Vertical Integration with an Increasing Retail Supply Function.

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April 4, 2008

Abstract

There are contradictory views concerning how vertical integration within an industry or supply chain would affect end-user prices and welfare. Although the elimination of double marginalisation supports the view that vertical integration would induce a reduction in retail prices, there would be countervailing effects when retail network externalities result in an increasing retail supply function. If these effects are significant or exceed an identifiable threshold, then vertical integration will destroy rather than improve welfare. This paper develops a simple successive duopoly model for a vertically structured supply chain and derives the Cournot-Nash equilibria at the wholesale and retail stages. We identify that welfare will be destroyed by vertical integration when the cost of making retail deliveries is increasing in the total retail quantity at a *sufficiently high* rate. This is intuitive in that the negative welfare effect of the reduction in total profits when vertical integration occurs, due to the now higher costs associated with the retail deliveries, will exceed the positive effect of an increased consumer surplus, owing to the elimination of double marginalisation.

1 Introduction

The question of whether vertical integration within an industry or supply chain would lead to lower or higher retail prices remains controversial in both research and competition policy. Arguments favouring the former outcome claim that since vertical integration serves both to reduce the effect of double marginalisation (Spengler [1950]) and the burden of transaction costs in the supply chain

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‡The authors gratefully acknowledge the extensive supervisory input of Fred Schroyen (Department of Economics, NHH) in preparing this draft. We nevertheless remain solely liable for any errors and omissions therein.

(Williamson [1971]), efficiency consequently improves which imposes a downward pressure on retail prices. Nevertheless, contrary arguments that vertical integration would have market concentration effects support the notion that vertical integration may indeed create conditions that are conducive to the exercise of market power and would thereby result in higher retail prices.

An early direction in the literature examining this question was provided by Mckenzie [1951] and then followed up by Vernon and Graham [1971], Schmalensee [1973], Hay [1973] and Warren-Boulton [1974]. They examined the question of whether forward integration by an upstream monopoly manufacturer into a downstream stage would increase or decrease retail prices. The crux of their argument was that when there are substitution possibilities (variable proportions) in the use of inputs at the downstream stage, vertical integration would induce an expansion in the downstream utilisation of the intermediate product and an expansion of the retail output. While this would result in higher profits or an increase in the producer surplus, the altered degree of market concentration at the downstream stage could lead to a rise in the retail price which would reduce the consumer surplus and possibly, welfare.[1]

Another direction in the literature examining this question was provided by Bork [1969] and followed up by Greenhut and Ohta [1976], [1978].[2] Ignoring the presence of substitution possibilities in the use of inputs at the downstream stage (fixed proportions), they identify that while vertical integration by an upstream monopolist into a competitive downstream stage would not alter downstream utilisation of the intermediate product, it would reduce vertical costs, resulting in higher profits or an increased producer surplus, and would also tend to reduce the retail price, thereby raising the consumer surplus and consequently, welfare. Tirole [1988], although not assuming fixed proportions, examines vertical integration within a successive monopoly setting and identifies that not only do vertical costs fall with the reduction of double marginalisation, but that the profits or producer surplus also rises, while the retail price falls with both consumer surplus and total welfare consequently improving.

When the upstream and downstream stages are oligopolistic i.e a successive oligopoly, an important consideration is whether vertical integration is partial or complete. Partial vertical integration means that both vertically integrated and non vertically-integrated firms co-exist within the same supply chain. The implications of such an arrangement for prices, output and welfare have been much examined in contributions to the vertical foreclosure literature by Rey and Tirole [1986], Salinger [1988], Ordover et al. [1990] and Gaudet and Van Long [1995]. Complete vertical integration on the other hand, means that the supply chain shifts from being dis-integrated or vertically separated into being

[1]Schmalensee (1973) shows that the retail price rises following vertical integration, when the downstream or retail production function is Cobb-Douglas and the elasticity of demand is constant and exceeds one. Hay (1973) shows with a constant elasticity of substitution production function that the retail price rises, provided the elasticity of substitution exceeds the elasticity of retail demand. Warren-Boulton (1974) identifies that the retail price may yet rise with vertical integration even though Hay's condition is unfulfilled.

[2]See also comments to Greenhut and Ohta's contributions provided by Perry [1978].

fully vertically integrated, and has been variedly addressed by Greenhut and Ohta [1979], Lin [1988] and Bonano and Vickers [1988].[3]

While the impact of vertical integration on retail prices (and by extention welfare) remains the subject of intense debate, identifying the welfare benefits of vertical integration will evidently depend on understanding the nature of final consumers' response to changes in the retail price. This observation assumes particular relevance when the final demand is both heterogeneous and segmented, with the final demand segments (or sub-markets) reflecting such diverse characteristics as the price responsiveness of demand, consumers' willingness to pay and their consumption size. An open question under such conditions is whether the effects of segmentation and integration are additive or interactive. In other words, whether segmentation would in any way influence the effect of vertical integration and what the nature of such influence would be.

An important aspect of business activity is to be found in supply chains that rely heavily on the use of a common distribution resource or network, particularly at the retail level. Prominent examples are to be found in network industries like electric power, telecommunications, water and transport among others. At critical periods, congestion in the distribution network could generate severe externality effects with the implication that the retail delivery cost per-unit would be increasing in the size of the total retail deliveries - hence an increasing retail supply function.[4]

Also, with retailers focusing on minimising the costs required to serve final consumers and segmenting such consumers into groups that vary from low cost-high value to high cost-low value costumers, they will tend to initially acquire and retain the higher value customers and thereafter the lower value ones.[5] The implication is that the costs incurred in making retail deliveries would be increasing in the size of the total retail deliveries, which again implies an increasing retail supply function. An open question under such conditions is therefore how the increasing retail supply function would influence the effect of vertical integration and what the nature of such influence would be.

[3] Greenhut and Ohta [1979] assume fixed proportions and identify that vertical integration has a positive welfare effect with profits and output rising and the retail price falling. Lin [1988], without assuming fixed proportions, focuses on the incentives of firms to vertically integrate. He identifies that remaining vertical separated may be preferrable to being vertically integrated when the retail demand is sufficiently inelastic or if licensing or franchising opportunities are available. This is because vertical separation has the effect of dampening price competition, thereby allowing firms to raise prices and earn higher profits. Bonano and Vickers [1988] obtain a similar result. They identify that firms will have a strategic motive to remain vertically separated, inasmuch as their equilibrium profit under separation exceeds that under vertical integration, which is the case in their setting.

[4] A network externality arises when the independent actions of one actor within a system or supply chain, a retailer for instance, imposes economic costs on the activity of a rival retailer. A simple example is when the first retailer's actions independently congest a jointly utilised retail distribution network, thereby imposing a higher retail distribution cost on the second retailer.

[5] The Low cost-high value customers are characterised by: no latepayers, minimal call-centre activities, low distribution costs and/or low marketing costs; while the High cost-low value customers are characterised by: high debt collection costs, high call-centre activities, high distribution costs and/or high marketing costs.

With an increasing retail supply function, any benefit from vertical integration will be progressively eroded as the total retail quantity expands. This suggests some critical or threshold value for the marginal cost of making retail deliveries around which welfare would be either increasing or decreasing or be unaffected by vertical integration.

There are also open questions on the economic profitability of vertical integration between upstream and downstream firms within the supply chain and when such firms will have sufficient incentives to integrate (see Lin [1988] and Bonano and Vickers [1987]). Answers to these questions may have far-reaching implications for public policy on the unbundling of firms, promotion of retail competition and the allocation of network costs within a supply chain or the wider industry.

An indication of how end-user segmentation may affect the outcome of vertical integration is provided by Perry and Groff [1985]. They examine the welfare implications of forward integration by an upstream monopolist when the downstream stage is monopolistically competitive. The final consumers have a benefit function that is symmetric in the output of each (differentiated) product and there is a constant elasticity of substitution between these products.[6] Perry and Groff identify that while vertical integration on the one hand eliminates the double marginalisation effect, reducing final prices and increasing welfare, there is a countervailing effect from the direct monopolisation of each product. This effect arises because vertical integration leads to a reduction in the extent of product differentiation, which in turn reduces welfare. Inasmuch as the latter effect dominates the former, then vertical integration will destroy welfare.

