working paper
department
of economics

VERTICAL INTEGRATION IN COMPETITIVE MARKETS UNDER UNCERTAINTY

By

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Number 174 April 1976

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This paper is based on my Ph.D. thesis, "Market Behavior Under Uncertainty", M.I.T., September, 1975. I wish to thank Professors Franklin M. Fisher, Peter A. Diamond, Robert E. Hall, and Paul L. Joskow for valuable comments and advice.

1. Introduction

Vertical integration has never been a well understood phenomenon. Although it is possible to postulate conditions such as technological coordination where the incentives for vertical integration are obvious, it is still difficult to rationalize the amount of vertical integration that occurs in our economy. The dissatisfaction with the treatment of vertical integration is best expressed by Williamson,

> "The study of vertical integration has presented difficulties at both the theoretical and policy levels of analysis. That vertical integration has never enjoyed a secure place in value theory is attributable to the fact that, under conventional assumptions, it is an anomaly."[1]

It has always been somewhat of a mystery why businessmen, as well as researchers, so often conclude that the signficant force explaining the vertical integration movement has been the desire to obtain a more certain supply of inputs - even though these inputs appear to be sold on what most would call a competitive market. Why are markets not doing their jobs of allocating resources and why should uncertainty create incentives for vertical integration?

Elsewhere,[2] I have argued that most markets do not precisely fit the classical requirements that prices can fluctuate instantly to equate supply

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[1] O. Williamson - "The Vertical Integration of Production: Market Failure Considerations", American Economic Review, May, 1971.

[2] D. Carlton - "Market Behavior Under Uncertainty", M.I.T. Ph.D. thesis, September, 1975.

and demand or that buyers and sellers can always buy and sell all they want of the good. Although ignoring these complications may be allowable for understanding certain types of economic behavior, the thesis of this paper is that it is only when the question of vertical integration is examined in the context of these more general and realistic competitive conditions (which include the classical conditions as a special case) that the incentives for and consequences of vertical integration can be fully understood. Moreover, the analysis provides a justification for the frequently voiced claim of businessmen that they vertically integrated to obtain a more certain source of input supplies.

In the next section, we discuss the previous thinking about vertical integration, especially regarding the effects of uncertainty. Then, the theory of a single competitive market under uncertainty is presented. Within this market framework, the effects of the transmission of uncertainty between different markets is then examined. Focusing on this transmission of uncertainty, the analysis shows that vertical integration can be regarded as a means of transferring risk from one sector of the economy to another. From a private point of view vertical integration is very attractive. Firms have an incentive to integrate to insure a supply of input to satisfy their "high probability" demand. However, in a market characterized by uncertainty, externalities abound, and it turns out that for the models under discussion, vertical integration is socially undesirable. The free market cannot be relied upon to achieve the socially desirable allocation of risk and production.

On the other hand, vertical integration does have some desirable attributes. We show that a vertically integrated firm is more likely to

introduce socially beneficial technology than is a nonintegrated firm. We are led to a Shumpeterian view of the world where static inefficiency in market structure must be tolerated to obtain a type of dynamic efficiency in the introduction of technology.

It is important to keep in mind throughout this paper that under classical assumptions about competition with constant returns to scale, there are no private incentives or disincentives for vertical integration, no undesirable social consequences for vertical integration, and no effects resulting from vertical integration on innovative activity.

2. Relation to Previous Research

The literature in industrial organization is replete with statements to the effect that it is the uncertainty of factor supplies that creates incentives for vertical integration. For example, Chandler, in his discussion of the reasons for the formation of the largest companies in the United States argues "the initial motives for expansion or combination and vertical integration had not been specifically to lower unit costs or to assure a larger output per worker by efficient administration of the enlarged resources of the enterprise. The strategy of expansion had come...from the desire...to have a more certain supply of stocks, raw materials and other supplies..."[1] In studying Dupont's reasons for integrating General Motors, Chandler finds that "the need for assured supplies demanded increasing vertical integration."[2] Regarding General Motors, we find that "Durant personally organized a number of them [i.e., vertically integrated] in order to make certain that his assembly line would have a dependable supply of parts."[3] Despite the frequency with which the argument about the need for assured supplies appears in historical studies of vertical integration, it is usually never explained why the factor supply is uncertain, or why an uncertain factor supply should create incentives for vertical integration.

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[1] A. Chandler, Jr. - Strategy and Structure: Chapters in the History of American Industrial Experience, M.I.T. Press, 1964, pp. 37.

[2] ibid. p. 84

[3] ibid. p. 116

At a more theoretical level, several authors concerned with industrial organization have suggested that uncertainty could provide an incentive for vertical integration. As early as 1937, Coase[1] argued that with constant returns to scale in production the very existence of a firm depends on some sort of market imperfections. The firm organizes when its internal allocative ability is superior to that of a market. Coase claimed that uncertainty about finding sellers of factors of production could provide one justification for the existence of a firm. Applying Coase's reasoning to the question of vertical integration many years later, Malmgrem[2] indicated that the presence of uncertainty could create incentives for vertical integration. "Activities which tended to fluctuate, causing fluctuations in prices and outputs in the market, could be integrated and balanced against one another."[3] Malmgrem argued that when prices do not reflect scarcity, vertical integration can occur. More recently, Williamson[4] discussed how uncertainty can make it difficult to establish contracts, and could provide incentives for vertical integration. None of the discussions ever address the issue of whether vertical integration is a socially desirable response to the uncertainty in the market.

Until very recently, there had been no attempt to analytically investigate the claims of the above authors as regards the effect of uncertainty on the incentives for vertical integration. Recently, two economic theorists have sought to bridge the gap in the literature.

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[1] R. Coase - "The Nature of the Firm", Economica, November, 1937.

[2] H. Malmgrem - "Information, Expectations, and the Theory of the Firm", Quarterly Journal of Economics, November, 1971.

[3] ibid.

[4] Williamson, op. cit.

Arrow[1] has shown that as in the deterministic case, the presence of uncertainty in a factor market with a freely fluctuating price does not create any incentives for vertical integration. Arrow then proceeds to investigate the case where informational advantages accrue to vertically integrated firms. In a paper closely related in topic to this one, Green showed that if rationing is possible in the factor market, then all firms would have an incentive to fully integrate. Green then goes on to examine the case where a vertically integrated firm is assumed to have a less efficient technology for producing the input. Prices are exogenous in Green's model so that prices need bear no relation to scarcity or rationing probability. In Green's model, final product firms face no uncertainty in their demand for their product and are able to sell all of their product at the exogenous market price.

The focus of this paper is to show that in markets characterized by the type of uncertainty and price inflexibility discussed earlier, the transmission of uncertainty from the product market to the factor market can create strong private incentives for vertical integration to occur, even when such vertical integration is socially undesirable. In order to concentrate on the effects of the transmission of uncertainty, we will avoid making any of the usual assumptions that can lead to vertical integration. In both the final product and factor market, firms will compete with each other, will be untaxed, and will have constant returns to

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[1] K. Arrow - "Vertical Integration and Communication", Institute for Mathematical Studies in the Social Sciences, November, 1974. A version of this paper appears in The Bell Journal of Economics, Spring, 1975.

