VERTICAL INTEGRATION IN COMPETITIVE MARKETS UNDER UNCERTAINTY*

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I. 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 [11].

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.

It has always been somewhat of a mystery why businessmen, as well as researchers, so often conclude that the significant 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 (Carlton [2], [3], [4]), I have argued that most markets do not precisely fit the classical requirements that prices can fluctuate instantly to equate supply and demand or that buyers and sellers can always buy and sell all they want of the good. Although it is possible to ignore these complications and still understand certain types of economic behavior, it is the thesis of this paper that 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. In addition, 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.

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After a discussion of the previous thinking regarding vertical integration, the theory of a single competitive market under uncertainty is presented. Then, the effects of the transmission of uncertainty between different markets are examined. Focusing on this transmission, the analysis shows that vertical integration can be regarded as a means of transferring risk from one sector of the economy to another. 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 is shown that private incentives for vertical integration can exist even when 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 non-integrated firm. We are thereby led to a Schumpeterian 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.

II. 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 [5, p. 37], 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 large 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 . . .’. In studying Du Pont’s reasons for integrating General Motors, Chandler [5, p. 84] finds that ‘the need for assured supplies demanded increasing vertical integration’. Despite the frequency with which the argument about the need for assured supplies appears in historical studies of vertical integration, usually it is never explained why the factor supply is uncertain, or why an uncertain factor supply should create incentives for vertical integration.

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 [6] 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 [9] 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.’ Malmgrem argued that when prices do not reflect scarcity, vertical integration can occur. More recently, Williamson [11], [12] discussed how uncertainty can make it difficult to deal in a market, and could provide incentives for vertical integration.

Until very recently, there had been no attempt analytically to investigate the claims of the above authors as regards the effect of uncertainty on the incentives for vertical integration. Recently, two economists have sought to bridge this gap in the literature. Arrow [1] investigated the case where vertically integrated firms are able to obtain information about supply conditions earlier than the non-integrated firm. In a paper closely related in topic to this one, Green [7] showed that if rationing is possible in the factor market, then all firms would have an incentive to integrate fully. Green then went 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.

In the model of this paper, both output and input firms will face uncertainty in demand. The transmission of uncertainty from the product market to the input market will be an important feature of the model. Prices in each market will be endogenously determined and will be related to rationing frequency. The same input technology will be available to all firms, but firms will differ in their ability to sell the input.

III. MARKET BEHAVIOR WITH DEMAND UNCERTAINTY AND PRICE INFLEXIBILITY

Before developing a model of how markets interact under uncertainty, it is necessary briefly to present a theory of how a single market under uncertainty operates and how the equilibrium price is endogenously determined.¹

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

¹ For a fuller development of the theory, see Carlton [2], [3], [4].
unused or insufficient production capacity). Therefore, in this model, firms must 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 deliver at any particular time. When he goes to the firm, a buyer knows the probability of being able to purchase the goods 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.\(^2\) Consumer preferences can be represented by iso-utility curves in \((1 - \lambda, p)\) space, where \(1 - \lambda\) stands for the probability of obtaining the good, and \(p\) is the price. Iso-utility curves slope upward.

The amount of the good with which a firm begins the market period (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, \(p\), and the probability of satisfaction, \(1 - \lambda\). It is possible to draw iso-profit curves in \((1 - \lambda, p)\) space. Along the relevant portions, 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.

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 that offer the highest utility levels. Firms have an incentive to 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.\(^3\) Equilibrium for such markets is depicted in Figure 1 as a tangency between the zero profit curve \((\pi = 0)\) and an iso-utility curve \([\mu(1 - \lambda, p) = \bar{u}]\).

\(^2\) For simplicity, we assume no searching on the part of buyers and no inventory holdings on the part of firms. Provided that search and inventory holding are costly, the basic ideas of how markets operate under uncertainty would not be altered by their inclusion. 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 often do not observe such phenomena because of transaction costs.

\(^3\) For any given number of firms, equilibrium involves zero expected profits. The reason is that if the firms were earning positive profits, one firm would have an incentive to offer a slightly better \((1 - \lambda, p)\) mix and obtain the other firms' customers. Notice that there is no monopoly power caused by consumer ignorance since customers know firms' reputations. See Carlton [\(2\)] for fuller discussions.
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).

