that (23) is exactly equal to (1.2a) with $x^2 p_{xq} < 0$ added. The question here is, how must q be changed in (1.2a) while holding x constant such that (1.2a) yields something positive, thereby fulfilling (23). As $\partial^2\pi/\partial q^2 < 0$ by (1.4a), it turns out that a decrease in q is necessary. This is represented in Figure 1 by the fact that the curve $\partial\pi_1/\partial q = 0$ lies below the curve $\partial\pi/\partial q = 0$. This is the commitment effect which is seen to decrease q and to increase x. Obviously, the exact position of q under disintegration depends on the relative strength of demand and commitment effect.

Finally, the second part of the proposition has to be demonstrated. Given an arbitrary x the level of q that maximizes joint profits is implicitly defined by (1.2a), yielding $p_q - C_q^1/x = 0$. Note, however, that rearranging (23), the quality that is provided under disintegration can be described by the equation $p_q - C_q^1/x = xp_{xq} < 0$. Using (1.4a) we therefore arrive at the conclusion that q is smaller than the amount that maximizes joint profits. ■

Proposition 2 shows that when there is upstream investment, two effects govern the quality provision of an independent upstream firm (which are graphically displayed in Figure 1). First, there is the demand effect that tends to increase quality in the disintegrated case for the same reason as in the last section. Anticipating double marginalization, the manufacturer increases quality as goods will be sold to a more exclusive class of consumers. Second, and new in this section, is the commitment effect. As the quality level is chosen before the retailer decides on its markup, the quality level can be set strategically in order to influence the extent of double marginalization downstream. In order to prevent the downstream firm from demanding a high margin, the upstream firm strategically reduces the level of quality. The manufacturer effectively produces a mass product (in terms of quality) in order to commit the retailer not to market it as a luxury good (in terms of quantity).

Note that this commitment introduces an inefficiency into the provision of quality. The upstream firm's behavior here is akin to what a social planner does in a second best world: when there is a distortion in one dimension of the market (here the price-distortion caused by double marginalization), it becomes optimal to introduce a distortion in a second dimension (here by reducing quality). Note also that the result of Proposition 2 immediately carries over to the more general case where both q_1 and q_2 are important: if quality may be higher or lower under integration without downstream investment, it may also be higher or lower with downstream investment.

From the proof of Proposition 2 one can see that the demand effect is particularly strong when demand is more concave (less convex). Intuitively this corresponds to a situation where a relatively large proportion of consumers has a high willingness to pay. The commitment effect will be important whenever p_{xq} is large, implying that quality reductions are particularly effective in deterring retailers from going upmarket. In order to be able to get a more direct feel for the relative impact of the two effects, it may, however, be desirable to refer to a concrete special case that illustrates when the model tips from a lower to a higher choice of quality. Proposition 3 provides such a case.

Proposition 3 *Assume that both firms have a constant returns to scale technology. Then, if the demand function is linear in the price, successive monopolies with upstream investment provide the same level of quality as a vertically integrated firm.*

Proof. The requirement of constant returns to scale implies that the cost functions are of the form $C^1(x,q) = xc_1(q)$ and $C^2(x) = xc_2$, where c_2 is a constant. Linearity in p implies that inverse demand takes the form $p = a(q)x + b(q)$ for some functions $a(q)$ and $b(q)$. Using these demand and cost functions, it is straightforward to show that (1.1a) now corresponds to

$$2a(q)x + b(q) - c_1(q) - c_2 = 0 \tag{24}$$

and that (1.2a) corresponds to

$$x = \frac{c_1'(q) - b'(q)}{a'(q)}. \tag{25}$$

Likewise, (13) is given by

$$4a(q)x + b(q) - c_1(q) - c_2 = 0 \tag{26}$$

and (16) by

$$x = \frac{c_1'(q) - b'(q)}{2a'(q)}. \tag{27}$$

Substituting (24) in (25) and rearranging or (26) in (27) and rearranging both yields

$$2a(q)\frac{c_1'(q) - b'(q)}{a'(q)} + b(q) - c_1(q) - c_2 = 0, \tag{28}$$

which is a function of q alone. Thus, the level of quality produced by independent firms is identical to the level that a vertically integrated manufacturer provides. ■