[2] J. Green - "Vertical Integration and Assurance of Markets", Discussion Paper 383, Harvard Institute of Economic Research, October, 1974.

scale in production. Integrated and nonintegrated firms will have the identical production technologies available to them so that there is no asymmetry in the production efficiency of the factor input. The prices in both the final and factor market will be endogeneously determined in accordance with the analysis in the following section. Firms will have an incentive to integrate to lower the probability of being unable to obtain the factor input (i.e., to better "assure" themselves of supplies). Firms will have an incentive not to integrate to avoid the probability of being left with unused input. We see then that vertical integration involves a balancing of risks. Does the firm wish to bear the risk of having unsold inputs itself or does it prefer to let some other firm in the factor market bear the risk of having an unsold product?

3. Market Behavior Under Uncertainty

Before developing a model of how markets interact under uncertainty, it is first necessary to develop a theory of how a single market under uncertainty operates. In this section, the theory of competitive equilibrium under uncertainty is briefly discussed. For a fuller development of the theory see Carlton, op. cit.

For most markets, prices do not adjust at each instant of the day to keep supply and demand in balance, firms never feel they can sell all they want at the going price, and production cannot occur instantly. More realistic assumptions would be that in order to be an effective "signal" prices stay fixed for some period of time. An individual firm never knows exactly what demand for its product will be each day, even if total demand for the industry is unchanging. The firm usually will know the probability distribution of demand it faces. Since production is not instantaneous, firms must make production decisions before observing demand, and hence take a risk of either overproducing or underproducing (or, more generally, of having unused or insufficient production capacity). In this model, firms make decisions on price and production before their demand can be observed.

Buyers know the price a firm charges, but do not know whether the firm has any goods left to sell at any particular time. When he goes to the firm, a buyer knows the probability of being able to purchase the good at the stated price of that firm (i.e., firms acquire reputations for reliability). A good produced by a particular firm now has two relevant characteristics, its price and the probability that it is available.

For simplicity, we assume no searching on the part of buyers and no inventory holdings on the part of firms. Provided that search cost and inventory holding are costly, the basic ideas of how markets operate under uncertainty would not be altered by their inclusion (although the analysis would become mathematically intractable). We do not allow firms to trade the good with each other or allow recontracting markets to develop. This last requirement corresponds to the observation that in the real world, we do not always see such phenomena occuring, presumably because of transaction costs.

The amount of the good that a firm begins the market period with (or more generally the amount of productive capacity available) will affect the probability that a buyer will be able to purchase the good from that firm. Notice that the stochastic structure of demand imposes real costs on the firm. Given the stochastic structure of demand, the expected profits of a firm will depend on the price it charges and on how many customers it is able to satisfy. Equivalently, we can say that expected profit depends on price and the probability of satisfaction.

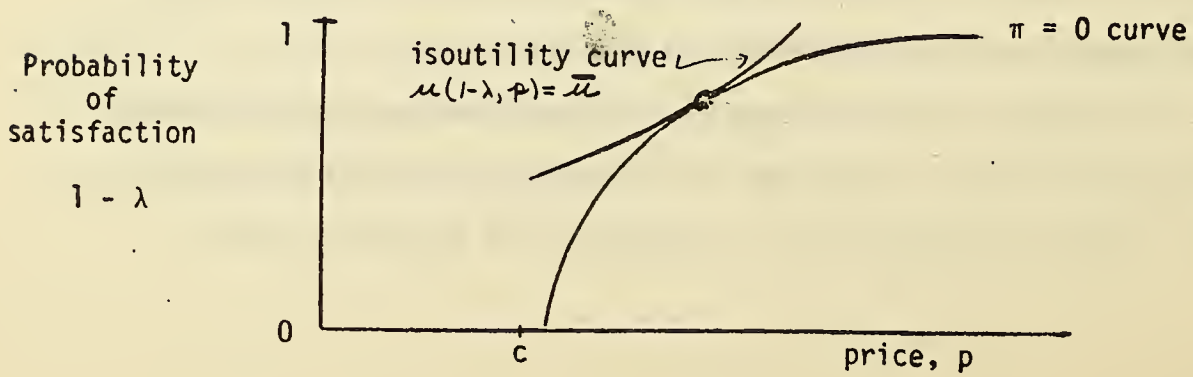
Letting $1-\lambda$ = probability of a buyer obtaining the good and p = the price, it is possible to draw isoprofit curves in $(1-\lambda,p)$ space. These curves slope upward reflecting the fact that as a firm increases the probability of satisfying a customer by stocking more or having additional capacity, the price must rise to cover the increased risk of having unsold goods, or available, but unused, capacity.

On the other side of the market, consumers have preferences between the price they pay for a good and the probability that they obtain the good. Consumer preferences can be represented by isoutility curves

in $(1-\lambda,p)$ space, where once again $1-\lambda$ stands for the probability of obtaining the good, and p is the price. Isoutility curves slope upward. We impose no restrictions on the shape of these isoutility curves other than the weak restriction that the slope of these curves is positive and bounded away from zero and infinity.

For purposes of this paper, it suffices to consider the case where all firms and all customers are identical. In such markets, firms compete with each other on the utility level (i.e., the $(1-\lambda,p)$ mix) that they offer to consumers. Consumers will choose to frequent only those firms who offer the highest utility levels. Firms bid up the utility level until expected profits are driven to zero. Just as in other competitive markets, in this market equilibrium, no firm offering less than the best deal (i.e., best utility level) in the market will receive any customers. Equilibrium for such markets is depicted below as a tangency between the zero profit curve ($\pi = 0$) and an isoutility curve ($u(1-\lambda,p) = \bar{u}$). (With no additional assumptions on the shape of the isoutility curves, multiple tangencies and tangencies involving isoutility curves with less than the maximum attainable utility level are possible. For detailed discussions of market dynamics, nonexistence of equilibrium, and multiple equilibria, see Carlton, Ch. 2, op. cit.)

Market Equilibrium



We assume for simplicity a constant cost, c, for producing one unit of the good. Notice that if instantaneous production were possible, there would be no risk that a firm need incur. In such a case, the zero profit curve becomes vertical at $p = c$, utility level competition becomes equivalent to price competition, and the equilibrium is identical to the traditional supply and demand equilibrium.

The noteworthy features of competitive equilibrium under uncertainty are that, in general, 1) the probability that a customer will be unable to purchase the good definitely exceeds zero, 2) the price will always exceed the constant marginal cost, c, of production, and 3) the total amount supplied and total amount demanded will not in general be equal.

In equilibrium, price must exceed the marginal cost of production since the revenue from sold goods must compensate not only for the cost of production of these goods, but also for the cost of production of the unsold goods (or equivalently, compensate for unused but available productive capacity).

The social welfare implications of markets under uncertainty are much different from those of markets under certainty. For example, it is possible to show that in a two good world (where the alternative good is always available), the competitive pressures will not lead to a Pareto efficient outcome in the sense that it is possible to organize production in an uncertain world so as to make consumers better off. Under plausible

conditions on preferences, it can be shown that production of the good subject to shortages should be subsidized.[1]

It is also possible to prove that as the ratio between customers and firms increases, the competitive equilibrium under uncertainty approaches percentagewise the equilibrium under certainty. In other words, as the customer per firm ratio increases, the equilibrium price approaches the constant cost of production, c, and the equilibrium probability of satisfaction approaches one. The ratio between supply and demand approaches one, while the absolute discrepancy between the two grows unboundedly. The rate of convergence of the competitive equilibrium under uncertainty to that under certainty is slow, and in general customer per firm ratios in excess of 5000-10000 are required before convergence to 1% of the deterministic equilibrium can occur. (See Carlton, op. cit., for more details.)