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.

IV. 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. 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

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4 This is the key assumption of the model.
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.\(^5\) 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 does not 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 better to assure itself of the supply of the input.\(^6\) Stage 1 firms cannot ship the factor input between themselves, nor can stage 2 firms for the same reasons as discussed in section III. As before, we assume re contracting 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 factor input

\(^5\) In a constant returns to scale world, the firm is indifferent between producing a given quantity of input for itself in advance and purchasing (in advance) that given quantity of input on a long-term contract at the constant production cost. With constant returns to scale and production lags, the only defining characteristic of a vertically integrated firm is that it bear the risk that input will not be sold. The question of whether there are incentives for vertical integration (either by long-term contract or in-house production) is the one this paper addresses. The question of which form (long-term contract or in-house production) vertical integration takes is a different question. Transaction costs (Williamson [11], [12]) can explain why in-house production may be the preferred mode of vertical integration.

\(^6\) Let me give one reason to illustrate why this assumption is plausible. 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 non-sharing 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 lumpy 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.

The idea that it would be fruitful to investigate the case where vertically integrated firms do not sell their input was suggested in Arrow [1]. The assumption of non-selling is discussed further in our conclusions. It does not affect the conclusion that vertical integration can be privately desirable but socially undesirable. The assumption is similar in spirit to Green's assumption that a vertically integrated firm has a less efficient production technology than a non-integrated one.
must be produced before its demand can be observed. The final product is produced (instantaneously) by a Leontief technology that requires $K$ units of capital and one 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. Prices of the final product and factor input are set before any demands are observed. Prices will be endogenously determined in accordance with the analysis of section III.

In order to illustrate most simply the effects of uncertainty we adopt the following model to represent stochastic demand to the firm. (The model is intended to be illustrative. Other more complicated and realistic stochastic processes of demand to the individual firm would lead to the same conclusions, but different formulae.) There are $L$ identical customers, $N_1$ stage 1 firms, and $N_2$ stage 2 firms with $N_2$ less than $N_1$. In each market period, each of the $L$ customers randomly frequents 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 input 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, 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 III, 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 III.

The key 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. An important question to ask is whether, under competition, firms are forced to take into full

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7 The assumption that $N_2 < N_1$ will ensure that stage 2 firms are more efficient at absorbing risk than stage 1 firms. Despite this comparative disadvantage, we will show that private incentives can encourage stage 1 firms to vertically integrate. We will then show that this vertical integration is socially undesirable. If we assume that $N_2 > N_1$, then stage 1 firms would be the more efficient risk absorbers. The private incentives identified in the subsequent analysis would lead to vertical integration that would benefit society. One point of the model is to show that private incentives for vertical integration can exist even when vertical integration is socially undesirable.

8 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.
account the effect of their operating policies on the transmission of uncertainty to other markets.\textsuperscript{9}

V. PRIVATE INCENTIVES FOR VERTICAL INTEGRATION

The way the market of this model 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 $(p_{\text{int}} - c)$ by producing the input itself rather than buying it on the factor market at price $p_{\text{int}}$. (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 integrate vertically 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\textsuperscript{10} to calculate the profit functions, and to

\textsuperscript{9}As mentioned previously, the conclusions developed below depend only on demand being random at the individual firm level. The model with fixed $L$, $N_1$, and $N_2$ is meant to be illustrative. It is one way to generate a simple stochastic demand process for the firm. It is not intended to suggest that having a fixed (non-random) total number of customers is in any way related to the question of vertical integration.

Another possible stochastic process is the Poisson. Demand to stage 1 firms is Poisson with parameter $\lambda_1$, and demand to stage 2 firms is Poisson with parameter $\lambda_2$, where $\lambda_2$ will depend on the amount of vertical integration. With no vertical integration $\lambda_1 < \lambda_2$ has the same content as $N_1 < N_2$ in the model in the text. Because a Poisson and binomial with small probabilities generate indistinguishable random demands to a firm, the model in the text can be reinterpreted as a Poisson one. Note that since the issues of total customer arrival being non-stochastic and the number of firms being discrete are simply not relevant for a Poisson process, they are surely not relevant for the model in the text. The binomial is used only to generate easy-to-use random firm demands. If the reader feels uncomfortable with the assumption in the text of discrete non-stochastic $L, N_1, N_2$, he can reinterpret all the results in terms of a Poisson process.