There are few indications as to how an increasing retail supply function may influence the outcome of vertical integration. It is nevertheless reasonable to expect that this may prove significant. For simplicity, we will assume that such retail supply costs are positive and linearly increasing in the total retail delivery, at a parametrically defined rate equal to theta.

Our approach is to model price formation for a successive duopoly supply chain that engages in Cournot-Nash competition at the upstream and downstream stages. We assume that the supply chain structure may be either vertically separated: which is when wholesalers and retailers function as independent, profit-maximising entities, or vertically integrated: which is when a wholesaler and retailer combine to form a single firm. The simplistic paradigm thus adopted allows us to derive precise analytical results for the total profits, net consumer surplus and aggregate welfare, from which we are able to identify how segmentation and an increasing retail supply function would influence the outcome of vertical integration.

The main result of this paper is to identify that an increasing retail supply function would impose a significant constraint on the welfare gains from vertical integration. The reason for this is intuitive. When the cost of making retail

[6] We may plausibly draw parallels between a monopolistically competitive downstream stage and a segmented retail market. This is because by successfully differentiating a homogeneous product, which in this case means the intermediate input, each monopolistic competitor effectively creates a retail segment that is equivalent to the demand for its own product.

deliveries rises at a sufficiently high rate, the increase in consumer surplus from eliminating the effect of double marginalisation and thereby making increased retail deliveries to consumers at a lower price, will be effectively countervailed by a decrease in producer surplus (profits) owing to the increasing retail costs that are incurred while making such deliveries. Under these conditions, vertical integration will destroy welfare.

Furthermore, we identify that regardless of whether the industry is vertically integrated or not, having two end-user segments improves welfare relative to a situation with a single segment. This suggests that increasing the number of end-user segments may "by itself" be welfare improving. Since the analysis is however not extended beyond the case of two segments, it is difficult to precisely define the limitations to this result.

The paper is organised as follows: In the next section we examine the benchmark case of vertical integration with a single retail market or end-user segment. Section 3 extends the analysis to examine the case of two retail markets or end-user segments. Section 4 then concludes.

2 Price formation with a single retail market: The benchmark

Let us consider a supply chain with the simple vertical paradigm: On the wholesale market, upstream producers sell their output of an intermediate product to retailers who in turn resell this product to final consumers on a single retail market. We will assume that the retailers do not make significant modifications to the intermediate product.

2.1 Vertical separation

To capture the price formation process with vertical separation, we will assume that the wholesale and retail markets are duopolistic. This implies that the retailers are price-takers on the wholesale market but price-setters on the retail market.[7] Denote the wholesale producers and retailers by the respective subscripts i, i^-, j and j^-. Producer i's payoff is given by:

$$\pi_i = p_w (Q_w) q_{wi} - C (q_{wi}) \tag{1}$$

where $p_w (Q_w) q_{wi}$ is the wholesale market revenue from selling output q_{wi} at the wholesale price $p_w (Q_w)$ and $Q_w = q_{wi} + q_{wi^-}$ is the total wholesale output. Production costs are non-negative and the constant marginal production cost is denoted as $C_i^{'}$. Retailer j's payoff is given by:

$$\pi_j = p_r (X_r) x_{rj} - m (X_r) x_{rj} - p_w (Q_w) x_{rj} \tag{2}$$

[7] The duopoly restriction is imposed for simplicity and may be readily extended to reflect an oligopolistic situation. Furthermore, all interactions are assumed to occur in a static setting with full information and no uncertainty.

where $p_r(X_r)\,x_{rj}$ is the retail market revenue from delivering x_{rj} to final consumers at the retail price $p_r(X_r)$ and $X_r = x_{rj} + x_{rj^-}$ is the total retail demand. $m(X_r) = \theta X_r$ is the delivery cost per-unit of retail delivery and is assumed to be linear in the total retail demand. Thus θ is the weakly positive and constant rate of increase in the marginal delivery cost, and it is parametrically specified.

2.1.1 Cournot Nash equilibria on the wholesale and retail markets

On the wholesale market, a Cournot-Nash equilibrium would capture a situation in which the duopolists compete directly on the output dimension. Either producer's strategic output is, as follows from the definition of a Nash equilibrium, required to be a best-response to the rival's strategy.[8] As typifies the use of Cournot strategies, each producer will have a reaction function that defines his optimal output as a function of the rival's output and the equilibrium price is determined by the equalisation of the wholesale market supply with demand.

A Cournot-Nash equilibrium on the retail market describes a situation in which retailers compete for market shares, being informed about how the final consumers will respond to the retail price, or having knowledge of the retail demand function. Each retailer's optimal strategy is required to be a best-response to the rival's strategy and as on the wholesale market, the equilibrium price is again determined by the equalisation of the retail market supply with demand.[9]

In this vertical setting, the wholesale producers are assumed to move first by setting the output quantities that determine the wholesale market price. This supports their description as "upstream". Since the retailers must accept the wholesale price, which serves as input in their choice of retail market sales, they are appropriately described as "downstream". Identifying the equilibrium outcomes by backward induction implies that we must first define the equilibrium outcome on the retail market taking the wholesale market price to be given, and then proceed to identify the equilibrium outcome on the wholesale market.

2.1.2 Equilibrium on the retail market

The single retail market may be interpreted as one having a single retail segment.[10] Assume that the final demand on this market is represented by the linear inverse demand function[11]:

$$p_r(X_r) = A_1 - bX_r \tag{3}$$

[8] According to Kreps and Scheinkman (1983), the Cournot equilibrium would also describe a situation in which the producers having pre-committed themselves to given capacity levels at an earlier stage, now proceed to compete on price.

[9] Applying again the Kreps and Scheinkman (1983) result, the retail market Cournot equilibrium may also be interpreted as the outcome of the price-setting game that ensues when retailers have at an earlier stage pre-committed themselves to a given level of final sales, perhaps through forward contracting on the wholesale market.

[10] With third-degree price discrimination, this means that consumers are homogeneous and have the same price-elasticity of demand.

[11] Linearity is assumed to allow for analytically tractable results.

with $A_1 > 0$. We then obtain retailer j's first-order condition with $x_{rj} > 0$ to be:

$$\frac{\partial \pi_j}{\partial x_{rj}} = A_1 - 2bx_{rj} - bx_{rj^-} - 2\theta x_{rj} - \theta x_{rj^-} - p_w(Q_w) = 0 \tag{4}$$

which defines the Cournot reaction function as:

$$x_{rj}\left(x_{rj^-}\right) = \frac{A_1 - p_w(Q_w)}{2[b+\theta]} - \frac{x_{rj^-}}{2} \tag{5}$$

By assuming the retailers to be symmetric we can identify that:

$$x_r^* = \frac{A_1 - p_w(Q_w)}{3[b+\theta]} \tag{6}$$

which says that either retailer's sales will in equilibrium be increasing in the intercept of the retail demand function, but will be decreasing in the wholesale market price $p_w(Q_w)$, in the slope of the inverse demand function b, and in the delivery cost parameter θ.