With this description of how single markets operate under uncertainty, we can now turn to the study of vertical integration as the transmission of uncertainty between different markets.

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[1]We have not allowed insurance markets to develop. An insurance contract would provide compensation if the good were unavailable. There are well-known reasons why such insurance markets do not exist in the real world. For example, ascertaining that the customer actually made an attempt to purchase the good could require huge monitoring costs. If insurance markets could be costlessly run, then the private market would lead to an efficient outcome in this two good world.

4. The Model

This section presents a simple model of the transmission of uncertainty between a product market and one of its factor markets. The model is intended to elucidate the incentives and consequences of (backward) vertical integration.

There are two types of firms, stage 1 and stage 2 type firms. Stage 1 firms require factor inputs from stage 2 firms to produce the final good. There are N_1 identical stage 1 firms and N_2 identical stage 2 firms, with N_2 less than N_1. Demand facing an individual stage 1 firm is random during any market period. Therefore, the derived demand of stage 1 firms for factor inputs is random. In the stage 2 factor market, the demand facing any firm is also random. The final good cannot be produced without the factor input, and the amount of the factor input available in any period must be determined before any of the demands for the final product can be observed. Therefore, there is a risk that a unit of input will be produced but not used by the time the market period ends. We assume that unused input is discarded at the end of the market period. However, even if inventory can be held from one period to the next, as long as there are costs to holding inventories, the same types of qualitative results as developed below will hold. Prices are set at the beginning of each market period before any demands are observed, and are not allowed to vary within any market period.

We allow stage 1 firms the option of producing some of the factor input for itself. We refer to the production and holding of the input by stage 1 firms as vertical integration. If a stage 1 firm

produces the factor input for itself, it bears the risk of having unused input at the end of the market period. A stage 1 firm is not allowed to sell its inputs in the stage 2 factor market. This last assumption is designed to capture the notion that a vertically integrated firm is trying to produce for its own needs to better assure itself of the supply of the input.[1] Stage 1 firms cannot ship the factor input between themselves, nor can stage 2 firms for the same reasons as discussed in Section 3. As before, we assume recontracting markets do not develop.

We assume that the production technologies for producing the final product and factor input both involve constant returns to scale. The same technology for producing the factor input is available to both stage 1 and stage 2 firms. It costs c to produce one unit of the factor input. The final product is produced (instantaneously) by a Leontief technology that requires K units of capital and 1 unit of the factor input sold in the stage 2 market to produce one unit of the final good. The capital input is always available at a constant price r per unit.

The market operates in the same manner as described earlier. There are assumed to be L identical customers. In each market period, each of the L customers randomly frequents[2] one stage 1 firm where he demands the final product according to his demand curve. Every time a stage 1 firm observes a customer demand for its product, it attempts to obtain the factor inputs necessary to produce the customer's demand for the final product. The stage 1 firm first tries to use up its own holdings, if any,

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[1]See next page for footnote.

[2]More precisely, each customer randomly frequents one stage 1 firm from among those firms which he feels are offering the best deals in the market.

[1]Let me give two possible reasons and examples to illustrate why this assumption is reasonable. First, an output firm might be distrustful of the quality of an input purchased from another competing output firm. Second, there may be transaction costs or other increases in bureaucratic costs as a company expands from being a seller of output to becoming a seller of both outputs and inputs. Complex organizations can increase costs.

This nonsharing of an input supply by output producers is quite common. As an example consider a firm's secretarial pool that is occasionally idle. It is not frequently the case that an employer will try to obtain outside typing in order to keep his secretaries fully busy. Next, consider a firm that keeps stocks of some input for production. This firm will usually not be always willing to sell its input. The firm will usually enter the input market as a seller only if its stock of input starts piling up and the firm becomes convinced that it miscalculated its needs. Only when the firm becomes sure that it has made a sizable miscalculation will it pay for the firm to incur transaction costs and enter the input market as a seller.

A model with equivalent implications can be constructed by assuming that vertically integrated firms can purchase input from each other, but the input is also demanded by other sectors of the economy, and that vertically integrated firms do not sell to these other sectors.

of the factor input, and then, when its factor holdings are depleted, it enters the stage 2 factor market. Once in the factor market, the stage 1 firm randomly frequents a stage 2 firm to try to obtain the necessary inputs to be able to satisfy its customer. If the stage 1 firm is unable to obtain the input from the stage 2 firm, then the stage 1 firm is unable to satisfy the demand of the customer. This customer returns home dissatisfied. As discussed in Section 3, customers have preferences, which firms recognize, between the price of the good and the probability of obtaining that good. For any given level of factor holding by the stage 1 firms, we can imagine the stage 1 and stage 2 firms competing in their respective markets on the price and probability of satisfaction until each market reaches the competitive equilibrium described in Section 3.

The important feature of this market structure is that the amount of the factor input that stage 1 firms decide to hold affects the stochastic nature of the demand that stage 2 firms see. Vertical integration by stage 1 firms affects the risky environment in which stage 2 firms operate.

5. Issues Associated with Firm Interaction Under Uncertainty

Now that the model of the transmission of uncertainty between the stage 1 and stage 2 markets has been described, we can state more clearly the issues that we wish to examine. The decision of stage 2 firms about how much of the input to produce affects the probability that a stage 1 firm will be able to obtain the input and produce the final product. If a stage 1 firm becomes dissatisfied with the operating policy of stage 2 firms, the stage 1 firm can produce some of the input for itself, and itself bears the risk of having unsold input at the end of the market period. The decision of stage 1 firms to produce some of the input for themselves and bear the risk of having unsold input, affects the entire stochastic structure of demand that the stage 2 firms will see, and hence influences the equilibrium that is reached in the stage 2 market[1] which, in turn, influences the equilibrium that is reached in the stage 1 market.

Firms in each market compete amongst themselves until equilibrium is reached in the manner described in Section 3. Therefore, we know that in the equilibrium in both the stage 1 and stage 2 markets, each firm's operating policy reflects the preferences of its customers, and that the prices reflect the probability of obtaining the good. The important question to ask is whether, under competition, firms are forced to take into full account the effect of their operating policies on the transmission of uncertainty to other markets. What happens to the welfare of consumers as final product firms produce some of the factor input for themselves and themselves bear the risk of having unsold input? From the consumers'

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[1] Recall from Section 3, that the stochastic structure of demand affects the operating cost of firms.

point of view, is there some preferred allocation between the stage 1 and stage 2 firms for producing the input and bearing the risk of having unsold inputs? Do the incentives under competition lead firms to adopt this preferred market structure, or, are the incentives under competition perverse, and discourage firms from adopting the preferred operating policies? If competition does not lead to the preferred market structure, how does the competitive equilibrium differ from the preferred one? If suddenly a new technique for producing the output becomes available, is it more likely to be adopted when the market structure is integrated or nonintegrated?