Section X discusses more fully the essential features of market operation that are required for the conclusions developed below to apply.

\textsuperscript{10}See Appendix. Note that the condition expressing the incentive for vertical integration is derived without making any assumptions about the specific probabilistic process generating demand. We now will use the binomial demand process presented earlier to obtain insights into the likelihood of the above inequality being true. The reader who postulates a different stochastic demand process would simply calculate $[1 - P_2(0)]$ and use it in the subsequent argument.
derive the condition that there will definitely be an incentive to integrate vertically if

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

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

\[ \varphi_{\text{int}} = \text{price of the intermediate product when purchased in the stage 2 market, and} \]

\[ c = \text{cost of producing the input.} \]

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

\[ [1 - Pr(o)] \varphi_{\text{int}}. \]

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 \(1/N_1\), and size \(L\), we have that

\[ [1 - Pr(0)] = 1 - (1 - 1/N) L \leq 1 - \exp(-L/N_1). \]

Therefore, we can write that there will definitely be an incentive for vertical integration if

\[ (1) \]

\[ \left[ 1 - \exp \left( \frac{-L}{N_1} \right) \right] \varphi_{\text{int}} > c. \]

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

The implications of (1) are disturbing. For any value of \(L/N_1\), we know that incentives for vertical integration can exist since it is always possible to choose a set of consumer preferences which yield an equilibrium \(\varphi_{\text{int}}\) such that the inequality holds. Moreover, for even small values (e.g. 20) for the customer per firm ratio, \(L/N_1\), \(1 - \exp(-L/N_1) \approx 1\), so that the inequality will hold provided \(\varphi_{\text{int}} > c\). 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 marginal, not average, probability of using an additional input. The way the markets operate, the price of the

\[ ^{11} \text{The reader should convince himself that for fixed } L \text{ and no vertical integration, } \varphi_{\text{int}} \text{ is independent of } N_1. \text{ It is not possible to determine whether (1) is more likely to hold as the number of customers increases to infinity. As } L \to \infty, \text{ } 1 - \exp(-L/N_1) \to 1 \text{ so incentives to vertically integrate increase. However, as } L \to \infty, \varphi_{\text{int}} \to c \text{ (Carlton [4]), so disincentives also increase. Which effect will predominate depends on the specific slope of the iso-utility curves that determine market equilibrium.} \]
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, \( p_{\text{Int}} \), 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.\(^{12}\) The conclusion of this analysis is that it is quite likely that there will exist strong private incentives for vertical integration to occur.

VI. 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, markets under uncertainty are not Pareto-efficient in the absence of insurance markets, and usually lump sum subsidies are required to achieve optimality (Carlton [2], [4]). The second issue is whether a vertically integrated market structure is superior to a non-vertically 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 as follows. The number of final product stage 1 firms exceeds that of factor input stage 2

\(^{12}\) Again, it is important to stress that these arguments for vertical integration apply for any random per firm demand. The case of binomial demand worked out in the text simply illustrates the strength of the incentives for one particular example.
firms. Therefore, stage 2 firms are more efficient absorbers 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 customers, market structures involving vertical integration will have higher total input costs than those involving no vertical integration. Since competition insures that cost savings are passed on to customers, it follows that consumers can always be made better off whenever there is any vertical integration in the system.

VII. THREE POSSIBLE EQUILIBRIUM MARKET STRUCTURES

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 as discussed in section III. There are three equilibrium market structures. The first one is no vertical integration. The second one is partial vertical integration, in which stage 1 firms are vertically integrated, but still rely on stage 2 markets to provide some inputs. The third one is 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.

With partial vertical integration, the stage 2 market acts like an insurance market for supplying the factor input to the stage 1 market. 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 can be 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.

VIII. THE CONSEQUENCES OF VERTICAL INTEGRATION ON MARKET EQUILIBRIUM

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, causing it to vanish. 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, \( p_{it} \), 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 [2].)