2.1.3 Equilibrium on the wholesale market

Recognising in (6) that $X_r^* = x_{rj}^* + x_{rj^-}^*$ means we can now define the wholesale market's inverse demand by the function:

$$p_w(Q_w) = A_1 - \frac{3}{2}[b+\theta] X_r^* \tag{7}$$

Observe that in the wholesale market equilibrium we must have $X_r^* = Q_w = q_{wi} + q_{wi^-}$. Using (7) in (1) means that producer i chooses the Cournot quantity q_{wi} to maximise the wholesale market pay-off:

$$\pi_i = A_1 q_{wi} - \frac{3}{2}[b+\theta][q_{wi} + q_{wi^-}] q_{wi} - C(q_{wi}) \tag{8}$$

with the first-order condition for $q_{wi} > 0$ given as:

$$\frac{\partial \pi_i}{\partial q_{wi}} = A_1 - 3[b+\theta] q_{wi} - \frac{3}{2}[b+\theta] q_{wi^-} - C_i^{'} = 0 \tag{9}$$

which gives producer i's Cournot reaction function to be:

$$q_{wi}(q_{wi^-}) = \frac{A_1 - C_i^{'}}{3[b+\theta]} - \frac{q_{wi^-}}{2} \tag{10}$$

and by assuming symmetry between the producers we can identify that:

$$q_{wi}^{*VS} = \frac{2\left[A_1 - C_i^{'}\right]}{9[b+\theta]} \tag{11}$$

which says that producer i's equilibrium wholesale market output will be increasing in the intercept of the retail demand function, but will be decreasing in the marginal production cost $C_i^{'}$, in the slope of the retail inverse demand function and in θ. Now recognising (11) in (7) with $X_r^* = 2q_{wi}^{*VS}$ gives:

$$p_w^{VS}\left(Q_w^*\right) = \frac{1}{3}\left[A_1 + 2C_i^{'}\right] \tag{12}$$

which intuitively says that the equilibrium wholesale market price will be increasing in the intercept of the retail demand function and in the marginal production cost. Having $q_{wi}^{*VS} > 0$ in (11) implies that we must also have:

$$A_1 > C_i^{'} \tag{13}$$

Inserting (12) into (6) then gives either retailer's optimal sales quantity to be:

$$x_r^{*VS} = \frac{2\left[A_1 - C_i^{'}\right]}{9\left[b + \theta\right]} \tag{14}$$

and by recalling (3) with $X_r^* = 2x_r^*$ we obtain the equilibrium retail market price to be:

$$p_r^{VS}\left(X_r^*\right) = \frac{\left[5b + 9\theta\right]A_1 + 4bC_i^{'}}{9\left[b + \theta\right]} \tag{15}$$

which infers that the retail price will be increasing in the transportation cost parameter θ provided:

$$\frac{\partial p_r^{VS}}{\partial \theta} = \frac{4bA_1}{9\left[b + \theta\right]^2} > 0 \tag{16}$$

which is always satisfied, and in the slope of the retail inverse demand function b provided that:

$$\frac{\partial p_r^{VS}}{\partial b} = \frac{4\theta\left[C_i^{'} - A_1\right]}{9\left[b + \theta\right]^2} < 0 \tag{17}$$

which will be strictly negative given that $A_1 > C_i^{'}$.

2.2 Vertical integration

Vertical integration is assumed to arise when an upstream producer forward integrates into the downstream retail market.[12] Forward integration by both producers means that the supply chain's structure migrates from being a sucessive vertical duopoly, in which all players (i, i^-, j and j^-) exist and function as separate entities, into one having two separate and parallel entities either one of which combines the function of upstream production with downstream retailing.[13]

[12] The analysis would also be applicable to the case of a downstream retailer that integrates backwards, through a merger/acquisition, into upstream production.

[13] We will assume that i merges with j and i^- with j^-.

Observe that we do not analyse vertical foreclosure, which seeks to identify the effect of partial vertical integration by a producer/retailer on an unintegated rival - see for example Salinger (1988). Rather, our analysis assumes complete vertical integration which describes the situation in which either producer/retailer becomes vertically integrated.[14] Complete vertical integration means that transfers between the upstream and downstream segments cease to be conducted across the wholesale market at the Cournot-Nash equilibrium price. Such transfers are now internalised by each vertically integrated firm and made at the marginal production cost. Hence the Cournot-Nash equilibrium is only relevant for the retail market.

2.2.1 Equilibrium on the retail market

Since the conditions on the retail market do not change with vertical integration, we may recall j's retail market reaction function in (5). Recognising that upstream-to-downstream transfers will occur at the marginal production cost means that $p_w^{VI} = C_i^{'}$. We will therefore have:

$$x_{rj}^{VI}\left(x_{rj^-}^{VI}\right) = \frac{A_1 - C_i^{'}}{2\left[b+\theta\right]} - \frac{x_{rj^-}^{VI}}{2} \tag{18}$$

and with retailer symmetry we can easily identify that:

$$x_r^{*VI} = \frac{A_1 - C_i^{'}}{3\left[b+\theta\right]} > x_r^{*VS} \tag{19}$$

which shows that the equilibrium retail market sales made by each retailer rises by a third with vertical integration, relative to the sales made under vertical separation. Also, using x_r^{*VI} in (3) reveals the retail price under vertical integration to be:

$$p_r^{*VI} = \frac{\left[b+3\theta\right]A_1 + 2bC_i^{'}}{3\left[b+\theta\right]} < p_r^{*VS} \tag{20}$$

which shows that p_r^{*VI} will understate the corresponding price under vertical separation p_r^{*VS} provided that $A_1 > C_i^{'}$ is satisfied - which follows from (13).

2.3 Welfare analysis

We may now examine the welfare implications of a shift from vertical separation to vertical integration when there is a single retail market.

[14] In other words, our analysis considers only the discrete evolution of the industry structure between vertical separation and vertical integration. Consideration is not given to the effect of partial vertical integration as presented, for example, in Salinger (1988) and in Ordover et al. (1990).

2.3.1 Vertical separation

Producer i's equilibrium profit under vertical separation will be:

$$\pi_i^{*VS} = \left[p_w^{VS}\left(Q_w^*\right) - C_i^{'}\right] q_{wi}^{*VS} \tag{21}$$

and by recognising (11) and (12) this gives:

$$\pi_i^{*VS} = \frac{2\left[A_1 - C_i^{'}\right]^2}{27\left[b+\theta\right]} \tag{22}$$

Similarly, retailer j's profit will be:

$$\pi_j^{*VS} = \left[p_r^{VS}\left(X_r^*\right) - 2\theta x_r^{*VS} - p_w^{VS}\left(Q_w^*\right)\right] x_r^{*VS} \tag{23}$$

which with (12), (14) and (15) gives:

$$\pi_j^{*VS} = \frac{4\left[A_1 - C_i^{'}\right]^2}{81\left[b+\theta\right]} \tag{24}$$

The net consumer surplus will be:

$$\begin{aligned} CS^{*VS} &= \int_0^{X_r^{*VS}} p_r\left(X_r\right) dX - p_r^{VS}\left(X_r^*\right) X_r^{*VS} \qquad (25) \\ &= A_1 X_r^{*VS} - \frac{b}{2}\left[X_r^{*VS}\right]^2 - p_r^{VS}\left(X_r^*\right) X_r^{*VS} \end{aligned}$$

and recognising from (14) that $X_r^{*VS} = 2x_r^{*VS}$ means that:

$$CS^{*VS} = \frac{8b\left[A_1 - C_i^{'}\right]^2}{81\left[b+\theta\right]^2} \tag{26}$$

Total welfare is therefore:

$$W^{*VS} = 2\pi_i^{*VS} + 2\pi_j^{*VS} + CS^{*VS} \tag{27}$$

inserting (22), (24) and (26) into which gives:

$$W^{*VS} = \frac{4\left[7b+5\theta\right]\left[A_1 - C_i^{'}\right]^2}{81\left[b+\theta\right]^2} \tag{28}$$

which shows that total welfare with vertical separation is unambiguously positive, and is increasing in the intercept of the retail demand function but decreasing in the marginal cost of upstream production.