6. Private Incentives for Vertical Integration

The way the market operates, there are basically two offsetting considerations involved in the decision of a stage 1 firm to produce a unit of input for itself.

First, since it costs only c per unit to produce the input, the stage 1 firm will save (p_{int} - c) by producing the input itself rather than buying it on the factor market at price p_{int}. (Recall that it is a characteristic of markets that operate under uncertainty that the equilibrium price exceed the cost of production.) In other words, if the stage 1 firm produces the input itself, then the firm assures itself of having the necessary input to make a more profitable sale, if demand should materialize. Offsetting this saving is the potential risk that the input will be produced at cost c, but will not be used because of insufficient demand. By producing the input for itself, the stage 1 firm bears the risk of the unsold input, while when the stage 1 firm relies on the factor market for the input, it is the stage 2 firms who bear this risk.

Let us now consider whether there is any incentive for stage 1 firms to produce the input at all. Suppose that stage 1 firms produce none of the factor input and rely entirely on the stage 2 markets for the input. Imagine that the stage 1 and stage 2 markets have reached equilibrium in the manner described earlier. By the conditions of market equilibrium, expected profits are zero in each market.

There will definitely be an incentive to vertically integrate if the expected profit is positive when a stage 1 firm holds enough input to satisfy one customer when evaluated at the equilibrium associated with

no vertical integration. It is straightforward[1] to calculate the profit functions, and to derive the condition that there will definitely be an incentive to vertically integrate if

$$[1 - Pr(0)]\ p_{int} > c\ , \text{ where}$$

$[1 - Pr(0)]$ = probability that at least one customer frequents the stage 1 firm,

p_{int} = price of the intermediate product when purchased in the stage 2 market, and

c = cost of producing the input.

This inequality is intuitively plausible. If a stage 1 firm decides to stock one unit of input, its cost increases, with certainty, by c. Its expected savings from not having to go into the factor market for that one unit of input is $[1 - Pr(0)]\ p_{int}$. When savings exceed costs, the stage 1 firm will hold the factor input.

It is possible to simplify this inequality. Since the random process is binomial with probability $\frac{1}{N_1}$, and size L, we have that $[1 - Pr(0)] = 1 - (1 - \frac{1}{N})^L \doteq 1 - e^{-L/N_1}$. Therefore, we can write that there will definitely be an incentive for vertical integration if

$$(1 - e^{-L/N_1})\ p_{int} > c\ . \qquad (1)$$

It is clear from the inequality (1), that for fixed L,[2] the inequality is more likely to hold the smaller is the number, N_1, of stage 1 firms.

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[1]See Appendix 1.

[2]It is not possible to determine whether (1) is more likely to hold as the number of customers increases to infinity. As $L \to \infty$, $1 - e^{-L/N_1} \to 1$ so incentives to vertically integrate increase. However, as $L \to \infty$, $p_{int} \to c$, so disincentives also increase. Which effect will predominate depends on the specific slope of the isoutility curves.

Equivalently, for a fixed number of customers, L, the inequality is more likely to hold as the customer per store ratio L/N_1 becomes larger.

This last result emphasizes the importance of examining the uncertainty in the market clearing process. Earlier, it was mentioned that for large customer per firm ratios, the market equilibrium under uncertainty approached that under certainty at least percentagewise. In such a case, one might have thought that the deterministic analysis which ignored the uncertainty in the market would suffice, and the more complicated analysis which explicitly considered the uncertainty was unnecessary. What we see here though is that it is precisely the case of having a large customer per firm ratio in stage 1 markets that can lead to strong incentives for vertical integration. A deterministic analysis of this market structure would have been unable to find any incentives or disincentives for vertical integration to occur.

The implications of (1) are disturbing. For <u>any</u> value of L/N_1, we know that incentives for vertical integration can exist since it is always possible to choose a set of preferences which yield an equilibrium p_{int} such that the inequality holds. Moreover, for even small values (e.g., 20) for the customer per firm ratio, L/N_1, $1 - e^{-L/N_1} \approx 1$, so that the inequality will hold provided $p_{int} > c$. But, by the earlier discussion, we know that the equilibrium price in an uncertain market must always exceed its cost, since it is necessary that price not only cover per unit production costs, but also the production cost of unsold goods. Hence, we expect there to be strong incentives for vertical integration.

The incentives for vertical integration come about because the stage 1 firms base their decisions to integrate on the <u>marginal</u>, not

average, probability of using an additional input. The way the markets operate, the price of the factor in the stage 2 market reflects not only the cost c of producing the input, but also the average probability of not being able to sell that input. When a stage 1 firm is deciding whether to hold one unit of the input itself, it is not concerned with the average probability of being unable to use any unit of input. Rather, since the stage 1 firm will use its input holdings first, the stage 1 firm is concerned with the probability of being able to use that first unit of input. For even low to moderate values of the customer per firm ratio in stage 1 markets, L/N_1 (e.g., 15-20), this probability is practically 1 (i.e., each stage 1 firm is virtually assured of being able to use up its one unit of input), so that (1) will almost certainly hold since the price of the stage 2 factor, p_{int}, exceeds c. It is precisely because stage 1 firms can use their own input to satisfy their "high probability" demand and use the stage 2 market to satisfy their "low probability" demand that incentives for vertical integration occur. The conclusion of this analysis is that it is quite likely that there will exist strong private incentives for vertical integration to occur.

7. Social Consequences of Vertical Integration

Having established strong private incentives for at least some vertical integration to occur, we now investigate the welfare consequences of vertical integration. It is useful to keep in mind that there are two distinct welfare issues involved. First, as mentioned earlier, markets under uncertainty are not Pareto-efficient in the absence of insurance markets, and usually lump sum subsidies are required to achieve optimality. The second issue is whether a vertically integrated market structure is superior to a nonvertically integrated one, whether or not lump sum subsidies are paid. It is this second issue that we now address.

If all firms within any stage behave identically, then there is always a higher probability that a unit of the factor input will be used if it is held in a stage 2 rather than a stage 1 firm. Stated in another way, since the number of stage 1 firms exceeds the number of stage 2 firms, a unit of the factor will be more frequently used if it is given to a stage 2, and not a stage 1, firm, From this simple observation, we can obtain the following.

Theorem 1: Any market structure involving vertical integration achieves a lower level of expected utility than can a market structure involving no vertical integration.

The reasons why Theorem 1 is true can be explained intuitively as follows.[1] The number of final product stage 1 firms exceeds that of factor input stage 2 firms. Therefore, stage 2 firms are more efficient absorbers

[1]An analytic proof appears in Carlton, op. cit.

of risk in the sense that stage 1 firms would have to hold more of the input than stage 2 firms in order to satisfy the same fraction of the population. Although holdings of the input by stage 1 firms reduces the demand seen by stage 2 firms, this reduction in demand is not great enough to offset the inefficient risk absorption by stage 1 firms. Therefore, stage 2 firms must decrease their input holdings by less than the amount that stage 1 firms increase their input holdings, if the same fraction of the population is to be satisfied. So, when stage 1 firms produce any input for themselves, more total input in the system must be produced or the fraction of customers who are satisfied will decline. To satisfy any given fraction of consumers, market structures involving vertical integration will have higher input costs than those involving no vertical integration. Since competition insures that cost savings are passed on to consumers, it follows that consumers can always be made better off whenever there is any vertical integration in the system.