Suppose that the equilibrium market structure involves complete vertical integration. Under a plausible assumption on preferences, 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 produce more 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.

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13 See Carlton [2] for further details. 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 [2], [4]) 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 iso-utility curves are of such a shape that multiple tangencies (i.e. multiple equilibrium) with the zero profit curve do not occur.
Suppose now that equilibrium market structure involves partial vertical integration. The main result is that under appropriate assumptions (see Carlton [2]) 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' and the stage 2 firms become less efficient absorbers of risk than were they 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.

IX. 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 non-integrated and in an 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

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14 '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.
of a 'derived' iso-utility curve. A derived iso-utility curve reflects trade-offs between the price of the input and the probability of obtaining the input. These trade-offs 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 \(p_f = rK + p_{\text{int}}\), where \(p_f\) is the price of the final good, \(p_{\text{int}}\) 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 \(u(1 - \lambda, p_f) = \tilde{u}\). Substituting in for \(p_f\) from the zero profit condition, we find that \(u(1 - \lambda, rK + p_{\text{int}}) = \tilde{u}\) now expresses the consumer trade-offs in \((1 - \lambda, p_{\text{int}})\) space.\(^{15}\) Equilibrium in the stage 2 market is determined by the tangency between this derived iso-utility curve and the stage 2 zero profit curve \((\pi_2 = 0)\).

The important feature about derived iso-utility 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 \(l < 1\), any increase in \(p_{\text{int}}\) would translate into a smaller price increase in \(p_f\) than it would if \(l = 1\). In this case, the derived iso-utility curves would become flatter than they are in the case of \(l = 1\). 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 \(p_{\text{int}}^0\). The stage 1 firms will adopt the new technology only if it is more efficient when the price of capital is \(r\) and the price of the input is \(p_{\text{int}}^0\). But this marginal calculation is not sufficient to guarantee that consumers would not be better off under the new technology. Figure 2 illustrates this point.

\(^{15}\) More generally, for any given level of vertical integration, the probability of obtaining the input and the price of the input map one to one onto \((1 - \lambda, p_f)\) space. Preferences defined in \((1 - \lambda, p_f)\) space thereby induce 'derived' preferences in the space of probability of obtaining input and price of input.
Point E is the original market equilibrium. The derived iso-utility curve through point E is drawn using the input–output coefficients of the old technology. The level of utility achieved by consumers along this curve is $\bar{u}$. The derived iso-utility 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 iso-utility curves cross at point B, where each technology is equally efficient (i.e. $p_{int}^B + rK = lP_{int}^B + rK_1$). Beyond point B, the new technology is more efficient. Notice that the dotted iso-utility curve crosses the zero profit ($\pi_2 = 0$) curve. Therefore, there exists some point C (see figure 2) of tangency between the derived iso-utility curve with the new technology and the $\pi_2 = 0$ 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 production of the input, it can co-ordinate its $(P_{int}, 1 - \lambda)$ mix to its own specifications. Because of this possibility of co-ordination, 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. Whether consumers would be better off if all stage 1 firms adopted a new technology is a non-marginal change. In this case, marginal incentives at the firm level do not give the correct signals as to whether the non-marginal change is desired. Equivalently, in a competitive market, marginal incentives are not always sufficient to ensure that equilibrium is at a global optimum.\footnote{In the case of complete vertical integration, the stage 1 firms effectively act as stage 2 firms since they produce their own input.}

\footnote{That is, 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 remediying a market failure that occurs when marginal and global incentives differ.}
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 technology being adopted. With the ability to co-ordinate its choice of output technology with the characteristics of the input, the vertically integrated firm may introduce the new more desirable technology, while the non-integrated 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 proves that vertical integration can be socially undesirable. However, socially desirable technologies are more likely to be developed and introduced in a market structure involving vertical integration in which individual firms can co-ordinate input characteristics with their choice of technology, than in a market structure involving no vertical integration in which such individual firm co-ordination does not occur. 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.