2.3.2 Vertical integration

Recall that i and j are now vertically integrated. Thus the combined profit for a vertically integrated firm will be:

$$\begin{aligned}\pi_{i+j}^{*VI} &= \pi_j^{*VI} + \pi_i^{*VI} && (29)\\ &= \left[p_r^{VI}(X_r^*) - 2\theta x_r^{*VI} - p_w^{VI}(Q_w^*)\right] x_r^{*VI} + \left[p_w^{VI}(Q_w^*) - C_i^{'}\right] q_{wi}^{*VI}\end{aligned}$$

Recognising in (29) that $p_w^{VI}(Q_w^*) = C_i^{'}$ and then inserting (19) and (20) gives:

$$\pi_{i+j}^{*VI} = \frac{\left[A_1 - C_i^{'}\right]^2}{9\left[b+\theta\right]} \tag{30}$$

Comparing (30) with the sum of (22) and (24) shows that:

$$\pi_{i+j}^{*VI} < \pi_i^{*VS} + \pi_j^{*VS} \tag{31}$$

The net consumer surplus with vertical integration will be:

$$\begin{aligned}CS^{*VI} &= \int_0^{X_r^{*VI}} p_r(X_r)\,dX - p_r^{VI}(X_r^*)\,X_r^{*VI} && (32)\\ &= A_1 X_r^{*VI} - \frac{b}{2}\left[X_r^{*VI}\right]^2 - p_r^{VI}(X_r^*)\,X_r^{*VI}\end{aligned}$$

into which we insert (19) given that $X_r^{*VI} = 2x_r^{*VI}$ to obtain:

$$CS^{*VI} = \frac{2b\left[A_1 - C_i^{'}\right]^2}{9\left[b+\theta\right]^2} \tag{33}$$

comparing (33) with (26) shows that:

$$CS^{*VI} > CS^{*VS} \tag{34}$$

Total welfare is therefore:

$$W^{*VI} = 2\pi_{i+j}^{*VI} + CS^{*VI} \tag{35}$$

into which we insert (30) and (33) to obtain:

$$W^{*VI} = \frac{2\left[2b+\theta\right]\left[A_1 - C_i^{'}\right]^2}{9\left[b+\theta\right]^2} \tag{36}$$

comparing (36) with (28) shows that:

$$W^{*VI} \geq W^{*VS} \text{ iff. } \theta \leq 4b \tag{37}$$

otherwise we will have that:

$$W^{*VI} < W^{*VS} \tag{38}$$

Results (37) and (38) show that an expansion in aggregate welfare will only follow vertical integration when theta is sufficiently low, otherwise vertical integration will destroy welfare.

3 Price formation with two retail markets

Within a vertically structured supply chain, end-user segmentation becomes evident when the retailers are able to differentiate the final demand into multiple classes or sub-markets, each one of which posesses a distinguishing characteristic.[15] The benchmark analysis conducted in the preceeding section has examined the welfare implications of vertical integration when there is a single retail segment. We will now extend the analysis to examine the welfare implications of vertical integration with two retail segments.

To render the analysis more fitting to the realities of an electric power setting, or of some other supply chain with a commonly utilised retail distribution network, we will interprete the two retail segments as representing the domestic and industrial retail markets. That the analogy be plausible however, one would anticipate an industrial demand that is more price responsive than the domestic demand; that posesses a higher marginal willingness to pay at any given quantity; and that consumes a higher quantity at any given price.

3.1 Vertical separation

To capture the price formation process when there is vertical separation and two retail markets, the earlier assumption of a successive duopoly is maintained and we will proceed by deriving the Cournot-Nash equilibria on the wholesale and retail markets. Both retail markets are modelled as though the single retail market in the benchmark analysis were split into two distinct retail markets - representing the domestic and industrial segments respectively. The final demand on both retail markets is assumed to be independent and the Cournot-Nash equilibria are simultaneously determined. As usual the solution procedure follows the backward induction method.

The domestic segment is represented by the linear inverse demand function:

$$p_r\left(X_r^D\right) = A_2 - cX_r^D \tag{39}$$

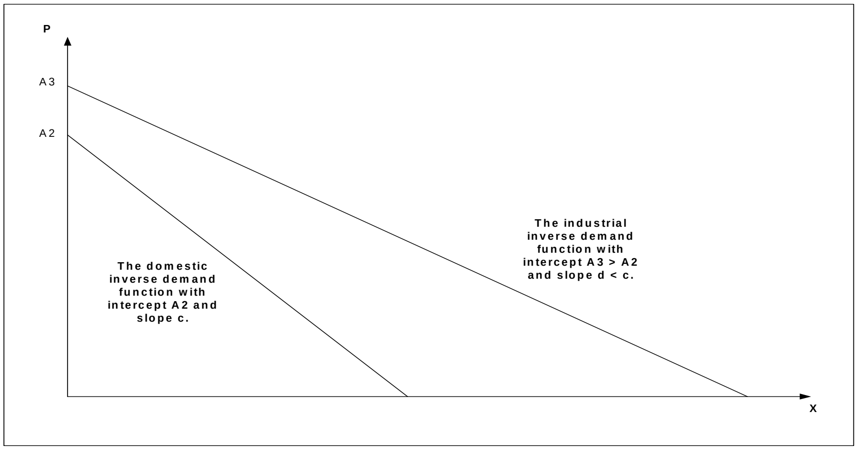
while the industrial segment has the linear inverse demand function:

$$p_r\left(X_r^I\right) = A_3 - dX_r^I \tag{40}$$

where $A_3 > A_2$ and $c \geq d$.[16]

[15] An example of such a practice is the use of third-degree price discrimination that would allow a retail monopolist to separate final consumers into multiple classes based on differences in their elasticities of demand.

[16] Observe here that $c \geq d$ is required in order that the industrial demand have a higher price elasticity than the domestic demand. $A_3 > A_2$ is also required in order that the industrial demand be always higher than the domestic demand. Hence the industrial linear inverse demand is everywhere higher than the domestic linear inverse demand. This is shown in the figure above.



The linear inverse demand functions.

Given that (39) and (40) aggregate to (3), we can re-define d and A_3 as:

$$d = \frac{bc}{c-b} \tag{41}$$

and

$$A_3 = \frac{cA_1 - bA_2}{c-b} \tag{42}$$

respectively.

3.1.1 Optimal behaviour by retailer j on the retail markets

Retailer j's payoff from both retail markets will be:

$$\pi_j = p_r\left(X_r^D\right)x_{rj}^D + p_r\left(X_r^I\right)x_{rj}^I - \left[m\left(X_r^D + X_r^I\right) + p_w\left(Q_w\right)\right]\left[x_{rj}^D + x_{rj}^I\right] \tag{43}$$

where the first two terms on the RHS in (43) represent the sales revenues from the domestic and industrial retail markets respectively. The first square bracket of the third term represents the sum of the transportation cost and wholesale price per-unit, while the second square bracket represents j's total retail sales. The total sales on either market is written as: $X_r^D = x_{rj}^D + x_{rj-}^D$ and $X_r^I = x_{rj}^I + x_{rj-}^I$. Solving (43) with respect to x_{rj}^D and x_{rj}^I gives the first-order conditions for interior solutions to be:

$$\frac{\partial \pi_j}{\partial x_{rj}^D} = A_2 - 2\left[c+\theta\right]x_{rj}^D - \left[c+\theta\right]x_{rj-}^D - 2\theta x_{rj}^I - \theta x_{rj-}^I - p_w\left(Q_w\right) = 0 \tag{44}$$

and

$$\frac{\partial \pi_j}{\partial x_{rj}^I} = \frac{cA_1 - bA_2}{c-b} - 2\left[\frac{bc}{c-b} + \theta\right]x_{rj}^I - \left[\frac{bc}{c-b} + \theta\right]x_{rj-}^I - 2\theta x_{rj}^D - \theta x_{rj-}^D - p_w\left(Q_w\right) = 0 \tag{45}$$

which allows us to define:

$$x^D_{rj} = \frac{A_2 - p_w(Q_w) - 2\theta x^I_{rj} - \theta x^I_{rj-}}{2[c+\theta]} - \frac{x^D_{rj-}}{2} \tag{46}$$

and

$$x^I_{rj} = \frac{A_3 - p_w(Q_w) - 2\theta x^D_{rj} - \theta x^D_{rj-}}{2[d+\theta]} - \frac{x^I_{rj-}}{2} \tag{47}$$

and then using (47) in (46) means we are able to define retailer j's Cournot reaction function on the domestic market as:

$$x^D_{rj}\left(x^D_{rj-}\right) = \frac{d[A_2 - p_w(Q_w)] + \theta[A_2 - A_3]}{2[cd + c\theta + \theta d]} - \frac{x^D_{rj-}}{2} \tag{48}$$

and the corresponding function on the industrial market as:

$$x^I_{rj}\left(x^I_{rj-}\right) = \frac{c[A_3 - p_w(Q_w)] - \theta[A_2 - A_3]}{2[cd + c\theta + \theta d]} - \frac{x^I_{rj-}}{2} \tag{49}$$