Proposition 3 tells us that with constant returns and linear demand, a producer with an independent retailer is equivalent to a vertically integrated manufacturer in terms of quality provision.[8,9] The acquisition of a retailer by a producer will therefore only affect the retail price but not the product as such. Note that only linearity in p is required, so that demand and cost functions are generally allowed to be non-linear in q. This is important because the scaling of q can only be sensibly defined up to a positive monotone transformation, which would render linearity requirements void.

5 The Scale Effect

After showing that a relaxation of Condition 1 can alter Section 3's conclusion that independent firms always provide more quality, we will now see that the same result can be obtained if instead Condition 2 is relaxed. Contrary to Section 3, we therefore assume that the cost function is such that quality investments become cheaper with scale. That is, the per unit costs of producing a given level of quality decreases with the number of units that are produced.

Obviously, Section 3's first order conditions still apply in this section. The equilibrium char-

[8] While the generality of this result should not be overemphasized, linearity may be more than a convenient focal point of the analysis. Bresnahan and Reiss (1985) estimate manufacturer and retailer margins in the car industry and can not reject the hypothesis that the demand functions for the large number of models they consider are linear.

[9] The result of Proposition 3 readily extends to the class of cost functions of the form $C = F + c(q)x$, which nests all constant returns functions. The latter were chosen in the proposition merely because of their particular importance in the long run.

acteristics implied by them, however, change as Condition 2 can not be applied anymore. This is stated in Proposition 4.

Proposition 4 *Assume Condition 1 holds. Then successive monopolies provide a higher level of quality (if the demand effect is sufficiently strong) or a lower level of quality (if the scale effect is sufficiently strong) than a vertically integrated firm. Given output, quality is such that joint profits are maximized.*

Proof. The proof is immediate by following the proof of Proposition 1 step by step and noting that the numerator of dq/dp_t is now indeterminate in sign as $xp_{xq} < 0$, while $p_q - C^2_{xq} = C^2_q/x - C^2_{xq} > 0$ since Condition 2 does not hold. ■

The scale effect that is introduced here by assuming that Condition 2 does not hold tends to decrease the quality that independent firms provide. The reason is straightforward. Double marginalization reduces the quantity sold. But as the provision of quality becomes more costly when production is at a smaller scale, the downstream firm chooses to offer less of it.

The strength of the scale effect is directly determined by the characteristics of the cost function. Most importantly, if the provision of quality tends to increase fixed cost, the scale effect will be important, while it will be of less relevance if quality provision predominantly affects marginal costs. This explains why vertical separation of network infrastructure tends to decrease quality (as suggested by Economides, 1999, and Buehler et al., 2004). Both the scale effect and the commitment effect are very important in those industries as network investment occurs upstream and will predominantly increase fixed costs. Whenever the commitment effect offsets the demand effect as in Proposition 3, even a small scale effect will necessarily push quality into the negative under vertical separation.

6 Welfare

The analysis so far has been positive, describing in some detail how vertical integration influences product choice. In this section, we will now turn to the normative question whether vertical integration is desirable from a welfare point of view. There are two parts to this. First, vertical integration allows to overcome double marginalization which is unambiguously desirable as prices are decreased and profits increased. Second, however, we must consider the impact of integration on quality. As Spence (1975) and Sheshinski (1976) have shown, if output is taken as given, monopolies provide too little quality from a welfare point of view when $p_{xq} < 0$. Hence, whenever higher quality levels can be achieved under disintegration, this makes integration *less* attractive. In principle, therefore, the general wisdom that vertical integration of successive monopolies is beneficial could loose its validity once the endogeneity of product characteristics is acknowledged.