Theorem 1 can be heuristically explained in terms of sharing. Consider the following example. There are two bakeries, side by side, and 100 customers who each day randomly frequent one bakery and buy one loaf of bread. If the bakeries are willing to share their production of bread with each other, then only 100 loaves need be produced to satisfy the entire population. If the bakeries refuse to share (or else if it is costly to share) with each other, then each bakery must produce 100 loaves of bread to be sure to satisfy the customer population. Sharing allows 100, instead of 200, loaves to suffice. Exactly analogous reasoning applies to vertical integration. When stage 1 firms produce the input for themselves, they in effect do not share it with other stage 1 firms.

However, when all stage 1 firms rely on stage 2 firms for the factor input, they are essentially "sharing" from common resource pools. Since insurance-like costs can always be lowered when no sharing is taking place, vertical integration can impose unnecessary costs on society.

8. Equilibrium Market Structure

Let us now turn to a discussion of the equilibrium market structure. We say that a market structure is in equilibrium if at the current level of vertical integration, stage 1 firms have no incentive to alter the amount of input that they produce for themselves, and if the stage 1 and stage 2 markets are equilibrating in accordance with the principles discussed earlier of how markets clear under uncertainty. There are basically 3 types of possible equilibrium market structures. First is the case of no vertical integration. The second and third types of market structures both involve vertical integration. We call the second type of vertical integration, partial vertical integration. As its name suggests, in this market structure, stage 1 firms are vertically integrated, but still rely on stage 2 markets to provide some inputs. The third type of market structure is that of complete vertical integration, in which each stage 1 firm relies only on itself for its supply of the input and the stage 2 market disappears completely.

If the equilibrium market structure is of the type involving incomplete vertical integration, then the stage 2 market acts like an insurance market for supplying the factor input to the stage 1 market. To see this last point, notice that whenever a stage 1 firm makes a sale of a final product, it makes a higher per unit profit when it is able to use its own input (produced at cost c) in the manufacture of the final good rather than when it uses an input purchased on the stage 2 market at a price p_{int} (which exceeds c). A stage 1 firm continues to enter the stage 2 market simply because it needs to satisfy its customers. It is cheaper for a

stage 1 firm to satisfy its customer through use of the high price stage 2 market, rather than produce extra input for itself and bear the risk that the unit of input will go unsold.

9. The Consequences of Vertical Integration on Market Equilibrium

In this section, we examine how the market equilibrium is affected when the equilibrium market structure involves some vertical integration. How does the market equilibrium with vertical integration compare to the market equilibrium when vertical integration is not allowed? From Theorem 1, we already know that, compared to the expected level of utility achievable in a competitive equilibrium with no vertical integration, the expected level of utility is lower in any market structure involving vertical integration. Since vertical integration lowers the maximum expected level of utility, it is possible that the level of utility could be driven so low that consumers would prefer not to enter the stage 1 market. Thus, one consequence of vertical integration can be to drive output markets out of existence. Having mentioned this possibility, we shall concentrate in the subsequent analysis on the effects of vertical integration when the markets under study remain in existence.

The questions we ask are whether the price, p_f, of the final product, the price, p_{int}, of the factor sold in the stage 2 market, and the probability of satisfaction, $1 - \lambda$, are higher or lower in a vertically integrated market structure than in a market structure in which vertical integration is not allowed. This section states the main results and provides explanations for them. The reader interested in the technical proofs is referred to Carlton, op. cit.

Suppose that the equilibrium market structure involves complete vertical integration. Under a plausible assumption on preferences,[1]

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[1] footnote on next page

[1]The assumption is analogous to the assumptions of "normal" goods in economic theory. We assume that if the customer per firm ratio increases so that the consumers are offered a better "menu" of price-probability of satisfaction combinations, then the consumer will prefer a combination in which he is made better off in both dimensions. (As the customer per store ratio increases, the zero profit curve, used to define equilibrium, shifts up so that consumers are faced with a better set of price-probability of satisfaction choices.) In other words, the consumer will choose a combination with a lower price and higher probability of satisfaction. This assumption appears very reasonable since it is possible to prove (see Carlton, op. cit.) that as the customer per firm ratio increases, the market equilibrium price approaches its minimum possible value of c, and the probability of satisfaction approaches its maximum value of one. Hence the consumer must be made better off in terms of both the price and probability of satisfaction for sufficiently large increases in the customer per firm ratio. To see the analogy of the above assumption to consumer theory, note that we usually assume that a consumer in a two good world would increase his consumption of both goods in response to an increase in income (i.e., as his "menu" between the two goods improves). We also make an assumption that the isoutility curves are of such a shape that multiple tangencies (i.e., multiple equilibrium) with the zero profit curve do not occur.

it is possible to establish that the market equilibrium with complete vertical integration involves a higher price and lower probability of satisfaction than does the market equilibrium with no vertical integration. Stage 1 firms are less efficient absorbers of risk than stage 2 firms in the sense that stage 1 firms with complete vertical integration have to spend more resources on production of inputs than do stage 2 firms, with no vertical integration, to satisfy any given fraction of the population. The final price to the consumer has to rise to cover this increased cost of operation in the case of complete vertical integration. Moreover, because stage 1 firms cannot satisfy customers as efficiently as stage 2 firms, the equilibrium probability of shortage in the case of complete vertical integration rises from its value in the market equilibrium when vertical integration is not allowed. From these two results, it also follows that the total amount of the output that is purchased is lower in the case involving complete vertical integration than in the case involving no vertical integration, provided per capita demand depends negatively on price.

Suppose now that the equilibrium market structure involves partial vertical integration. The main result is that the price of the input purchased in the stage 2 market is higher in the case involving partial vertical integration than in the market equilibrium when no vertical integration is allowed. This result follows from the fact that in the case of partial vertical integration, the stage 2 markets become "riskier"[1]

[1]"Risk absorbing" efficiency is inversely related to the customer per firm ratio. When stage 1 firms produce some of their own input, the stage 2 firms see less than L customers, so that the customer per firm ratio of stage 2 firms falls from its value in the case of no vertical integration.

and the stage 2 firms become less efficient absorbers of risk than they were in the case of no vertical integration. This inefficiency results in increased costs to stage 2 firms. To cover their increased costs, the stage 2 firms have to raise their prices to the stage 1 firms. Surprisingly, it does not appear possible to prove that the stage 1 firms pass this increased cost along to the consumer in terms of higher prices for the final good. It seems possible, though I suspect unlikely, that with partial integration, the price of the stage 2 input could rise, but the price of the final good could fall. In this case, we know from Theorem 1 that the probability of satisfaction would have to fall sufficiently so that consumers are worse off in the case of partial vertical integration than in the case of no vertical integration.

In summary then, any market structure involving vertical integration provides a lower level of utility to consumers than can a market structure involving no vertical integration. Any vertical integration causes an inefficiency in the ability of firms to absorb risk, and usually will result in higher prices in the input market. When the equilibrium market structure involves complete vertical integration, we expect that both the probability of shortage and the price of the final good will rise from their equilibrium values in the case when integration is not allowed.