In a symmetric equilibrium the sales by either retailer on the domestic market will be:

$$x^{D*}_r = \frac{d[A_2 - p_w(Q_w)] + \theta[A_2 - A_3]}{3[cd + \theta d + c\theta]} \tag{50}$$

while the sales on the industrial market will be:

$$x^{I*}_r = \frac{c[A_3 - p_w(Q_w)] - \theta[A_2 - A_3]}{3[cd + \theta d + \theta c]} \tag{51}$$

3.1.2 Equilibrium on the wholesale market

By recognising the total retail market sales to be: $X^*_r = 2x^{D*}_r + 2x^{I*}_r$ we can identify the wholesale market's inverse demand function to be:

$$p_w(Q_w) = \frac{dA_2 + cA_3 - \frac{3}{2}[cd + \theta d + c\theta] X^*_r}{d+c} \tag{52}$$

and since in the wholesale market equilibrium we must have $X^*_r = Q_w = q_{wi} + q_{wi^-}$, producer i's equilibrium payoff may now be expressed as:

$$\pi_i = \left[\frac{dA_2 + cA_3}{d+c}\right] q_{wi} - \frac{3}{2}\left[\frac{cd + \theta d + c\theta}{d+c}\right][q_{wi} + q_{wi^-}] q_{wi} - C(q_{wi}) \tag{53}$$

and by repeating (9) - (10) it is again identifiable that in a symmetric wholesale market equilibrium we will have:

$$q^{*VS}_{wi} = \frac{2\left\langle dA_2 + cA_3 - C'_i[d+c]\right\rangle}{9[cd + \theta d + c\theta]} \tag{54}$$

Then recognising (54) in (52) with $X_r^* = 2q_{wi}^{*VS}$ gives:

$$p_w^{VS}(Q_w^*) = \frac{[dA_2 + cA_3] + 2C_i^{'}[d+c]}{3[d+c]} \tag{55}$$

Recognising (55) in (50) and (51) gives either retailer's optimal sales on the domestic market as:

$$x_r^{D*VS} = \frac{d\left[\frac{[2d+c3]A_2 - cA_3 - 2C_i^{'}[d+c]}{3[d+c]}\right] + \theta[A_2 - A_3]}{3[cd + \theta d + c\theta]} \tag{56}$$

and on the industrial market as:

$$x_r^{I*VS} = \frac{c\left[\frac{[3d+2c]A_3 - dA_2 - 2C_i^{'}[d+c]}{3[d+c]}\right] - \theta[A_2 - A_3]}{3[cd + \theta d + \theta c]} \tag{57}$$

and then recognising (56) and (57) in (39) and (40) respectively, with $X_r^D = 2x_r^{D*VS}$ and $X_r^I = 2x_r^{I*VS}$ gives the equilibrium price on the domestic market as:

$$p_r^{VS}\left(X_r^{D*}\right) = \frac{A_2 3[cd + \theta d + c\theta] - 2cd\left[\frac{[2d+c3]A_2 - cA_3 - 2C_i^{'}[d+c]}{3[d+c]}\right] - 2c\theta[A_2 - A_3]}{3[cd + \theta d + c\theta]} \tag{58}$$

and on the industrial market as:

$$p_r^{VS}\left(X_r^{I*}\right) = \frac{A_3 3[cd + \theta d + \theta c] - 2dc\left[\frac{[3d+2c]A_3 - dA_2 - 2C_i^{'}[d+c]}{3[d+c]}\right] + 2d\theta[A_2 - A_3]}{3[cd + \theta d + \theta c]} \tag{59}$$

3.2 Vertical integration

When there is vertical integration with two retail segments, we will only need to derive the Cournot-Nash equilibria on these markets. As earlier, it is assumed that i merges with j and i^- with j^-.

3.2.1 Equilibrium on the retail market

Recalling (50) and (51) and recognising that we will have $p_w^{VI} = C_i^{'}$ defines each retailer's symmetric equilibrium sales on the domestic and industrial markets as:

$$x_r^{D*VI} = \frac{d\left[A_2 - C_i^{'}\right] + \theta[A_2 - A_3]}{3[cd + \theta d + c\theta]} > x_r^{D*VS} \tag{60}$$

and

$$x_r^{I*VI} = \frac{c\left[A_3 - C_i^{'}\right] - \theta[A_2 - A_3]}{3[cd + \theta d + \theta c]} > x_r^{I*VS} \tag{61}$$

respectively. Then recognising x_r^{D*VI} and x_r^{I*VI} in (39) and (40) respectively, with $X_r^D = 2x_r^{D*VI}$ and $X_r^I = 2x_r^{I*VI}$ gives the equilibrium price on the domestic market as:

$$p_r^{VI}\left(X_r^{D*}\right) = \frac{[cd + c\theta + 3\theta d]\, A_2 + 2c\theta A_3 + 2cdC_i^{'}}{3\,[cd + \theta d + c\theta]} < p_r^{VS}\left(X_r^{D*}\right) \tag{62}$$

while the equilibrium price on the industrial market will be:

$$p_r^{VI}\left(X_r^{I*}\right) = \frac{[cd + \theta d + 3\theta c]\, A_3 + 2d\theta A_2 + 2dcC_i^{'}}{3\,[cd + \theta d + \theta c]} < p_r^{VS}\left(X_r^{I*}\right) \tag{63}$$

Recognising (41) and (42) in (62) and (63) shows that the domestic and industrial prices under vertical integration will understate the corresponding prices with vertical separation, provided $A_1 > C_i^{'}$ is satisfied. Identifiably, vertical integration will always result in a rise in the quantity sold and a fall in the retail price on both retail markets.

3.3 Welfare analysis

The welfare implications of a shift from vertical separation to vertical integration with two retail markets are examined below.

3.3.1 Vertical separation

Producer i's equilibrium profit under vertical separation will be:

$$\pi_i^{*VS} = \left[p_w^{VS}\left(Q_w^*\right) - C_i^{'}\right] q_{wi}^{*VS} \tag{64}$$

and by recognising (54) and (55) in (64) we obtain:

$$\pi_i^{*VS} = \frac{\left\{d\left[A_2 - C_i^{'}\right] + c\left[A_3 - C_i^{'}\right]\right\}^2}{27\,[d + c]\,[cd + \theta d + \theta c]} \tag{65}$$

Similarly, retailer j's profit will be:

$$\pi_j^{*VS} = p_r^{VS}\left(X_r^{D*}\right) x_{rj}^{D*VS} + p_r^{VS}\left(X_r^{I*}\right) x_{rj}^{I*VS} - \left[m\left(X_r^{D*} + X_r^{I*}\right) + p_w^{VS}\left(Q_w^*\right)\right]\left[x_{rj}^{D*VS} + x_{rj}^{I*VS}\right] \tag{66}$$

which with (55), (56), (57), (58) and (59) becomes:

$$\pi_j^{*VS} = \frac{\left\{\begin{array}{c} 4d^2\left[A_2 - C_i^{'}\right]^2 + 4c^2\left[A_3 - C_i^{'}\right]^2 + 9\theta\,[d + c]\,[A_2 - A_3]^2 \\ +cd\left[9A_2^2 - 10A_2A_3 + 9A_3^2\right] - 8cd\left[A_2C_i^{'} + A_3C_i^{'} - C_i^{'2}\right] \end{array}\right\}}{81\,[d + c]\,[cd + \theta d + \theta c]} \tag{67}$$