To analyze this question formally, let us begin by inspecting the market solution of Section 3, where Conditions 1 and 2 hold. The welfare function $W(x, q)$ consists of gross consumer surplus minus the costs of production.

$$W(x,q) = \int_0^x p(z,q)dz - C^1(x) - C^2(x,q) \tag{29}$$

Maximizing (29) with respect to x and q gives the first order conditions

$$\frac{\partial W}{\partial x} = p(x,q) - C_x^1 - C_x^2 = 0 \tag{30}$$

and

$$\frac{\partial W}{\partial q} = \int_0^x p_q(z,q)dz - C_q^2 = 0. \tag{31}$$

with the associated second order conditions

$$\frac{\partial^2 W}{\partial x^2} = p_x - C^1_{xx} - C^2_{xx} < 0, \tag{32}$$

$$\frac{\partial^2 W}{\partial q^2} = \int_0^x p_{qq}(z,q)dz - C^2_{qq} < 0 \tag{33}$$

and

$$\begin{aligned} \frac{\partial^2 W}{\partial x^2}\frac{\partial^2 W}{\partial q^2} - \left(\frac{\partial^2 W}{\partial x \partial q}\right)^2 &= (p_x - C^1_{xx} - C^2_{xx}) \\ &\times \left[\int_0^x p_{qq}(z,q)dz - C^2_{qq}\right] - (p_q - C^2_{xq})^2 > 0. \end{aligned} \tag{34}$$

It will again be useful to depict the optimum graphically. Figure 2 shows it as the intersection of the curves $W_x = 0$ and $W_q = 0$, which are given by (30) and (31). To prove that both curves are indeed downward sloping around the optimum, the implicit function theorem is applied to (30) and (31) to yield

$$\left.\frac{dq}{dx}\right|_{\partial W/\partial x=0} = -\frac{\frac{\partial^2 W}{\partial x^2}}{\frac{\partial^2 W}{\partial x \partial q}} = -\frac{p_x - C^1_{xx} - C^2_{xx}}{p_q - C^2_{xq}} < 0 \tag{35}$$

and

$$\left.\frac{dq}{dx}\right|_{\partial W/\partial x=0} = -\frac{\frac{\partial^2 W}{\partial x \partial q}}{\frac{\partial^2 W}{\partial q^2}} = -\frac{p_q - C^2_{xq}}{\int_0^x p_{qq}(z,q)dz - C^2_{qq}} < 0. \tag{36}$$

The negative signs can be inferred from (32), (33) and the fact that $\partial^2 W/(\partial x \partial q) = p_q - C^2_{xq} < 0$. To see that this latter cross-derivative is negative first note that by Condition 2, $C^2_{xq} \geq C^2_q/x$. By (31) in turn, $C^2_q/x = \left[\int_0^x p_q(z,q)dz\right]/x$. As $p_{xq} < 0$ by assumption, we must also have $\left[\int_0^x p_q(z,q)dz\right]/x > p_q$. Thus, $C^2_{xq} > p_q$, the desired result.

Comparing the relative slopes of (35) and (36), we immediately find that the curve $W_x = 0$ is

