VERTICAL INTEGRATION RESULTS AND APPLICATIONS TO THE REGULATION OF SUPERMARKET ACTIVITY

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ABSTRACT

This paper provides formal proofs of vertical integration results including not only the well-known double marginalization arguments but also results on an extension incorporating conditions of quality, efficiency and 'make or buy' decisions for potentially vertically integrating firms. Each of these results is illustrated with reference to supermarket applications and associated regulatory issues.

Key words
Vertical Integration Transfer Price Supermarkets Regulation

JEL Classifications
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1. Introduction

This paper has two related purposes. Firstly we present new formalizations of profit maximizing and transaction cost related arguments for vertical integration and vertical coordination. Secondly, we will show how these formalizations can be useful by illustrating them with reference to coordination between supermarkets and their suppliers, together with associated issues concerning regulation by the UK Competition Commission.

The key results are theorems which formally establish the otherwise well known result that collective profits of a firm and its supplier may be increased if actions are coordinated so that the supplier's transfer price is set below that at which its product would have been supplied in the absence of coordination. A corollary is that, if profits are appropriately redistributed, both firm and subsidiary may gain by vertical integration or vertical coordination vis a vis maximizing their profits independently. Further theorems will extend these results to cases with costs potentially associated with increasing product quality and/or production efficiency. All of these results will be illustrated using examples with reference to supply chains in the food industry and to supermarkets.

The paper is organized as follows: Section 2 provides a review of literature on vertical integration and regulation in the food industry. In Section 3 a stylised model and associated theorems of vertical integration are established and illustrated by reference to the UK Competition Commission's 2000 report on supermarkets. Section 4 focuses on literatures concerning vertical coordination with specific reference to product quality and to control of production efficiency in supermarket supply chains. With that context in Section 5 models developed in Section 3 are extended to include quality as well as production efficiency issues in a "make or buy" formulation in that way modelling decisions between vertically coordinated production and externally sourced inputs to production. Section 6 concludes.

2. Vertical Integration and Regulation in the Food Industry

There is a substantial and well-known literature on the advantages and disadvantages of vertical integration. Authors on this topic include Spengler (1950), Arrow (1975), Grossman and Hart (1986), Perry (1989) and Baumol (2001). But, given that the emphasis here is on supermarkets and food supply chains, we concentrate on a more specialised literature to argue the potential advantages of vertical integration in the food sector. In that context Hirsch and Votaw (1952) state that power will naturally come with economic size of the firm and that a large supermarket has an advantage over the small independent grocery shop in that it can benefit from savings derived from large scale purchasing and savings resulting from the exercise of monopsony power. Others, including Etgar (1978), Perry (1989), Martin (1994) and Dobson and Waterson (1996), have argued more generally that supermarket firms integrate in order to obtain market power and monopoly position. They argue that market power, if exercised, can control prices in the produce markets, undercut retail prices so as to force out competitors, shift risk and price fluctuations to the producers, as well as giving power to dictate terms and conditions to suppliers and to integrate vertically

and horizontally. Dobson and Waterson (1996) conclude, too, that the emergence of powerful retailers with market power has shifted the bargaining position from the manufacturers to the retailers.

Clearly great size and power stemming from market control and the threat to competition and to suppliers may operate against the public interest and for that reason may qualify for investigation by the competition authorities. However, while market integration in general and market power stemming from vertical integration in particular may operate against the public interest, it has also long been argued that it may not do so. On this issue Spengler (1950) stated that vertical integration may be welfare enhancing and such cases should not be subject to the competition law. Comanor (1967) argued that vertical integration does not necessary lead to an expansion of market power, although it may have a major impact on concentration at specific stages of production. This is also consistent with Baumol (2001), who argued that the regulatory agencies have now recognised that coordination of prices can be desirable if the firms involved are vertically, rather than horizontally, related. The key point here is that vertical integration tends to increase output because double marginalisation is eliminated. In such cases a competition agency may have a more favourable view of vertical integration than of horizontal integration and tend to avoid interference in such joint ventures.

Issues with reference to vertical integration were central to the work of the UK Competition Commission when it undertook a major investigation on the supply of groceries to UK supermarkets (See Competition Commission 2000). This involved a two-stage investigation, firstly to determine whether the major supermarket firms were earning excessive profits and secondly to determine the source of the profits and how the profits were being earned (op cit p.12). One area of concern was the nature of the relationship between supermarkets and their suppliers. Two aspects were identified regarding the trading relationship between the main parties (supermarket firms) and their suppliers. The first, with regard to buyers and buyer power, was examined in the context of:-

> …the extent to which the main parties are able to obtain lower prices from their suppliers as a result of their size and importance to the supplier's business, as opposed to those justified by reduction in costs" (Competition Commission, Appendix 11.5, p.429).

In this regard the Competition Commission noted that, since the two parties have differing objectives because suppliers seek higher prices while supermarkets want to buy at the lowest, tension might arise (p.230). In particular suppliers argued to the Competition Commission that the power of the supermarkets has the ability to drive down suppliers' prices to uneconomic levels (p.67). In this context the buyer power of the multiples can be construed as stemming from a dominant position over suppliers and this is consistent with the findings of the Competition Commission that the supermarket firms are always in a dominant position compared to small suppliers (Appendix 11.2, p.392). In any case supermarkets are able to exercise buyer power since they also have considerable selling power. For example the four largest UK supermarket firms measured by shares of grocery sales in 1998/1999 controlled 71.2 per cent, with Tesco having 24.6 per cent.