The net consumer surplus will be:

$$\begin{aligned}
& CS^{D*VS} + CS^{I*VS} && (68)\\
= & \left\{ \int_0^{X_r^{D*VS}} p_r\left(X_r^D\right) dX - p_r^{VS}\left(X_r^{D*}\right) X_r^{D*VS} \right\} \\
& + \left\{ \int_0^{X_r^{I*VS}} p_r\left(X_r^I\right) dX - p_r^{VS}\left(X_r^{I*}\right) X_r^{I*VS} \right\} \\
= & \left\{ A_2 - \frac{c}{2}\left[X_r^{D*VS}\right] - p_r^{VS}\left(X_r^{D*}\right) \right\} X_r^{D*VS} + \left\{ A_3 - \frac{d}{2}\left[X_r^{I*VS}\right] - p_r^{VS}\left(X_r^{I*}\right) \right\} X_r^{I*VS} \\
= & \frac{2}{81} \frac{\left\{ \begin{array}{c} 4cd^3\left[A_2 - C_i^{'}\right]^2 + 4c^3 d\left[A_3 - C_i^{'}\right]^2 \\ + \left[9\theta^2 d^2 + 18cd^2\theta + 18c^2 d\theta + 18cd\theta^2 + 9c^2\theta^2\right]\left[A_2 - A_3\right]^2 \\ + c^2 d^2\left[9A_2^2 - 10A_2A_3 + 9A_3^2\right] - 8c^2 d^2\left[A_2C_i^{'} + A_3C_i^{'} - C_i^{'2}\right] \end{array} \right\}}{\left[d + c\right]\left[cd + \theta d + \theta c\right]^2}
\end{aligned}$$

Total welfare is therefore:

$$W^{*VS} = 2\pi_i^{*VS} + 2\pi_j^{*VS} + CS^{D*VS} + CS^{I*VS} \tag{69}$$

inserting (65), (67) and (68) into which gives:

$$W^{*VS} = \frac{4}{81} \frac{\left\{ \begin{array}{c} \left[9d^2\theta^2 + 18cd\theta^2 + 9c^2\theta^2\right]\left[A_2 - A_3\right]^2 \\ + \left[5d^3\theta + 7cd^3\right]\left[A_2 - C_i^{'}\right]^2 + \left[5c^3\theta + 7c^3 d\right]\left[A_3 - C_i^{'}\right]^2 \\ + c^2 d\theta\left[18A_2^2 - 26A_2A_3 + 23A_3^2\right] - c^2 d\theta\left[10A_2C_i^{'} + 20A_3C_i^{'} - 15C_i^{'2}\right] \\ + cd^2\theta\left[23A_2^2 - 26A_2A_3 + 18A_3^2\right] - cd^2\theta\left[20A_2C_i^{'} + 10A_3C_i^{'} - 15C_i^{'2}\right] \\ + c^2 d^2\left[9A_2^2 - 4A_2A_3 + 9A_3^2\right] - 14c^2 d^2\left[A_2C_i^{'} + A_3C_i^{'} - C_i^{'2}\right] \end{array} \right\}}{\left[d + c\right]\left[cd + \theta d + \theta c\right]^2} \tag{70}$$

3.3.2 Vertical integration

With i and j now vertically integrated the combined profit for an integrated firm will be:

$$\pi_{i+j}^{*VI} = \pi_i^{*VI} + \pi_j^{*VI} = \frac{d\left[A_2 - C_i^{'}\right]^2 + c\left[A_3 - C_i^{'}\right]^2 + \theta\left[A_2 - A_3\right]^2}{9\left[cd + \theta d + \theta c\right]} \tag{71}$$

Comparing (71) with the sum of (65) and (67) shows that we will have:

$$\pi_{i+j}^{*VI} < \pi_i^{*VS} + \pi_j^{*VS} \tag{72}$$

iff:

$$\begin{aligned}
&\pi_{i+j}^{*VI} - \pi_i^{*VS} - \pi_j^{*VS} \qquad (73)\\
= \quad & -\frac{1}{81}\left\{\frac{[dA_2 + cA_3]^2 - 2C_i^{'}[d+c][dA_2 + cA_3] + [d+c]^2 C_i^{'2}}{[d+c][cd + \theta d + \theta c]}\right\} < 0
\end{aligned}$$

which simplifies to:

$$\left\langle [dA_2 + cA_3] - [d+c] C_i^{'} \right\rangle^2 > 0 \qquad (74)$$

Since the LHS in (74) is strictly positive, (72) will be satisfied. The total profit therefore falls unambigously with vertical integration. The net consumer surplus with vertical integration will be:

$$\begin{aligned}
& CS^{D*VI} + CS^{I*VI} \qquad (75)\\
= \quad & \left\{\int_0^{X_r^{D*VI}} p_r\left(X_r^D\right) dX - p_r^{VI}\left(X_r^{D*}\right) X_r^{D*VI}\right\}\\
& + \left\{\int_0^{X_r^{I*VI}} p_r\left(X_r^I\right) dX - p_r^{VI}\left(X_r^{I*}\right) X_r^{I*VI}\right\}\\
= \quad & \left[A_2 - \frac{c}{2} X_r^{D*VI} - p_r^{VI}\left(X_r^{D*}\right)\right]\left\{X_r^{D*VI}\right\} + \left[A_3 - \frac{d}{2} X_r^{I*VI} - p_r^{VI}\left(X_r^{I*}\right)\right]\left\{X_r^{I*VI}\right\}\\
= \quad & \frac{2}{9}\left\{\frac{d^2 c\left[A_2 - C_i^{'}\right]^2 + dc^2\left[A_3 - C_i^{'}\right]^2 + \left[d\theta^2 + 2dc\theta + c\theta^2\right][A_2 - A_3]^2}{[cd + \theta d + \theta c]^2}\right\}
\end{aligned}$$

Comparing (75) with (68) shows that:

$$CS^{D*VI} + CS^{I*VI} > CS^{D*VS} + CS^{I*VS} \qquad (76)$$

iff:

$$\begin{aligned}
& CS^{D*VI} + CS^{I*VI} - CS^{D*VS} - CS^{I*VS} \qquad (77)\\
= \quad & \frac{10}{81} cd\left\{\frac{[dA_2 + cA_3]^2 - 2[d+c][dA_2 + cA_3] C_i^{'} + [d+c]^2 C_i^{'2}}{[d+c][cd + \theta d + \theta c]^2}\right\} > 0
\end{aligned}$$

which simplifies to:

$$\left\langle [dA_2 + cA_3] + [d+c] C_i^{'} \right\rangle^2 > 0 \qquad (78)$$

Since the LHS in (78) is by construction strictly positive, then (77) will be satisfied. Meaning that the consumer surplus rises unambigously with vertical integration. Total welfare will therefore be:

$$W^{*VI} = 2\pi_{i+j}^{*VI} + CS^{D*VI} + CS^{I*VI} \qquad (79)$$

which gives:

$$W^{*VI} = \frac{2}{9} \frac{\left\{ \begin{array}{c} dc\theta \left[4A_2^2 - 6A_2A_3 + 4A_3^2\right] - 2dc\theta C_i' \left[A_2 + A_3 - C_i'\right] \\ +2\theta^2 \left[d+c\right]\left[A_2 - A_3\right]^2 + \left[d^2\theta + 2d^2c\right]\left[A_2 - C_i'\right]^2 \\ + \left[c^2\theta + 2dc^2\right]\left[A_3 - C_i'\right]^2 \end{array} \right\}}{\left[cd + \theta d + \theta c\right]^2} \tag{80}$$

and by comparing (70) with (80) we can identify that:

$$W^{*VI} \geq W^{*VS} \text{ iff. } \theta \leq 2\left[\frac{2cd}{d+c}\right] = 2b^h \tag{81}$$