10. Market Structure and the Choice of the Output Technology

In this section we examine how market structure and the transmission of uncertainty between firms can influence the choice of technology. So far, we have assumed that there is only one technology to produce the output, namely a Leontief technology which uses K units of capital and one unit of the input subject to shortages to produce one unit of output. Now we will assume that there suddenly becomes available a new Leontief technology with input requirements (K_1, ℓ). We examine the incentives for introduction of the new technology in a nonintegrated and integrated market setting. The main conclusion of this section is that introduction of a new technology that would benefit society is more likely to occur in a market with vertical integration than in one without vertical integration.

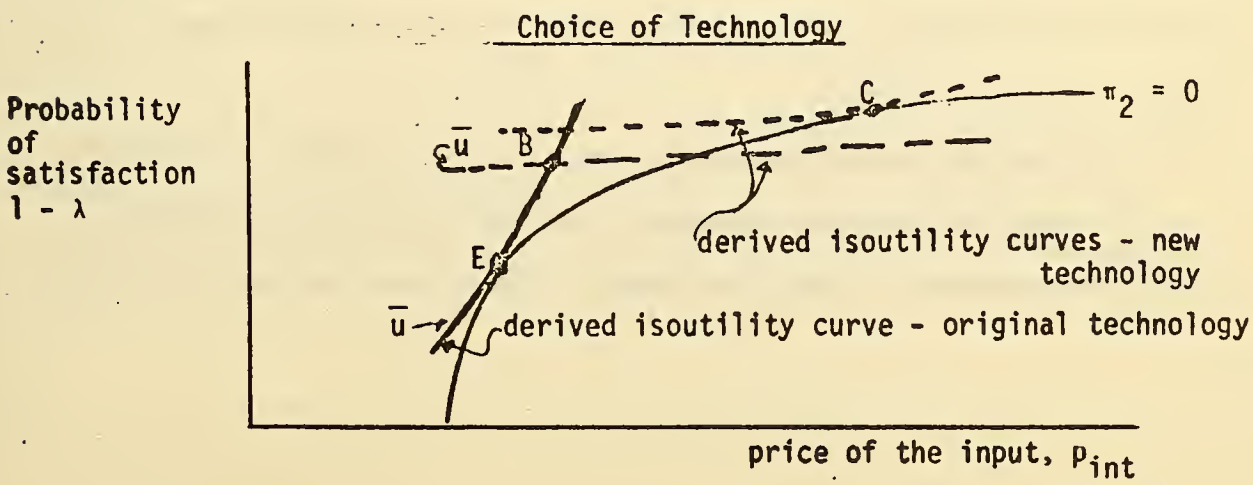
In the discussion of market clearing, it is useful to introduce the concept of a "derived" isoutility curve. A derived isoutility curve reflects trade-offs between the price of the input and the probability of obtaining the input that translate (through the stage 1 zero profit condition) into trade-offs that the consumer is willing to make between the price of the final good and the probability of obtaining the final good. A simple example is the best way to illustrate this concept.

Consider the case of no vertical integration. Assuming Leontief technology with coefficients (K,1), the zero profit condition for stage 1 firms is simply $p_f = rK + p_{int}$, where p_f is the price of the final good, p_{int} is the price of the input sold on the stage 2 market, and r is the price of capital. Preferences of consumers are represented by $u(1 - \lambda, p_f) = \bar{u}$. Substituting in for p_f from the zero profit condtion,

we find that $u(1-\lambda, rK + p_{int}) = \bar{u}$ now expresses the consumer trade-offs in $(1 - \lambda, p_{int})$ space. Equilibrium in the stage 2 market is determined by the tangency between this derived isoutility curve and the stage 2 zero profit curve.

The important feature about derived isoutility curves is that their shape will be influenced by the input-output coefficients of the technology. So, for example, if we had a new technology (K_1, ℓ) where $\ell < 1$, any increase in p_{int} would translate into a smaller price increase in p_f than it would if $\ell = 1$. In this case, the derived isoutility curves would become flatter than they are in the case of $\ell = 1$. We will refer to the original (K,1) technology as the "original" one, and the (K_1, ℓ) technology as the "new" one.

First, consider the market equilibrium that would occur if vertical integration is not allowed. Let the equilibrium factor price be p°_{int}. The stage 1 firms will adopt the new technology <u>only if</u> it is more efficient when the price of capital is r and the price of the input is p°_{int}. But this marginal calculation is not sufficient to guarantee that consumers would not be better off under the new technology. The diagram below illustrates this point.



Point E is the original market equilibrium. The derived isoutility curve through point E is drawn using the input-output coefficients of the old technology. The level of utility achieved by consumer along this curve is $\bar{u}$. The derived isoutility curve, corresponding to the same $\bar{u}$ when the input-output coefficients of the new technology are used, is drawn as a dotted line. The fact that the dotted curve passes above point E is equivalent to the statement that the new technology is less efficient than the old technology at the factor price associated with point E. The two derived isoutility curves cross at point B, where each technology is equally efficient (i.e., $p^B_{int} + rK = \ell p^B_{int} + rK_1$). Beyond point B, the new technology is more efficient. Notice that the dotted isoutility curve crosses the zero profit ($\pi_2 = 0$) curve. Therefore, there exists some point C of tangency between the derived isoutility curve with the new technology and the $\pi = 0$ curve that represents a level of utility above $\bar{u}$.

Consumers would be better off if all stage 1 firms adopted the new technology so that the market equilibrium would move to point C. Yet, because stage 1 firms have no control over the input market, they will not have any incentive to adopt the new technology, since it is inefficient at the initial market equilibrium E. The existing prices do not provide incentives for stage 1 firms to change technologies, nor for stage 2 firms to alter their behavior.

It is easy to see how vertical integration could remedy this situation. To make the point, it suffices to consider the case of complete vertical integration. Since each stage 1 firm totally controls its produc-

tion of the input, it can coordinate its $(p_{int}, 1 - \lambda)$ mix[1] to its own specifications. Because of this possibility of coordination, stage 1 firms will be able (and through competition will be forced) to move immediately to any achievable point that justifies the use of the new technology and makes consumers better off.

It is precisely because vertically integrated firms can exercise control over the characteristics $(p_{int}, 1 - \lambda)$ of the input, that they are able to introduce the new and more desirable technology. With no vertical integration, price signals are not sufficient to convey the benefits of switching to the new technology. The reason is that whether consumers would be better off if all stage 1 firms adopted a new technology is a nonmarginal change. In this case, marginal incentives at the firm level do not give the correct signals as to whether the nonmarginal change is desired. Equivalently, in a competitive market, marginal incentives are not always sufficient to insure that equilibrium is at a global optimum.[2]

In general, when the choice of technology affects the equilibrium characteristics (e.g., price, probability of satisfaction) of the input which, in turn, influence the choice of technology, then it is not necessarily true that the individual decisions by firms will lead to the correct

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[1] In the case of complete vertical integration, the stage 1 firms effectively act as stage 2 firms since they produce their own input.