The second concern of the Competition Commission was with regard to 52 other alleged practices of supermarket firms on their suppliers (op cit p.94), which were also the result of buyer power in the hands of the supermarkets, since without it the practices are unlikely to happen. The findings of the Competition Commission were that 30 of the practices identified adversely affected the competitiveness of suppliers and distorted competition (op cit p.6). The most common practice was requiring suppliers to make payments for better positioning and access to shelf space of their products within the stores or better known as slotting fees (p.102). This resulted in an environment where promotional and other marketing costs were loaded on to suppliers. As a consequence of market power combined with expense-inducing practices of the supermarkets with reference to suppliers, it can be argued that, while the supermarket costs were reduced and their profits correspondingly increased, suppliers' expenses increased due inter alia to payments to supermarkets associated with these buyer power related practices. This underlines the point that, if these firms are to be vertically integrated, the distribution of profits is likely to be a crucial issue and fundamentally so if both parties are to benefit from that integration.

So far no explicit distinction has been made between vertical integration and vertical coordination. It is now useful to identify explicit differences of two kinds. The first kind refers to administrative processes by recognizing a distinction between control of supplies of intermediate commodities through ownership of a supplier and control of supplies of intermediate commodities from a supplier by contractual means short of complete ownership. A second kind of difference refers to the nature of the contract between two vertically related enterprises - in our case, more specifically, to the determinants of the price and quantity supplied in a context of vertically related processes. These two kinds of differences are central to developments in the next section in which we present stylised models of the relationship of a supplier to one or more supermarket firms.

3. Some Formal Results on Vertical Integration

Assume that a firm s has a concave production function $x_s=f_s(L_s,K_s,y_s)$, where x_s is output, and L_s,K_s,y_s are respectively quantities of labour, capital and intermediate inputs employed. If (inverse) demand is given by the function $p(x_s)$ and unit costs of labour, capital and intermediate inputs are given by w,r and $p(y_s)$ respectively, then the profit maximizing level of output and optimizing levels for the acquisition and use of inputs by a firm s can be found via the optimization:

$$\begin{aligned} \text{Max } \pi_1 = \pi_1^* &= p(x_s)x_s - wL_s - rK_s - p(y_s)y_s \\ \text{st} \quad x_s &= f_s(L_s,K_s,y_s) \qquad \text{(I)} \\ x_s,L_s,K_s,y_s &\geq 0 \end{aligned}$$

Notice that in (I) the way in which the intermediate goods price $p(y_s)$ is determined is not specified. At this level of abstraction it might correspond to the optimizing price for an independently profit maximizing subsidiary or it might correspond to the optimal transfer price stemming from an optimization over two stages of production by a vertically integrated firm. More subtly, it might correspond to a transfer price where prices and quantities are vertically coordinated between a firm and a supplier of intermediate inputs to it. These three kinds of possibilities are now considered via programmes (II) and (III) and associated developments.

Assume that the production function for intermediate inputs by a supplier s-1 is $y_{s-1}=f_{s-1}(L_{s-1},K_{s-1},z_{s-1})$, where y_{s-1} is output, and L_{s-1},K_{s-1},z_{s-1} are quantities of labour, capital and intermediate inputs employed for its production with unit costs w,r and c_z respectively. Then the profit maximizing plan for a firm s-1 is given by:

$$\begin{aligned} \text{Max } \pi_2 = \pi_2^* &= p(y_{s-1})y_{s-1} - wL_{s-1} - rK_{s-1} - c_z z_{s-1} \\ \text{st } \quad y_{s-1} &= f_s(L_{s-1},K_{s-1},z_{s-1}) \qquad \text{(II)} \\ y_{s-1}, L_{s-1},K_{s-1},z_{s-1} &\geq 0 \end{aligned}$$

If firm s is the sole purchaser of output y_{s-1}, so that $y_s=y_{s-1}$ and $p(y_s)=p(y_{s-1})$, an optimal solution to (II) is in turn consistent with the successive optimization by a firm via (I) and a supplier via (II) in the absence either of vertical integration or of vertical coordination.

Next consider a situation in which firm s and its intermediate goods supplier, firm s-1, are vertically integrated for the (successive monopoly) case in which firm s acquires all of the output of firm s-1 so that $y_s=y_{s-1}$. In this case firm s can select its own price for inputs y_{s-1} from its upstream supplier s-1 and arrange production of x_s and of y_{s-1} to accord with the solution to an optimization over these two stages of production as follows:

$$\begin{aligned} \text{Max } \pi_3 = \pi_3^* &= p(x_s)x_s - wL_s - rK_s - wL_{s-1} - rK_{s-1} - c_z z_{s-1} \\ x_s &= f_s(L_s,K_s,y_s) \qquad \text{(III)} \\ y_s &= f_{s-1}(L_{s-1},K_{s-1},z_{s-1}) \\ x_s, L_1, K_1, y_s, L_{s-1}, K_{s-1}, z_{s-1} &\geq 0 \end{aligned}$$

Associating Lagrange multipliers λ_s, λ_{s-1} with the constraints of (III) the corresponding Lagrangean is:

$$\begin{aligned} \text{Max } \pi_3 = \pi_3^* = p_s(x_s) - wL_s - rK_s - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - \lambda_s[x_s - f_s(L_s,K_s,y_s)] \\ - \lambda_{s-1}[y_s - f_{s-1}(L_{s-1},K_{s-1},z_{s-1})] \qquad \text{(III)}^* \end{aligned}$$

In this case the Kuhn-Tucker conditions are sufficient for a maximum where, in each of the relations (3.1)-(3.7), if the variables on the left hand side are positive, the associated equations hold with equality:

$x_s \geq 0$	$\delta\pi_3/\delta x_s = p(x_s) + x_s\,\delta p/\delta x_s - \lambda_s \leq 0$	(3.1)
$L_s \geq 0$	$\delta\pi_3/\delta L_s = -w + \lambda_s\,\delta f_s/\delta L_s \leq 0$	(3.2)
$K_s \geq 0$	$\delta\pi_3/\delta K_s = -r + \lambda_s\,\delta f_s/\delta K_s \leq 0$	(3.3)
$y_s \geq 0$	$\delta\pi_3/\delta y = -\lambda_{s-1} + \lambda_s\,\delta f_s/\delta y_s \leq 0$	(3.4)
$L_{s-1} \geq 0$	$\delta\pi_3/\delta L_{s-1} = -w + \lambda_{s-1}\,\delta f_{s-1}/\delta L_{s-1} \leq 0$	(3.5)
$K_{s-1} \geq 0$	$\delta\pi_3/\delta K_{s-1} = -r + \lambda_{s-1}\,\delta f_{s-1}/\delta K_{s-1} \leq 0$	(3.6)
$z_{s-1} \geq 0$	$\delta\pi_3/\delta z = -c_z + \lambda_{s-1}\,\delta f_{s-1}/\delta z \leq 0$	(3.7)

Condition (3.1) is consistent with the optimal decision rule: produce a positive quantity $x_s>0$, if at all, then to the point where the marginal revenue accruing from its production is equal to its marginal production cost, λ_s.

If optimally $x_s>0$ then necessarily $L_s>0$, $K_s>0$ and $y_s>0$, since positive quantities of these three inputs are prerequisites for a positive output of x_s. In turn positive levels of inputs $L_{s-1}>0$, $K_{s-1}>0$ and $z_{s-1}>0$ are prerequisites for a positive level of output $y_s>0$. Consequently, if optimally $x_s>0$, all of conditions (3.1)-(3.7) must hold as equalities. In these circumstances (3.2)-(3.4) and (3.5)-(3.7) take on familiar interpretations according to which, at a profit maximizing optimum to (III), the value of marginal revenue product equates to marginal factor cost for each factor employed.

Condition (3.4) is the key relation here since, via the quantities λ_{s-1} and λ_s, it interrelates the marginal cost of acquiring quantities y_{s-1} at supplier s-1 and the marginal cost of supplying quantities x_s of output from supplier s. In this context therefore the quantity λ_{s-1} is a *transfer price* for inputs y_s which, by contrast with the *given* price $p(y_s)$ for inputs in (I), is necessarily optimally determined with reference to the overall problem (III). In fact $p(y_s)$ in (I) will not be consistent with the overall optimization (III) *unless* $p(y_s)=\lambda_{s-1}$, where λ_{s-1} is optimal in (III). This idea is formalized in Theorem I:

THEOREM I

If $y_{s-1}=y_s$ the overall profit generated by maximizing via (III)* and establishing an optimally determined endogenous transfer price λ_{s-1} is no less than profit generated via separate maximizations via (I) and (II) with an exogenous transfer price $p(y_s)$. i.e:

$$\pi_3^* \geq \pi_1^* + \pi_2^*$$

PROOF

If $y_{s-1}=y_s$ so that $p(y_{s-1})=p(y_s)$ then optimal solutions π_1^*, π_2^* to (I) and (II) together constitute a feasible but not necessarily an optimal solution π_3^* to (III).

COROLLARY 1

There is potentially an advantage both to user s and to supplier s-1 if they vertically integrate their actions so as to maximize their collective profits.

REMARK

Vertical integration with $y_{s-1}=y_s$ corresponds to a class of special cases where $p(y_s)$ in (I) and $=p(y_{s-1})$ in (II) are each equal in value to the optimizing value of λ_{s-1} in (III).

Increases in collective profit generated via (III) vis a vis (I) and (II) do not guarantee increased profits at each stage of production s, s-1. In fact vertical coordination or integration to maximize overall profit via (III) will generally *reduce* profits generated at production stage s-1. This is because, if the overall maximum is such that $\pi_3^*>\pi_1^*+\pi_2^*$, then the transfer price λ_{s-1} and quantity y_{s-1} are such that $\lambda_{s-1}<p(y_{s-1})^*$ and $y_{s-1}>y_{s-1}^*$, where $p(y_{s-1}^*)$ and y_{s-1}^* are optimal in (II). This result is established formally in Theorem 2:

THEOREM 2

With assumptions as in (I), (II) and (III), unless $\lambda_{s-1}=p(y_{s-1}^*)$, where λ_{s-1} is optimal in (III) and y_{s-1}^* is optimal in (II), the optimal solution to (III) is such that $\lambda_{s-1}<p(y_{s-1}^*)$ and $y_{s-1}>y_{s-1}^*$, where $p(y_{s-1}^*)$ and y_{s-1}^* are optimal in (II).

PROOF

There are three possibilities

- **$\lambda_{s-1}=p(y_{s-1}^*)$.** In this case $\pi_3^*=\pi_1^*+\pi_2^*$ and vertical integration/coordination would yield the same overall value as independent profit maximization at levels s and s-1.
- **$\lambda_{s-1}>p(y_{s-1}^*)$.** In this case profits contributed at level s-1 are reduced vis a vis an optimum to (II) since $p(y_{s-1})^*$ is associated with a profit maximizing solution to (II). Under this condition, too, profit at level s must be *reduced* vis a vis and optimum to (I) since unit costs of inputs y_{s-1} are then *increased* vis a vis an optimal solution to (II), it follows that, if $\lambda_{s-1}>p(y_{s-1}^*)$, that solution cannot be optimal in (III)
- **$\lambda_{s-1}<p(y_{s-1}^*)$.** In this case profits contributed at level s-1 will again be decreased vis a vis an optimum to (II) since $p(y_{s-1}^*)$ is associated with a profit maximizing solution to (II). But in this case the profit contribution at level s would be *increased,* since unit costs of inputs y_{s-1} are then *decreased* vis a vis an optimal solution to (II).