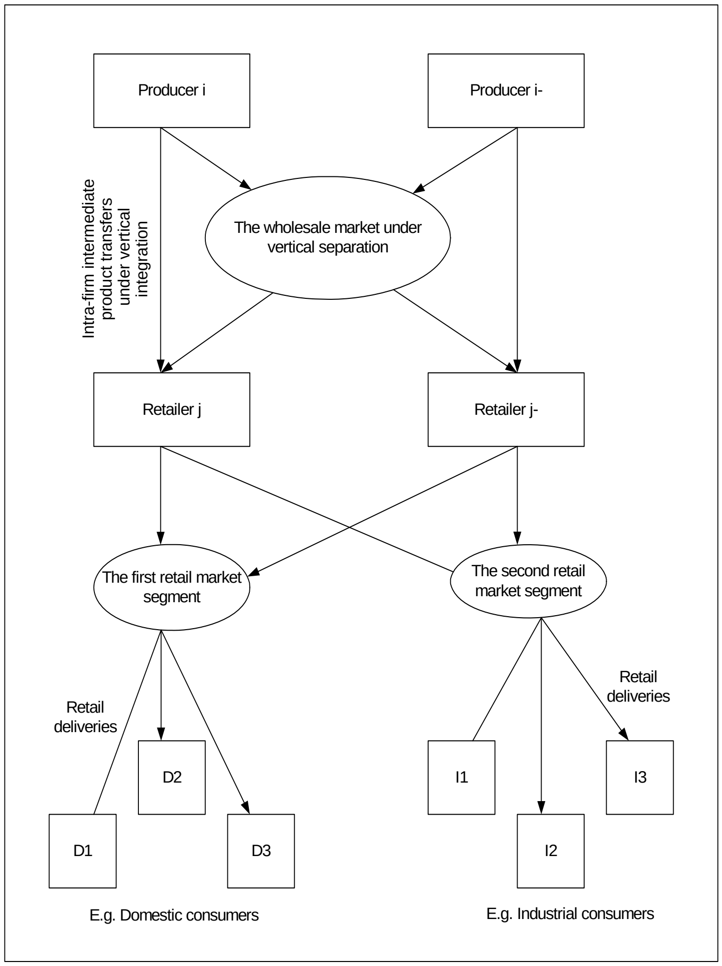
where $b^h = 2b$ represents the harmonic mean of the slopes of the inverse demand functions on both retail segments, or by recalling (41), is twice the slope of the aggregate inverse demand function.[17]

Otherwise we will have:

$$W^{*VI} < W^{*VS} \tag{82}$$

Results (81) and (82) show when there are two retail market segments, that vertical integration will only improve welfare when theta (the rate of change of the delivery cost as the total deliveries rise) is sufficiently low, and will destroy welfare should this threshold be exceeded. The segmented supply chain's vertical structure is described in the chart below:

[17] The harmonic mean is here defined as the reciprocal of the arithmetic mean of the slopes of the demand functions of the different segments.



A description of the supply chain's vertical structure.

3.4 Discussion

As in the benchmark case, the preceeding analysis of vertical integration, with two retail segments and a rising retail supply function reveals that the presence of such a retail supply function can significantly influence the welfare outcome following vertical integration.

With two retail market segments, the threshold for theta is identified to be twice the (harmonic) mean of the slopes of the inverse demand functions on both segments. As earlier explained, welfare will be destroyed by vertical integration (for some value of theta exceeding the threshold) because the expansion in consumer surplus that is attributable to the elimination of double marginalisation would be completely countervailed by a contraction in total profits, due to the now higher costs associated with making such retail deliveries. This explains the results obtained in (72) and (76). Since the mean of the slopes of the inverse demand functions for both retail segments is double the slope of the aggregate inverse demand function, then the threshold value for θ in (81) will be equal to that obtained in (37) when there is just a single retail segment.

It is thus inferrable that the rising retail supply function will exert a constraining effect on the welfare outcome of vertical integration i.e. whether vertical integration improves or destroys welfare, but that this effect will be independent of the number of retail segments since the defined threshold for theta remains unchanged. This suggests that for a given level of theta, the likelihood of vertical integration destroying rather than improving welfare will be unaffected by the extent to which the retail markets are segmented.

An interesting observation from (31) and (72) is that since the total profit identifiably falls with vertical integration, this may serve as a disincentive for separated firms, acting individually, to integrate. A related concern has been voiced by Lin [1988] who argues on p. 251 that:

> .. among oligopolists vertical disintegration (separation) may often be preferred, especially if demands are sufficiently inelastic... Disintegration serves to dampen price competition among manufacturers, thereby leading to higher equilibrium prices and possibly higher profits.

and continues on p. 253 with:

> .. The dampening of competition argument applies also when the product is homogeneous. Assume that firms facing final consumers use quantity as strategy, so the downstream equilibrium is Cournot, while a disintegrated manufacturer sets wholesale price w. Then the equilibrium profit of a manufacturer-distributor pair under disintegration is *always* larger than that of a manufacturer under integration. The reason is as follows. Under integration, total output is at the Cournot-duopoly level. Under disintegration, total output from the Cournot distributors is smaller, since each will have to incur a marginal cost (wholesale price) $w > 0$ .. Disintegration thus moves the industry away from the Cournot-duopoly output toward the monopoly output, increasing joint manufacturer-distributor profit.

Interestingly, Bonano and Vickers [1987] obtain a similar result, although they go about arguing this point using an analysis of the upstream reaction functions. On p. 261 they explain that:

> .. it pays manufacturer 1 to choose vertical separation and charge a wholesale price [w^1] in excess of production cost. In other words, by increasing w^1, manufacturer 1 shifts his retailer's reaction curve outwards and can choose the best point on retailer 2's reaction curve.

These arguments suggest that despite there being clear potential for an improvement in total welfare, left to its own devices, the market may be inadequate to induce vertical integration to realise such gains, since firms would naturally wish to maximise their profits.

There are nevertheless strong reasons why vertical integration may yet occur, even when this would result in a contraction in profits. These include the need to hedge the risk of simultaneously operating on the wholesale and retail markets, as a strategic deterrent against new entry, or as a means of consolidating the firms' operations through expansion, despite lowering the profitability per unit of retail delivery.

3.5 Identifying the effect of retail market segmentation on welfare

Momentarily suspending our examination of the welfare implications of a shift between the vertical separation and vertical integration, it will be useful to examine what are the welfare implications of having one/more (two in this case) retail market segments. To do this, we will proceed by taking the supply chain's structure (first under vertical separation and then under vertical integration) as given, and will examine how welfare varies between the cases with one or two retail market segments.

Under vertical separation, comparing (22) and (65), and then recognising (41) and (42) gives the difference in generator i's profit to be:[18]

$$\begin{aligned} \triangle\pi_i^{*VS} &= \left[\pi_i^{*VS}\right]^{benchmark} - \left[\pi_i^{*VS}\right]^{Two\ retail\ segments} \\ &= \frac{4}{27}\left\{\frac{\left\langle cd-[d+c]\,C_i^{'}\right\rangle\left\langle d\left[A_2-C_i^{'}\right]+c\left[A_3-C_i^{'}\right]\right\rangle}{[d+c]\,[cd+\theta d+\theta c]}\right\} \end{aligned} \tag{83}$$

which is positive provided that $A_3 > A_2 > C_i^{'}$ and $\frac{cd}{d+c} > C_i^{'}$, but is otherwise ambigously signed. Comparing (24) and (67) gives the difference in retailer j's profit to be:

$$\triangle\pi_j^{*VS} = -\frac{1}{27}\left\{\frac{\begin{array}{c} 4\left\langle cd-C_i^{'}\,[d+c]\right\rangle\left\langle d\left[A_2-C_i^{'}\right]+c\left[A_3-C_i^{'}\right]\right\rangle \\ +3\,[cd+\theta d+\theta c]\,[A_2-A_3]^2 \end{array}}{[d+c]\,[cd+\theta d+\theta c]}\right\} \tag{84}$$

which will be negative provided that $A_3 > A_2 > C_i^{'}$ and $\frac{cd}{d+c} > C_i^{'}$, otherwise the sign is ambigous. We can also identify the difference in the total profit (the

[18] Observe here that the total profit in the case of two retail segments is subtracted from that obtained in the benchmark case. This convention will be maintained for all subsequent comparisons.

sum of generator i's and retailer j's profits) to be:

$$\triangle\left[\pi_i^{*VS} + \pi_j^{*VS}\right] = -\frac{1}{9}\frac{\left[A_2 - A_3\right]^2}{[d+c]} < 0 \tag{85}$$

which is unambigously negative. Similarly comparing (26) with (68) gives the difference in the net consumer surplus to be:

$$\triangle CS^{*VS} = -\frac{2}{9}\frac{\left[A_2 - A_3\right]^2}{[d+c]} < 0 \tag{86}$$

which is also unambigously negative. Finally, comparing (28) with (70) gives the difference in welfare to be:

$$\triangle W^{*VS} = -\frac{4}{9}\frac{\left[A_2 - A_3\right]^2}{[d+c]} < 0 \tag{87}$$

which is also negative. As a check, observe that multiplying the total profit difference in (85) by two - to account for the two symmetric firms - and then adding (86) will give us (87). Conducting a similar comparative exercise under vertical integration yields exactly the same results as in (85), (86) and (87).