[2] i.e., if input firms "experiment" by moving marginally around the initial equilibrium, they are driven back to the initial equilibrium. The reader should notice that there is nothing in this section that uses the fact that there is uncertainty in the market. The conclusion is the general one that vertical integration can be one way of remedying a market failure that occurs when marginal and global incentives differ.

technology being adopted. In such cases, existing prices need not provide the correct signals for choice of a new technology. In the model of this paper, vertical integration is a mechanism by which individual firms can gain control over the two characteristics (i.e., price and probability of satisfaction) of the input that influences its choice of output technology. The final product firm that is vertically integrated is thereby better able to coordinate its choice of output technology with the characteristics of the input. With the flexibility of tailoring the input characteristics to its needs, the vertically integrated firm may introduce the new more desirable technology, while the nonintegrated firms who must take the input characteristics as given in the marketplace may get locked into the old technology and have no incentive to change production technologies.

In markets characterized by uncertainty, Theorem 1 proved that vertical integration can be socially undesirable. A more efficient market structure will usually involve no vertical integration. However, socially desirable technologies are more likely to be developed and introduced in a market structure involving vertical integration in which individual firms can coordinate input characteristics with their choice of technology, than in a market structure involving no vertical integration in which such individual firm coordination is impossible. We are led to the Schumpeterian view of the world that it may be necessary to tolerate some static inefficiency in market structure in order to create an environment in which socially desirable technologies can be developed and introduced.

11. Horizontal Merger and Social Welfare

Since the number of stage 1 and stage 2 firms is exogenous to this form of the model, one has to be very cautious about welfare interpretations when the number of firms change. One important caveat associated with the model deals with the implications of horizontal merger. In the model, it appears that the utility of consumers increases as the number of stage 2 firms declines to one. One has to be careful to avoid the inference that for the markets under study total horizontal integration of stage 2 firms is always desirable. The model is designed to study the transmission of uncertainty between firms in a competitive environment. However, large horizontal mergers could create monopoly power which by itself entails social costs. Horizontal integration may be desirable from the point of view of risk sharing (which is what the model is designed to focus on), but undesirable from the point of view of creating monopoly power. Whether there are any private incentives for horizontal merger to occur is an altogether different question. As discussed in Carlton, op. cit., it is possible to envision situations where there will be no incentives for horizontal mergers. Possible situations are when a) demand is spatially random so that merger at one place can reduce demand, b) there exist costs to merger, c) horizontal merger is legally prohibited. Moreover, as we shall soon see, the incentive for horizontal integration is not necessarily a natural feature of markets in which random demand creates incentives for vertical integration.

This paper has shown how a nonintegrated competitive market structure can be socially preferred to an integrated one. However, it is not true, for the model under discussion, that the nonintegrated market structure

is socially optimal. As mentioned earlier, when dealing with markets under uncertainty, in the absence of insurance markets the social optimum can involve paying lump sum transfers to the firms producing the good subject to shortages. Therefore, the socially optimal solution would be to have a nonintegrated market structure and usually to pay lump sum subsidies to the stage 2 firms. These subsidies would usually be used to encourage the stage 2 firms to expand production of the input that is subject to shortages.

12. Extensions, Interpretations, Evaluation

It is easy to extend the model to the situation where the stage 2 input can be sold to demanders who are not stage 1 firms. The incentives for vertical integration diminish as the stage 2 market expands (since p_{int} approaches c, and $1 - \lambda$ approaches 1). The incentives increase if the demanders of the stage 2 input have very different preferences than stage 1 firms. In general, we expect firms to be less likely to vertically integrate when they form a small part of the total demand for an input.

It is straightforward to interpret the "input" in the model as either capital or labor. The decision to vertically integrate then corresponds to decisions about labor or capital "hoarding" to insure that demand, if it materializes, can be met. The assumption that vertically integrated firms do not sell their inputs on the stage 2 market can be thought to correspond to either fixed contracts with no recontracting markets, or to the fact that it does not seem to occur frequently that firms would sell their capital or laborers to someone else within a market period.[1]

It is useful to point out that there is no distinction in the model between "long-term" contracts[2] at price c and in-house production at cost c. Clearly vertical integration can occur by either mode. As Williamson (1971) argues, uncertainty about supplier reliability or

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[1] For a treatment of labor hoarding along these lines, see R.E. Hall, "An Aspect of the Economic Role of Unemployment", Proceedings of the International Economics Association, April, 1975.

[2] A "long-term" contract is a one period contract that states that an output firm will accept delivery of a certain amount of input from an input firm.

other types of transaction costs can explain why in the real world vertical integration often takes the form of in-house production, and not long-term contracts. Notice that this consideration of which form vertical integration should take is much different from the issues studied in this paper of whether there is an incentive for vertical integration (whether by long-term contract or in-house production) to occur at all.

A belief in perfect competitive markets leads one to the conclusion that vertical integration does not have any desirable or undesirable features. A belief in competitive markets which possess the demand uncertainty and price inflexibility discussed earlier leads one to very different conclusions, as the simple model just presented illustrates. Which of the two views of competitive markets is appropriate will depend on the particular industry under study.

Sometimes models can be misleading because of the apparent simplicity or form of their assumptions. Let me now restate the four key features of the markets under study in an effort to distinguish the features that are important from those that are merely analytically convenient.

First, firms must never feel they can either buy or sell all they want at the going market price. In the model, the corresponding assumption was that firms faced demand and supply uncertainty. Not allowing firms to trade among themselves or allowing recontracting markets to develop was one simple way to characterize this "friction" in the market. Clearly, the qualitative features of market operation are unchanged if we allow firms to trade a "little" among themselves - while if firms trade "a lot" among themselves (i.e., recontracting markets exist), then we get right back to a perfect competitive market.

The second main feature of the markets under study really follows from the first feature. We require that there be some risk in any period that resources will not be fully utilized. The impact of this statement is that for many markets some unemployment of resources is a natural consequence of market operation.

The third feature involves the differential risk that a vertically integrated firm can impose between the use of its own inputs and the inputs of a factor market firm. Because a firm will always choose to use its own inputs first, there is always a higher probability that a firm will use a unit of its own input than a unit of input that factor market firms hold.

The final feature of the markets under study is that a vertically integrated firm be somehow less able than a factor market to satisfy input demands of other firms. In the model, we capture this feature by the (somewhat extreme) assumption that vertically integrated firms do not provide inputs to other firms. Clearly, once again, the qualitative results would be unchanged if we let vertically integrated firms do "some" selling on the input market. We know that for some industries such trading does occur, while for others it very rarely occurs, presumably for the transaction cost argument given in Section 4. The real question of course is how much trading occurs. If there is "a lot" of trading, then once again, we approach a perfect input market and we come back to the classical view of vertical integration. On the other hand, if vertically integrated firms will incur the necessary transaction cost and sell their inputs (or equivalently use their unused capital to produce inputs) to other competitors only if the firm feels that it miscalculated and has little immediate hope of using that input in satisfying the demand for its final product,

then we are driven to the view of vertical integration that this paper presents.