It follows that a necessary condition for an increase in overall profit such that $\pi_3^*>\pi_1^*+\pi_2^*$ is $\lambda_{s-1}<p(y_{s-1}^*)$ and thence, by the concavity of $p(y_{s-1}^*)$, that $y_{s-1}>y_{s-1}^*$.

COROLLARY 2

Together Theorems 1 and 2 imply that in the successive monopoly case a firm s and a supplier s-1 will potentially *both* gain from vertical integration iff: a) the transfer price is reduced accordingly and; b) the firms' shares π_1^{**},π_2^{**} of the relatively increased total profit $\pi_3^*>\pi_1^*+\pi_2^*$ are allocated between supplier and supplied in such a way that $\pi_1^{**}\geq\pi_1^*,\pi_2^{**}\geq\pi_2^*$.

COROLLARY 3

Theorems 1 and 2 and Corollary 2 together imply that under successive monopoly a firm and its supplier vertically integrating in such a way as to increase overall profit will yield an outcome raising outputs, lowering prices and increasing profits at both stages of production *iff* the relatively larger profit π_3^{**} is redistributed so that, $\pi_1^{**}\geq\pi_1^*$ *and* $\pi_2^{**}\geq\pi_2^*$. It follows that, if areas under (inverse) demand curves are measures of consumer welfare and profits are measures of producer welfare, then vertical integration will be associated with improvements both in producers' and in consumers' welfare. [Since output is up and production functions are concave by assumption, employment and the marginal returns to workers will also increase - arguably suggesting a welfare increase there too.]

REMARK

With reference to monopoly and vertical integration/coordination and supermarkets, a key question is not whether lower prices are exploitative, but whether overall profits are redistributed in cases in which supermarkets set lower prices to their supplier. We have noted (in Section 2) that this is *not* so - at least in the UK, where the Competition Commission found evidence of cases in which suppliers were paying for access to shelf space at supermarkets rather than being paid in the form of a profit share for lowering prices of their supplies to those supermarkets.

For simplicity in this section attention has been focussed so far on the single stage successive monopoly case via the assumption $y_s=y_{s-1}$. But these conditions are not fundamental to the proofs of Theorems 1 and 2 or their corollaries. Extensions to more general cases, including more than one stage with firms s,s-1,s-2 and also to non-successive monopoly conditions, can readily be obtained. As an illustrative example of the latter kind, consider a case in which a single upstream firm s-1

supplies inputs to a group of oligopolistic firms Rs=1s, 2s…Ns with outputs x_{Rs} and inputs L_{Rs},K_{Rs},y_{Rs}. Assuming that $\Sigma x_{Rs}=x_s$ and $\Sigma y_{Rs}=y_{s-1}$, the collusive oligopolistic analogue of (III)* is then:

$$\text{Max } \pi_4 = \pi_4^* = \Sigma p_{RS}(\underline{x}_{RS})x_{RS}-\Sigma wL_{Rs}-\Sigma rK_{Rs}-wL_{s-1}-rK_{s-1}-c_z z_{s-1}+\lambda_s[x_{Rs}-f_s(L_{Rs},K_{Rs},y_{Rs})] + \lambda_{s-1}[y_s - f_{s-1}(L_{s-1},K_{s-1},z_{s-1})] \quad \text{(IV)}^* + \varphi(\Sigma x_{Rs}-x_s)+\theta(\Sigma y_{Rs}-y_{s-1})$$

This formulation (or variants which would stem from more specialized oligopolistic conjectures) leads to Kuhn Tucker conditions and associated optimal decision rules analogous to those associated with (III)* above - including the analogue of the transfer price related condition (3.4) which provided the key to Theorems 1 and 2 and associated interpretations with reference to vertical integration. [An example of a variant is a market sharing conjecture with firm Rs profit maximizing and all others accepting known shares of the total output x_s. This could be modelled straightforwardly by attaching market-sharing conditions as additional constraints to (IV)*. This idea is developed in a more general context via (V) below.] Such extensions, in common with all of the other developments in this section, might be construed as open to interpretation as consistent *either* with reference to ownership related vertical integration, *or* with reference to non-ownership related vertical coordination. The level of abstraction of the models used to establish Theorems 1 and 2 and their corollaries is such that the distinction between ownership and coordination has so far been moot. A firm might have such power over a subsidiary that it could impose a coordinating solution equivalent to that obtained via (III) without owning its supplier - i.e. without being vertically integrated.

4. Vertical Integration, Product Quality and Transaction Cost

In the previous two sections attention was focussed on vertical integration and successive monopoly and advantages stemming from the absence of double marginalisation. In practice however firms may seek to gain advantages of integration without ownership of their suppliers by merely undertaking vertical coordination. In the absence of transaction cost, of uncertainty and of technical inefficiency stemming from organizational structure this distinction is inconsequential. But, given any of those circumstances it potentially becomes crucial.

A longstanding framework for vertical integration and vertical coordination arguments is that pioneered by Coase (1937) based on his market failure argument. The core idea is that the firm as the agent that will efficiently displace a market when the cost of using that market is higher than when the firm internalises that activity. In this context, in common with Coase, Williamson (1971) predicts that a firm will choose to integrate two vertically connected functions when the transaction costs of using the market mechanism are higher than when the decision is internalised within the two firms. In other words, firms will choose a method of establishing relationships based on a comparison of their net effect on the transaction cost. Williamson (1971 pp.114-122) further argues that complex transactions are not the kind that spot markets could handle most efficiently but require a closer relationship between a buyer and seller to accommodate the complexities. He suggests that transaction cost motivates the use of non-market arrangements to vertically co-ordinate activities.