Identifying the difference in total profits, net consumer surplus and welfare between the benchmark and two retail segment cases to be consistently negative demonstrates that having two retail segments is to be preferred to having a single one. Hence retail market segmentation is welfare improving (this observation remains valid regardless of whether the supply chain is vertically separated or integrated).[19] Furthermore, since the identified differences in (85) - (87) are equal under vertical separation and vertical integration, it is inferrable that the welfare effect of retail market segmentation is independent of the prevailing vertical structure.

3.6 Identifying the effect of retail market segmentation on prices and quantities

We may also conducting a similar exercise to the foregoing, but this time to identify the effect of retail segmentation on prices and quantities. Comparing (12) with (55) under vertical separation gives:

$$\triangle p_w^{*VS} = \frac{2}{3}\left[b - C_i^{'}\right] \tag{88}$$

where $b = \frac{cd}{c+d}$. This reveals that the wholesale price will fall with the introduction of a second retail segment, provided we have $b > C_i^{'}$. The converse would

[19] A caveat is however that since retailer profits will be higher without retail market segmentation when (84) is positive, they may have the incentives to resist its introduction, although total welfare would be improved.

obtain if the inequality were reversed. At the retail level, comparing (15) with (58) and (59) respectively (under vertical separation) gives:

$$p_r^{*VS} - p_r^{VS}\left(X_r^{D*}\right) = -\frac{1}{3}\frac{c\,[A2 - A3]}{[d+c]} > 0 \tag{89}$$

and

$$p_r^{*VS} - p_r^{VS}\left(X_r^{I*}\right) = \frac{1}{3}\frac{d\,[A2 - A3]}{[d+c]} < 0 \tag{90}$$

and having $A3 > A2$ means that (89) is identifiably positive, and (90) negative. Which implies that segmenting the retail market, while maintaining a vertically separated supply chain structure, would lead to a fall in the retail price paid by domestic consumers, but to a rise in the retail price paid by industrial consumers. A similar comparative exercise under vertical integration yields the same results as (89) and (90).

Comparing (11) with (54) and then recognising (41) and (42) gives the difference in the total wholesale output and retail sales quantity (under vertical separation) to be:

$$\triangle q_w^{*VS} = 0 \tag{91}$$

which clearly implies that the total industry output is unaffected by the number of retail market segments. Since the quantity demanded at the retail level is strictly decreasing in the retail price, then (89) and (90) infer that retail segmentation leads to a rise in the quantity consumed by domestic consumers, but to a drop in the quantity consumed by the industrial consumers. Domestic consumers as it therefore appears, are made better-off by introducing an additional retail segment, while the industrial consumers are made worse-off.

A concise summary of the derived results now follows:

Industry structure vs. Retail Market Segmentation	A Single Retail Market	Two Retail Markets	Comparison
Vertical Separation	$\pi_i^{*VS} + \pi_j^{*VS}$ CS^{*VS} $W^{*VS} : (A_1, b, C_i^{'}, \theta)$	$\pi_i^{*VS} + \pi_j^{*VS}$ $CS^{*DVS} + CS^{*IVS}$ $W^{*VS} : (A_2, A_3, c, d, C_i^{'}, \theta)$	$\Delta \left[\pi_i^{*VS} + \pi_j^{*VS}\right] < 0$ $\Delta CS^{*VS} < 0$ $\Delta W^{*VS} < 0$
Vertical Integration	π_{i+j}^{*VI} CS^{*VI} $W^{*VI} : (A_1, b, C_i^{'}, \theta)$	π_{i+j}^{*VI} $CS^{*DVI} + CS^{*IVI}$ $W^{*VI} : (A_2, A_3, c, d, C_i^{'}, \theta)$	$\Delta \pi_{i+j}^{*VI} < 0$ $\Delta CS^{*VI} < 0$ $\Delta W^{*VI} < 0$
Comparison	$\pi_{i+j}^{*VI} < \pi_i^{*VS} + \pi_j^{*VS}$ $CS^{*VI} > CS^{*VS}$ $W^{*VI} \geq W^{*VS}$ $iff : \theta \leq 4b$	$\pi_{i+j}^{*VI} < \pi_i^{*VS} + \pi_j^{*VS}$ $CS^{*DVI} + CS^{*IVI} > CS^{*DVS} + CS^{*IVS}$ $W^{*VI} \geq W^{*VS}$ $iff : \theta \leq 4\left[\frac{cd}{d+c}\right]$	0 0 0

A summary of the results.

4 Conclusion

The question of how increased vertical integration in an industry or supply chain would affect end-user prices and welfare remains a controversial one. The related literature reveals that while vertical integration would on the one hand, through reducing double marginalisation, tend to reduce end-user prices and to increase welfare, it would on the other hand have market concentration effects that would tend to raise end-user prices and to thereby reduce the consumer surplus and welfare.

We are able to identify that vertical integration occurring in a supply chain with an increasing retail supply function (which may be due to the presence of strong externalities in the retail distribution network) would result in a fall in the end-user price. Total welfare would however be reduced, provided the retail delivery costs are rising at a sufficiently high rate in the total retail quantity that is delivered. The explanation for this is that the increase in welfare due to the elimination of the double marginalisation effect, will be countered by a decrease in welfare owing to the rising costs incurred in making such deliveries. Understanding the effect of vertical integration with an increasing retail supply function therefore depends on identifying a critical value for the marginal cost of retail deliveries, around which welfare would be either increasing, decreasing or constant.

Segmentation on the end-consumer market, as is common in most network-dependent supply chains (particularly at the retail level) has no identifiable effect on the outcome of vertical integration when there is an increasing retail supply function. An increasing number of segments (we examine a movement from one to two segments) will however result in a welfare improvement, regardless of whether the supply chain is vertically integrated or not.

In our duopoly framework, vertical integration results in a contraction of the total profit, relative to a situation with vertical separation. This raises questions as to whether firms will have sufficient economic incentives to vertically integrate. On the face of it the fall in profits suggests that they will not, suggesting that vertical integration would only come about either by compulsion (e.g. by regulatory decree) or by a promise to compensate the firms for the reduction in their profits.[20]

The policy implications of these results are that mandatorily compelling firms within the supply chain to be unbundled (vertical separation) would have a favourable effect on their profitability and that allowing full price discrimination through end-user segmentation would actually improve welfare. Interestingly, these policy implications stand in clear conflict with conventional policy that tends to favour full vertical unbundling and minimal price discrimination for end-consumers.

Conversely, where the policy objective is to promote competition in the

[20] In the real world however, it remains perfectly plausible that firms voluntarily opt to vertically integrate despite suffering reduced profits. Such a decision may be rationalised on the basis of strategic, risk hedging or other motives in support of corporate consolidations. A proper analysis of these motivations is however excluded from the current analysis.

supply chain (note that this measure would only be valid when the end-user demands are sufficiently inelastic) then it may be advisable to compel integration in order to *un*-dampen price competition between oligopoly producers on the wholesale market.

Finally, in order to make vertical integration more (less) appealing in an environment with an increasing retail supply function, then it may be advisable to subsidise (increase) the retail distribution costs. Observe that such a policy can only be successful when the responsibility for such retail costs is borne outside the supply chain. Consider the example of the United Kingdom's electricity system where system or network charges are split between upstream producers (gencos) and downstream retailers (discos). Splitting network costs in this way would not affect the incentives to integrate, inasmuch as such costs are still being borne within the supply chain i.e. it does not matter what part of the supply chain bears these costs.

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