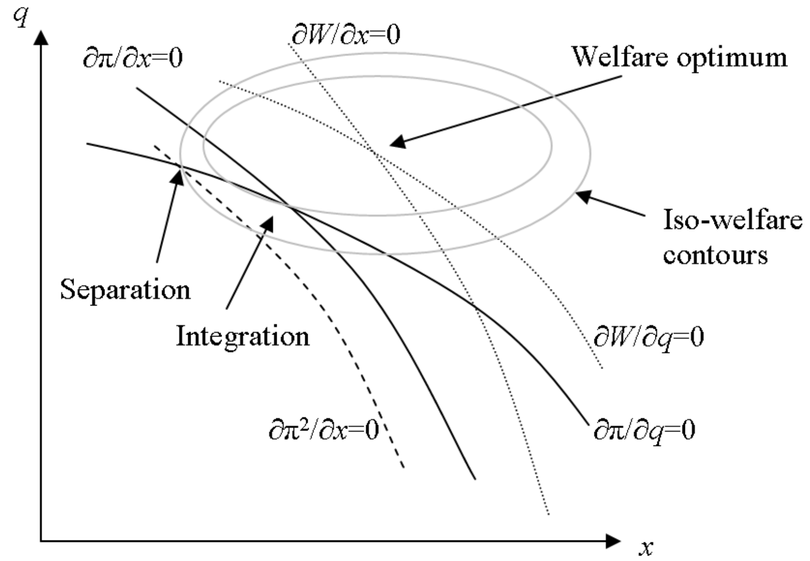

Figure 2: Welfare comparison

steeper than the curve $W_q = 0$ by (34) as depicted in Figure 2, which completes the picture for the welfare optimum.

Along the lines of the proof of Proposition 2 we can also represent the integrated and separated monopoly solution graphically, which are depicted in Figure 2 as the intersection of the curves $\pi_x = 0$ and $\pi_q = 0$ for the integrated case and $\pi_x^2 = 0$ and $\pi_q = 0$ for the disintegrated case. Using the same techniques as in the proof of Proposition 2 allows demonstrating that the three monopoly curves indeed lie strictly below the respective welfare curves.

In order to compare the welfare properties of the integrated and disintegrated solution, Figure 2 shows the iso-welfare contours that pass through the monopoly solutions. The contours are drawn such that welfare is higher under integration than under separation (the better-direction is inwards), but it is easy to see that this will in general depend on their specific shape, which can be derived as

$$\left.\frac{dq}{dx}\right|_{W=W(x,q)} = -\frac{\partial W/\partial x}{\partial W/\partial q} = -\frac{p(x,q) - C_x^1 - C_x^2}{\int_0^x p_q(z,q)dz - C_q^2} \tag{37}$$

by using (30) and (31). This expression (which primarily consists of first order derivatives) is quite unrelated to the slopes of the other curves in the figure (which primarily consist of second order derivatives). Hence, no meaningful general assertion can be made about the relative positions of the two iso-welfare contours.

Despite this theoretical indeterminacy there is a strong presumption that even if vertical integration of successive monopolies decreases quality, it is likely to increases welfare. First, note that vertical integration can not decrease welfare in our model unless monopoly regulation that *increases* prices would be efficient. While it is possible to construct theoretical examples of this kind (see Sheshinski, 1976), they are hardly considered very relevant in practice. Indeed there is a strong presumption that forcing monopolists to further raise prices is not desirable. Second, the possibility of welfare improving price increases is only a necessary, not a sufficient condition for vertical separation to be welfare enhancing. Third, the relative welfare merits of vertical separation are even further weakened in scenarios with a commitment effect and a scale effect. As shown in Propositions 2 and 4, they lead to a decrease in quality below even the level that firms would find optimal given equilibrium output.

7 Extensions and Discussion

This section will discuss a number of aspects of the basic model and analyze some important extensions.

Double Marginalization

In the basic model, the driving force behind the quality provision of successive monopolies is double marginalization. In principle, contractual solutions exist that prevent double marginalization and so one may wonder why firms not simply write optimal nonlinear contracts that implement the integrated allocation.

The problem with those schemes, however (and the reason why contractual solutions are often ruled out in the literature), is that they fail to prevent double marginalization in settings that are more realistic than the idealized textbook exhibition of vertically related markets. For instance, note that nonlinear pricing schemes leave all potential risk with the downstream firm if demand is uncertain. Transferring some of the risk to the upstream firm then necessarily involves a wholesale price above marginal costs (Rey and Tirole, 1986), so double marginalization reappears. But even if it were optimal for the downstream firm to carry the whole risk, pricing above marginal costs would still be necessary if there is asymmetric information between the firms concerning future demand conditions (Gallini and Wright, 1990). Moreover, a variety of historical and regulatory reasons make coordination difficult (see Smith, 1982). Tirole (1988, p. 176-177) contains a discussion and further arguments why contractual solutions will in general not make it possible to eradicate double marginalization.[10]