Another kind of motivation for coordination is provided by Arrow (1975) where he states that if there is a high level of uncertainty in the supply of up-stream goods, firms would be motivated to integrate, but if there is a low level of uncertainty, then spot markets become its preferable mode of transactions. This is further supported by Carlton (1979) who argues that firms will integrate in order among other things to secure first mover advantage where there is uncertainty in the supply of inputs.

With more specific reference to food supply chains, there are further and compelling motives for coordination, which include product quality, and production efficiency in addition to motives of reductions of transaction cost and of uncertainty. An empirical study on the food industries by Frank and Henderson (1992 p.941) suggests that transactional inefficiencies encountered in the industry promote increased utilization of non-market vertical arrangements. This analysis is of the Coasian type which identified four significant determinants of transaction cost, namely uncertainty, input supplier concentration, asset specificity and internalization cost. While for Frank and Henderson uncertainty is measured narrowly with reference to demand and to supply, for Hennessy (1996) uncertainty-related motives for vertical coordination include information asymmetry with regard to food quality and the cost of identifying quality. The uncertainty of quality as a result of information asymmetry was earlier recognised by Davies (1987). He found that, where the quality of the intermediate product from an upstream supplier is uncertain, it might be preferable for the user to integrate. While production characteristics of the food supply chain provide the main motives for vertical coordination, legislation concerning food safety and food quality in the food supply chains also contributes as a facilitating factor for vertical coordination (Ziggers and Trienekens 1999 and Fearne 1994).

In reality given that the number of suppliers serving each supermarket firm is large, it is not possible for it to integrate all its suppliers. According to Martinez (2002), in general supplier-retailer trading relationships may take several forms. Retailers may buy from the spot or open market, they may contract purchase, or they may undertake complete vertical integration with suppliers. In a wider context of the food sector Ziggers and Trienekens (1999) state that, since the food industry involves successive stages and big differences in scale between farm and non-farm activity, vertical coordination may be more appropriate than complete vertical integration. On the other hand there are cases where a supermarket firm is supplied by a single wholesaler, which in turn is being supplied by numerous suppliers.

Forces motivating coordination between supermarkets and their suppliers include not only the widely cited motive of transaction cost reduction but other reasons peculiar to the food industry. In that context the changing facet of consumer preferences and awareness towards food quality and safety issues and its relation to reasons for closer vertical coordination in some agriculture and food sectors has been explored by a number of authors. Martinez (2002) argues that two reasons, namely consumer preferences and health awareness in the food they consume, have led firms in the food industry to coordinate their activities. Underlining this: in certain food sectors and especially in the poultry, egg and pork industries, there has been a pronounced increase in vertical integration and contracting in recent years. (See Aust (1997), Kliebenstein and Lawrence (1995).) In each of these industries spot markets have apparently became a less efficient means of coordinating production and processing. Aust states that one of the reasons why integration and contracting has overtaken spot

markets in the food industry is the failure of the price mechanism to match the preferences of consumers in terms of quality and methods of production. Besides eliminating uncertainty of supply, quality uncertainty is also greatly reduced if firms in the supply chains are vertically coordinated.

In the next section we will investigate issues of transaction costs, of quality and efficiency by making extensions to the models developed in Section 3.

5. Quality, Efficiency and "Make or Buy"

Model (III) can be expanded to include quality by including a quality variable q in the inverse demand function with $\delta p(x_s,q)/\delta q>0$ by assumption (so that quality increases demand) together with a quality related cost relation Q(q), as in (V) below. This expanded representation also includes potentially efficiency and productivity enhancing resources g_1,g_2 and associated costs $G_1(g_1),G_2(g_2)$ where by assumption $\delta f_s(L_s,K_s,y_s,g_1)/\delta g_1>0$ and $\delta f_s(L_{s-1},K_{s-1},z_{s-1},g_2)/\delta g_2>0$. Finally "make or buy" decisions for intermediate inputs are included by means of the relations $y_s=y_1+y_2$, where y_s are acquisitions of intermediate inputs, y_1 is "make" and y_2 is "buy" at a unit cost c_2.

$$\text{Max } \pi_5 = \pi_5^* = p(x_s,q)x_s - wL_s - rK_s - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - c_2 y_2 - G_1(g_1) - G_2(g_2) - Q(q)$$

$$\text{s.t.} \quad y_s = y_1 + y_2$$

$$x_s = f_s(L_s,K_s,y_s,g_1) \qquad \text{(V)}$$

$$y_1 = f_{s-1}(L_{s-1},K_{s-1},z_{s-1},g_2)$$

$$x_s, L_1, K_1, y_s, L_{s-1}, K_{s-1}, z_{s-1} \geq 0$$

Elements of (V) could be used to make contact with literatures on advertising and on X-efficiency and associated managerial theories of the firm. For example the quality variable in the revenue relation is isomorphic with the advertising variable in Baumol's seminal sales revenue maximization model with advertising (Baumol (1959), and the incorporation of potentially X-inefficiency reducing resources g_i in the production functions and associated cost relations $G_i(g_i)$ is similar to that employed in Crew, Jones-Lee and Rowley (1971). But here the main focus is on another feature of this model, namely optimal rules yielding "make or buy" decisions and associated interpretations with reference to the choice between vertical integration or coordination with endogenously determined costs and quantities and supply from another source at a fixed unit cost c_2. These rules follow from the conditions for an optimum to (V). To determine these associate variables $\theta,\lambda_s,\lambda_{s-1}$ with the constraints of (V) to obtain the Lagrangean (V)*:

$$\text{Max } \pi_5 = \pi_5^* = p_s(x_s,q)\,x_s - wL_s - rK_s - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - c_2 y_2 - G_1(g_1) - G_2(g_2) - Q(q)$$

$$-\theta(y_s - y_1 - y_2) - \lambda_s[x_s - f_s(L_s,K_s,y_s,g_1)] - \lambda_{s-1}[y_1 - f_{s-1}(L_{s-1},K_{s-1},z_{s-1},g_2)] \qquad \text{(V)}^*$$