It is important to stress what features of the model are not important and are designed only to make the model easy to use. First, the total industry demand need not be fixed. All that is required for the results of the model is a random per firm demand, which is certainly implied by a random industry demand. Second, the welfare implications of the model derive from the assumption that vertically integrated firms cannot satisfy input demand as efficiently (from a risk sense) as input firms. The assumption that the number of stage 1 firms, N_1, exceeds the number of stage 2 firms, N_2, is a convenient way of capturing this feature in the simple model. (Notice that in the simple model if N_1 is less than N_2 then the factor market can never exist, and the simple model becomes uninteresting.) This assumption about the relative magnitudes of N_1 and N_2 is not meant to be an assumption about the relative numbers of establishments in each stage, but rather to be an assumption about the relative ability of each stage to absorb risk. Clearly, an alternative model which can lead to identical welfare conclusions is to have the factor market able to satisfy input demanders from other sectors of the economy while vertically integrated firms could not. This alternative model could postulate that each output firm obtained some share of total random demand.[1] The input firms then obtain some share of random derived demand. Moreover, there are other sectors of the economy whose demand for input is also random and uncorrelated with the random input demand

[1]To preserve the competitive environment, we simply require that the share of demand depends on the utility level offered. As in all competitive equilibria, if a firm does not offer the best deal (i.e., highest utility level) its demand goes to zero.

of the output industry under study. (To avoid complications about externalities, postulate that output firms in all sectors have similar preferences and similar random demands.) Input firms can pool risks, while vertically integrated firms are, by assumption,[1] unable to. With this new model, we obtain identical insights as before into the incentives for and consequences of vertical integration. Notice that in this alternative model there are no incentives for horizontal integration.[2] As discussed earlier, incentives for horizontal integration are <u>not</u> a necessary consequence of market forces that produce incentives for vertical integration.

The simple model used in this paper has the advantage that it is simple enough to use analytically (for example to derive the incentives for vertical integration), and yet maintain the four key features of market operation mentioned above. Given these four main features of market operation, the strong incentives for vertical integration arise because of the differential risk that a vertically integrated and input market firm face. The undesirable welfare implications of vertical integration result because the vertically integrated firm is a less efficient satisfier of input demand than is an input firm. It is incorrect to interpret the model as saying that all vertical integration is inefficient. Rather the model shows that in a world of uncertainty there can exist very strong private incentives for vertical integration to exist, even in cases where such vertical integration may be socially undesirable.

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[1] The assumption that vertically integrated firms do not sell their input to other sectors of the economy is based on the same transaction cost type arguments as expressed in Section 4.

[2] I thank Paul Krugman for this observation.

The question then arises as to whether the incentives and consequences that this paper identifies are a significant feature of market operation. The answer to this question will obviously depend on the particular market under study. However, it does seem that the model fits in well with descriptive studies of individual industries.

In an in-depth study of the automobile industry, White[1] examines the reason why auto companies vertically integrate, and, most relevant for this discussion, provides a descriptive explanation of how risks motivate vertical integration. White's descriptive discussion echoes many of the points raised earlier.

We argued that vertical integration was a means of transferring risk between firms. White states ". . .integration is a two-edged sword. Though it reduces the risk of supply failure, it also converts variable costs into fixed costs - . . .More money is at stake,. . .the financial penalties of losses (that is, risks) have increased."[2]

We found that there would exist strong private incentives for vertical integration to occur, and identified the possibility for partial vertical integration. The strong incentives for vertical integration arise because the vertically integrated firm is able to satisfy its high probability demand by itself, and pass on the low probability demand to some other firm. We found that for the case of partial integration, the factor market acted as a type of insurance market for the final product firm, with the final product firm making less of a profit on any item that used a factor market input than on an item that used an internally supplied input.

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[1] L. White - The Automobile Industry Since 1945, Harvard University Press, Cambridge, Mass., 1971.

[2] ibid., p. 80

On these issues, White writes, "A way of reducing the risks of vertical integration is through partial or tapered integration: a company can produce a portion of its needs of an item and buy the fluctuating remainder. This has the advantage of providing full utilization of its own equipment and allowing the suppliers to absorb the risk of fluctuations in demand. The company has to pay a premium to get someone else to absorb the risks, the the risk transfer is achieved. In the case of a supplier failure, production of the final good does not have to cease. . ."[1] "Tapered integration plays a large role in the industry."[2]

Moreover, as mentioned at the outset of this paper, businessmen frequently say that they vertically integrated to obtain a more certain supply of inputs. Based on such statements and descriptive studies like White's, it does appear that the incentives identified in models of market behavior under uncertainty do exert a significant influence on market outcomes for certain industries.

The results of this research emphasize the importance of distinguishing between market clearing under certainty and under uncertainty. An analyst using a deterministic approach to this problem would be led astray and would be unable to find any desirable or undesirable incentives or disincentives for vertical integration. It is only by explicitly analyzing the effects of uncertainty on market behavior that the incentives and consequences of vertical integration can be fully comprehended.

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[1] White, op. cit., p. 80

[2] ibid., p. 83

Appendix 1

Let cost 2 = $rK + p_{int}$ and cost 1 = $rK + c$. Notice that cost 2 represents the cost of producing one unit of the final good when the factor input is purchased from a stage 2 firm at price p_{int}, while cost 1 is the resource cost when the factor input has been produced by a stage 1 firm at the price c, where c is less than p_{int}. Let $\pi(i)$ stand for the profits of a stage 1 firm when it holds sufficient input to satisfy i customers by itself. For the case of no vertical integration (i.e., i = 0) we have that

$$\pi_1(0) = [p_f - \text{cost } 2] \sum_{0}^{L} i \; pr(i) \cdot (1 - \lambda) \cdot x(p), \text{ where}$$

$pr(i)$ = probability a firm obtains i customers, and

$x(p)$ = per capita demand.

For the case where the stage 1 firm holds just enough of the input to satisfy one customer, we have

$$\pi_1(1) = [\sum_{i=1}^{\infty} [[p_f - \text{cost } 1] + [p_f - \text{cost } 2](i - 1)(1 - \lambda)] \; pr(i) - pr(0) \cdot c] \; x(p) .$$

The expression for $\pi_1(0)$ is simply the net revenue per unit times the expected number of goods that are sold. The expression for $\pi_1(1)$ is more complicated, and reflects the fact that if at least one customer appears, then the firm will be able to make a net profit on that customer of $[p_f$ - cost 1], and a net profit of $[p_f$ - cost 2] on each of the remaining customers. The term $pr(0) \cdot c$ reflects the risk that the firm will have spent c on production of the input, yet no customers will appear to use that input. Since $\pi_1(0) = 0$, it follows that p_f = cost 2, and that

$$\pi_1(1) = [[\sum_1^{\infty} pr(i)][p_f - \text{cost } 1] - pr(0)\cdot c]\ x(p), \text{ or}$$

$$\pi_1(1) = [[\sum_1^{\infty} pr(i)][\text{cost } 2 - \text{cost } 1] - pr(0)\cdot c]\ x(p), \text{ or}$$

$$\pi_1(1) = [[\sum_1 pr(i)][p_{int} - c] - pr(0)\cdot c]\ x(p)\ . \qquad (2)$$

There will be an incentive for stage 1 firms to hold the input if $\pi_1(1) > \pi_1(0)$, or if $\pi_1(1) > 0$, or if

$$[1 - Pr(0)]\ p_{int} > c\ , \qquad (3)$$

where $1 - Pr(0)$ = the probability that at least one customer will frequent any stage 1 firm.

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