What Happens if $p_{xq} \geq 0$*?*

The assumption that $p_{xq} < 0$ was used at several points in this paper. It turns out that, if one assumes instead that $p_{xq} \geq 0$, the direction of the demand effect and the commitment effect change signs. In fact, the output contraction that is caused by double marginalization would lead firms to *decrease* quality because consumers with a higher willingness to pay then have a lower preference for quality. As a result, upstream firms would have an incentive to *increase* quality in order to stop downstream firms from restricting output to luxury consumers. The scale effect, on the other hand, is not affected by the sign of p_{xq}.

[10] These theoretical arguments are supported by a number of empirical studies that provide evidence for double marginalization in different industries. See, for instance, Bresnahan and Reiss (1985), Lafontaine (1995) and West (2000).

Ex-ante Investments

In the basic model it was assumed that firms make their choice of quality at the same time they decide on their price. This is certainly the right order of events in many vertical chains. In others, it may be more realistic to assume that firms first simultaneously decide on the level of quality they want to offer and then start a sequential pricing game. This is the case whenever quality choice is determined by long-standing investments, for example by the construction of a particular type of production plant or the acquisition of a certain machine.

In the situation analyzed in Section 4, where the upstream firm provides quality, obviously nothing changes as the upstream firm moves first anyhow. The case of downstream investment analyzed in Section 3, however, does change. When the downstream firm makes her quality choice prior to the upstream firm's price decision, the level of quality can be selected strategically to prevent excessive pricing by the upstream firm. So, maybe not surprisingly, the upstream firm will consider the commitment effect. In this case Proposition 3, which shows that integration does not affect quality in linear environments, can be extended to the case of downstream investment. In general, quality may be higher or lower under integration, depending on the same three effects that were illustrated in the basic model.

Price Discrimination

As consumers are heterogeneous in their preference for quality, it pays for firms to price discriminate between them by offering different qualities. This, however, does not change the general intuition of the effects that are analyzed in this paper. In fact, it can be shown that the results of the basic model qualitatively carry over to the case of price discrimination. For instance, the demand effect implies that successive monopolies provide a smaller range of qualities containing only higher levels of quality. Likewise, the commitment effect implies that independent firms sell a larger range of qualities, also containing lower levels of quality.

8 Conclusion

The previous literature on the quality effects of vertical integration has concluded that separation reduces quality because of vertical externalities. As it turned out, however, this presumption is wrong; under natural conditions separation even increases quality. Using a generic model of successive monopolies that embeds Tirole's (1988), Buehler et al.'s (2004) and Rey and Vergé's (2008) models as special cases, this paper has presented a general framework to analyze vertical quality provision. It was shown that the choice of quality is governed by three distinct effects which were isolated in the model. Out of those, only the quality-decreasing effect of vertical integration is always present, while the two quality-increasing effects appear only in particular environments. The juxtaposition of these effects has allowed us to provide a more nuanced view of important special cases.

Section 3 described situations where vertical integration tends to *decrease quality* (e.g., in the case of distributor's promotional services). Here the demand effect is likely to dominate the other two effects (if they are present at all). Section 4 described situations where vertical integration tends to *leave quality unaffected* (e.g., in the case of a producer/retailer relationship). With linear demand and constant returns to scale, the demand effect and the commitment effect even offset each other perfectly. Finally, Section 5 described situations where vertical integration tends to *increase quality* (e.g., in the case of network infrastructure). Here both the commitment effect and the scale effect work against the demand effect, which explains the previous results by Economides (1999) and Buehler et al. (2004).

It would be interesting to extend the model to a competitive downstream industry, with downstream firms offering differentiated products as in Perry and Groff (1985) and Kühn and Vives (1999). This appears to be a promising avenue for future research.

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