Necessary conditions for a maximum to (V)* are:-

$$\delta\pi_5/\delta x_s = p(x_s) + x_s\,\delta p/\delta x_s - \lambda_s \leq 0 \qquad (5.1)$$

$$\delta\pi_5/\delta L_s = -w + \lambda_s\,\delta f_s/\delta L_s \leq 0 \qquad (5.2)$$

$$\delta\pi_5/\delta K_s = -r + \lambda_s\,\delta f_s/\delta K_s \leq 0 \qquad (5.3)$$

$$\delta\pi_5/\delta y_s = -\theta + \lambda_s\,\delta f_s/\delta y_s \leq 0 \qquad (5.4)$$

$$\delta\pi_5/\delta L_{s-1} = -w + \lambda_{s-1}\,\delta f_{s-1}/\delta L_{s-1} \leq 0 \qquad (5.5)$$

$$\delta\pi_5/\delta K_{s-1} = -r + \lambda_{s-1}\,\delta f_{s-1}/\delta K_{s-1} \leq 0 \qquad (5.6)$$

$$\delta\pi_5/\delta z = -c + \lambda_{s-1}\,\delta f_{s-1}/\delta z \leq 0 \qquad (5.7)$$

$$\delta\pi_5/\delta q = x_s \delta p_s(x_s,q)/\delta q - \delta Q(q)/\delta q \leq 0 \qquad (5.8)$$

$$\delta\pi_5/\delta y_1 = \theta - \lambda_{s-1} \leq 0 \qquad (5.9)$$

$$\delta\pi_5/\delta y_2 = \theta - c_2 \leq 0 \qquad (5.10)$$

$$\delta\pi_5/\delta g_1 = -\,\delta G_1(g_1)/\delta g_1 + \lambda_s\,\delta f_s/\delta g_1 \leq 0 \qquad (5.11)$$

$$\delta\pi_5/\delta g_2 = -\,\delta G_1(g_1)/\delta g_1 + \lambda_s\,\delta f_s/\delta g_1 \leq 0 \qquad (5.12)$$

Interpretations of conditions (5.1)-(5.7) are analogous to those of (3.1)-(3.7) above, namely produce $x_s>0$, if at all, then to the point where the marginal revenue accruing from its production is equal to its marginal production cost, λ_s and if optimally $x_s>0$, then necessarily $L_s>0$, $K_s>0$ and $y_s>0$, since positive quantities of these three inputs are prerequisites for a positive output of x_s. In turn, *if optimally inputs y_s are acquired from firm s-1, then* positive levels of inputs $L_{s-1}>0$, $K_{s-1}>0$ and $y_{s-1}>0$ are prerequisites for a positive level of output $y_s>0$. It follows that, if optimally $x_s>0$, all of conditions (5.1)-(5.7) must hold as equalities. In those circumstances in a manner similar to conditions (3.2)-(3.4) and (3.5)-(3.7), conditions (5.2)-(5.4) and (5.5)-(5.7) take on familiar interpretations according to which at a profit maximizing optimum to (V), marginal revenue product equates to marginal factor cost for each factor employed.

A key difference between (III) and (V) is the incorporation of quality via the product quality variable q. Specifically condition (5.8) requires that for an optimum to (V) resources must be devoted to quality enhancements of demand to the point where the marginal demand related gain equates to the marginal cost of enhancing demand. Another key difference is that the quantity λ_{s-1}, rather than being simply a transfer price between a firm and a vertically integrated or coordinated supplier, is a transfer price *conditional upon* firm s-1 being a supplier to firm s. In that context the quantity θ takes on the interpretation of the marginal cost of acquiring intermediate inputs y_s, from firm s-1 in quantities $y_1\geq 0$ via (5.9), or from alternative sources in quantities $y_2\geq 0$ via (5.10), or from both.

In these ways conditions (5.9)-(5.10) relate to "make or buy " decisions and require that intermediate inputs be acquired from the lowest cost source - be that from an integrated subsidiary via quantities $y_1>0$, from a coordinated external source via quantities $y_2>0$, or from an optimal mix of both of these two sources. Together with conditions (5.4) they require that, for an overall optimum to obtain, the following conditions must hold:

$$\lambda_s\,\delta f_s/\delta y_s \leq \theta \leq \min\{\lambda_{s-1}, c_2\} \qquad (5.13)$$

We emphasise that, via (V), the quantity λ_{s-1} is a *transfer price* for inputs y_s, *if those are produced by a subsidiary rather than being bought in.* This last point underlines a key difference between implications of (III) and those of (V), namely the endogenization of the vertical coordination or integration decision vis a vis outside

acquisitions of intermediate inputs. From (5.13), $\theta=\min\{\lambda_{s-1},c_2\}$, where λ_{s-1} is the transfer price under the integrated structure and c_2 is the price via coordinated acquisition or outside purchase (spot market). Therefore the make or buy decision depends on the transfer price i.e. use y_1 if cheaper than y_2, or vice versa.

Finally conditions (5.11) and (5.12) require that efficiency enhancing resources be employed to the point where the marginal enhancement in value of production respectively by firm s and by firm s-1 equates to the marginal cost of securing that enhancement.

Analogues of Theorems 1 and 2 and associated corollaries could easily be developed with reference to (V). They would demonstrate that, *if* it were profitable to secure supplies for output at level s from a supplier s-1, then it would generally be *more* profitable to do so by introducing vertical integration or vertical coordination mechanisms to secure a collectively profit maximizing transfer price λ_{s-1}. However, in distinction from the models associated with Theorems 1 and 2, the system (V) includes the possibility of buying inputs from an outside "buy" source as an alternative to their acquisition from producer s-1. This is a key point since this "buy" alternative ensures an upper bound on the transfer price λ_{s-1}. In that way it provides another form of potentially cost reducing and profit increasing coordinating mechanism. This point is established more formally by means of Theorem 3:

THEOREM 3

With assumptions as in (V)* and if $c_2^* \leq c_2$ and/or $G_1^*(g_1) \leq G_1(g_1)$ and/or $G_2^*(g_2) \leq G_2(g_2)$ then:

$$\text{Max } \pi_5=\pi_5^*= p_s(x_s,q)\, x_s - wL_s - rK_s - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - c_2 y_2 - G_1(g_1) - G_2(g_2) - Q(q)$$
$$-\theta(y_s-y_1-y_2) - \lambda_s[x_s - f_s(L_s,K_s,y_s,g_1)] - \lambda_{s-1}[y_1 - f_{s-1}(L_{s-1},K_{s-1},z_{s-1},g_2)] \qquad (V)^*$$
$$\leq$$
$$\text{Max } \pi_5=\pi_5^*=p_s(x_s,q)\, x_s - wL_s - rK_s - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - c_2^* y_2 - G_1^*(g_1) - G_2^*(g_2) - Q(q)$$
$$-\theta(y_s-y_1-y_2) - \lambda_s[x_s - f_s(L_s,K_s,y_s,g_1)] - \lambda_{s-1}[y_1 - f_{s-1}(L_{s-1},K_{s-1},z_{s-1},g_2)] \qquad (V)^{**}$$

PROOF

Any solution to (V)* is a feasible but not necessarily an optimal solution to (V)**.

COROLLARY 4

An enterprise may cut its costs and increase its profits by buying intermediate inputs to production from outside vis a vis acquiring them from vertically coordinated or vertically integrated sources.

COROLLARY 5

An enterprise may cut its costs and increase its profits by introducing less costly methods of increasing productivity.

COMMENTS

- An interpretation of Corollary 4 is that the management of a firm may cut costs and increase profits by switching from a regime in which some or all intermediate inputs to production are sourced by means of vertical coordination or integration to one in which some or all of those inputs to production are sourced from outside those channels.
- An interpretation of Corollary 5 is that increases in productivity and associated increases in profits might be achieved by a change in ownership and/or in management where that change is associated with lower cost means of achieving productivity.
- The two preceding interpretations may be coincident and such that a change in management is associated both with a change in acquisition policy and with a change in

procedures associated with productivity enhancement. [A straightforward generalization of Theorem 3 could also include change in one or more of the production functions with those changes being interpreted as changes in production expertise associated with profit seeking changes in ownership/management.]

In practice, however, and surely in the context of food supply chains and activities of supermarkets, quality and efficiency are likely to be determined in a market with more than one supermarket. Also quality is likely to be a significant instrument of rivalry between these supermarkets. Accordingly consider a generalization of the model in (V) to include 1s,2s..Rs..Ns firms at level s with qualities q_{Rs} of each firm as arguments in the inverse demand functions of all of the others, as in (VI), where it is assumed, too, that the Ns firms will seek to maximize their collective profits.

$$\begin{aligned}\text{Max } \pi_6 = \pi_6^* = \Sigma[p_{RS}(x_{Rs}, q_{1s,}.q_{Rs,}.q_{Ns})x_{Rs} - \Sigma wL_{Rs} - \Sigma rK_{Rs} - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - \Sigma c_{2Rs} y_{2Rs} \\ - G_{Rs}(g_{1Rs}) - G_2(g_{2Rs}) - Q_{Rs}(q_{Rs})] \\ \text{s.t.} \quad y_{Rs} = y_{1Rs} + y_{2Rs} \qquad \text{(VI)} \\ x_{Rs} = f_{Rs}(L_{Rs}, K_{Rs}, y_{Rs}, g_{1Rs}) \\ y_{s-1} = f_{s-1}(L_{s-1}, K_{s-1}, z_{s-1}, g_{2Rs}) \\ \Sigma y_{1Rs} = y_{s-1} \\ x_{Rs}, q_{Rs}, L_{Rs}, K_{Rs}, y_{Rs}, y_{1Rs}, y_{2Rs}, L_{s-1}, K_{s-1}, z_{s-1}\ g_{1Rs}, g_{2Rs} \geq 0\end{aligned}$$

Associating Lagrange multipliers θ_{Rs}, $\lambda_{s,}$ μ_{s-1},λ_{s-1} with the constraints of (VI) first order conditions stemming from (VI) are similar to the single firm case considered via (V), but now firms potentially interact through perceived quality as well as price and thence cost and productive efficiency. In particular the analogue of condition (5.8) is given by (5.14) below and efficiency and productivity analogues of condition (5.13) for two representative firms 1s and 2s are given by (5.15a,b) below.

$$\Delta\pi_6/\delta q_{Rs} = \sum_{V_s=1_s}^{N_s} x_s \delta p(\ )/\delta q_{Vs} - \delta Q(q_{Rs})/\delta q_{Rs} \leq 0 \qquad (5.14)$$

Condition (5.14) has the interpretation: expand resources on quality enhancement to the point where the marginal net revenue contribution of quality enhancement equates to the marginal cost of quality enhancement. [Note that some $\delta p(\ )/\delta q_{Vs}$ will be positive but soe may be negative. Informally, perceived increases in a product's quality may increase or reduce demand for rivals' products.]

$$\lambda_s \delta f_{1s}(\ )/\delta y_{1s} \leq \theta_{1s} \leq \min\{\lambda_{1s-1}, c_{21s}\} \qquad (5.15a)$$
$$\lambda_s \delta f_{2s}(\ )/\delta y_{2s} \leq \theta_{2s} \leq \min\{\lambda_{2s-1}, c_{22s}\} \qquad (5.15b)$$

It follows from (5.15a) and (5.15b) that costs of intermediate inputs may be such that $\min\{\lambda_{1s-1}, c_{21s}\} = \lambda_{s-1}$ and $\min\{\lambda_{2s-1}, c_{22s}\} = c_{22s}$ so that firm 1s optimally acquires inputs in a vertically integrated manner from firm s-1 and firm 2s acquires intermediate inputs wholly from outside sources. [This may be so even if $c_{22s} = c_{22s}$]. Other possibilities are that one or both firms optimally acquires a mix of inputs, some from a vertically integrated source at optimally determined transfer prices λ_{1s-1}, λ_{2s-1} and others from vertically coordinated outside sources at acquisition prices c_{21s},c_{22s}. In any case conditions (5.15a,b) depend on relations $f_{1s}(\ )$,$f_{2s}(\ )$,$f_{s-1}(\ )$ which in turn depend on the properties of the productivity enhancing inputs g_{iRs} and their costs. It

follows that a firm would have an advantage over another *ceteris paribus* if its productivity enhancing inputs g_{iRs} were cheaper and their quality enhancement properties were greater.

In fact it is unlikely that firms will choose simply to maximize collective profit as in (VI). This is not only because such a solution may leave the supplying firm s-1 worse off in the sense of Theorem 1, but also because such behaviour is likely to be relatively easily detectable by the regulatory authorities. With this perspective we consider a market sharing extensions of (VI) via Theorem 4 in which it is assumed that a market leader or group of leaders will maximize collective profits subject to the conditions that each will accept at most a market share $\gamma_{Rs}\Sigma x_{Rs}$. [Compare (IV) above.]

THEOREM 4

With assumptions as in (VI) together with the assumptions that each firm at stage s will accept at most a market share $\gamma_{Rs}\Sigma x_{Rs}$ and that the firms seek to maximize their collective profits given those conditions, then:

$$\pi_7^* \leq \pi_6^*$$

Where π_6^* is the optimal solution to problem (VI) and π_7^* is given by:

$$\text{Max } \pi_7 = \pi_7^* = \Sigma p_{Rs}(x_{Rs}, q_{1s,}, q_{Rs,}, q_{Ns})x_{Rs} - \Sigma wL_{Rs} - \Sigma rK_{Rs} - wL_{s-1} - rK_{s-1} - c_z z_{s-1} - \Sigma c_{2Rs} y_{2Rs}$$

$$- G_{Rs}(g_{1Rs}) - G_2(g_{2Rs}) - Q_{Rs}(q_{Rs})$$

$$\text{s.t. } y_{Rs} = y_{1Rs} + y_{2Rs} \qquad \text{(VII)}$$

$$x_{Rs} = f_{Rs}(L_{Rs}, K_{Rs}, y_{Rs}, g_{1Rs})$$

$$y_{s-1} = f_{s-1}(L_{s-1}, K_{s-1}, z_{s-1}, g_{2Rs})$$

$$\Sigma y_{1Rs} = y_{s-1}$$

$$x_{Rs} \leq \gamma_{Rs}\Sigma x_{Rs}$$

$$x_{Rs}, q_{Rs}, L_{Rs}, K_{Rs}, y_{Rs}, y_{1Rs}, y_{2Rs}, L_{s-1}, K_{s-1}, z_{s-1}\ g_{1Rs}, g_{2Rs} \geq 0$$

PROOF

An optimal solution to (VI) is a feasible but not necessarily an optimal solution to (VII)

Clearly the multi firm specification in (VII) will yield one class of multifirm solutions for a potentially vertically integrated market which is oligopolistic at stage of production s via conditions analogous to those of (VI) but now moderated by effects of the additional market sharing constraints $x_{Rs} \leq \gamma_{Rs}\Sigma x_{Rs}$. Underlining the central themes of the paper, those optimality conditions will imply properties analogous to results both in Theorems 1 and 2 and their corollaries 1 and 2 and in Theorem 3 and corollaries 3 and 4. Specifically: via (VII) firms at level s in a supply chain may gain by collectively obtaining supplies from a potentially coordinated supplier, s-1, but that, if they do so, then that coordination will generally lead to a lowered transfer price for supplier and - in the absence of compensating profit transfers - to correspondingly reduced profits. And; via (VII) firms may gain vis a vis others among other things if they access to less costly outside sources of supply of intermediate inputs to production and/or if they have access to lower cost means of increasing productivity.

6. Conclusion

This paper has provided a proof and a number of formal generalizations of the well known double marginalization result to the effect that successive monopolists may each gain by vertically integrating their operations. These generalizations include market sharing and profit maximizing oligopoly cases. They also include make or buy

extensions which in turn yield criteria for more subtle kinds of decisions, namely decisions between vertically integrating and vertically coordinating elements of firms' supply chains.

Because of the strong current interest in regulatory issues in that industry, attention has been focussed here on supermarkets. But these results are clearly applicable to other industrial sectors too.

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