X. 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. In the absence of price discrimination among input demanders, the incentives for vertical integration tend to diminish as the stage 2 market expands (since \( f_{\text{Int}} \) approaches \( c \), and \( 1 - \lambda \) approaches \( 1 \)—Carlton [4]). In general, firms are less likely to integrate when they form a small part of total demand for the input since they would lose the risk pooling economics of large markets as they integrate. However, the incentives can increase if the other demanders of the stage 2 input have very different preferences and/or a riskier demand distribution than stage 1 firms. For example, vertical integration can become attractive when the other input demanders have high variability in their input demand and thereby drive up the input price. In this last situation, vertical integration becomes one mechanism to escape the costs that someone else’s variability of demand imposes on the market.

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 ensure 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 reflect the existence of either fixed contracts with no recontracting markets or firms who do not sell their
capital or laborers to someone else within a market period because of transaction costs.\textsuperscript{18}

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 never feel they can either buy or sell all they want at the going market price. In our model, the corresponding assumption is that firms face demand and supply uncertainty. Not allowing firms at the same stage to trade among themselves or allowing recontracting markets to develop is 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 assumption that $N_2 < N_1$ and by the (somewhat extreme) assumption that vertically integrated firms do not provide inputs to other firms. We have already mentioned (p. 195, n.7) that when $N_1 < N_2$, the private incentives for vertical integration (see section V) ensure complete vertical integration which for this particular case is socially desirable. As long as $N_1 > N_2$, the qualitative results of the model would be unchanged if we let vertically integrated firms do ‘some’ selling on the input market. We know that for some industries such trading

\textsuperscript{18} For a treatment of labor hoarding along these lines, see Hall [8].
does occur, while for others it very rarely occurs, presumably for the transaction cost argument given in section IV. The real question, of course, is how much trading occurs. If there is a lot of trading at flexible prices, then again, we approach a perfect input market and we come back to the classical view of vertical integration.\textsuperscript{19} On the other hand, if transaction costs to a vertically integrated firm are high, so that a vertically integrated firm will incur the necessary transaction cost and sell its inputs (or equivalently use its unused capital to produce inputs) to other competitors only if the firm feels that it has sizably 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. To obtain the conclusions of the model, all that is required 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 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 one which has the factor market able to satisfy input demanders from other sectors of the economy while vertically integrated firms cannot. This alternative model could postulate that each output firm obtains some share of total random demand.\textsuperscript{20} 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 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,\textsuperscript{21} unable to. With this new model we obtain the

\textsuperscript{19} If we maintain the assumption of non-instantaneous price adjustment but allow vertically integrated firms to sell their input, then the first three market features described above guarantee that there will be complete vertical integration for the reasons discussed in section V. Such a market structure may or may not be socially preferable to the non-integrated one. For $N_1$ much larger than $N_2$, the non-integrated market structure will definitely be preferred. For $N_1$ less than $N_2$, the integrated market structure will be preferred.

\textsuperscript{20} 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.

\textsuperscript{21} 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 IV.
identical insights into the incentives for and consequences of vertical integration. Notice that in this alternative model there are no incentives for horizontal integration. Incentives for horizontal integration are not a necessary consequence of market forces that produce incentives for vertical integration.

The model used in this paper has the advantage that it is simple enough to use analytically and yet maintains the four key features of market operation mentioned above. Given these 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 and that these incentives can exist, even in cases where such vertical integration may be socially undesirable.

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 [10] 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 [10, p. 80] 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.’

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

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22 I thank Paul Krugman for this observation.
23 Indeed, if $N_1 < N_2$, vertical integration is socially desirable and will occur for the reasons identified in section V.
24 It is important to recognize that this statement remains unaffected if we relax the fourth feature and allow vertically integrated firms to sell their input (see footnote 19). The assumption about non-selling of input is made because it is realistic for many markets, and it allows us to develop insights into the possible consequences of partial vertical integration.
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.

On these issues, White [10, p. 80] 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, but the risk transfer is achieved. In the case of a supplier failure, production of the final good does not have to cease...’ ‘Tapered integration plays a large role in the industry’ [10, p. 83].

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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APPENDIX

Let cost \( 2 = rK + \hat{p}_{\text{int}} \) and cost \( 1 = rK + \hat{c} \). 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 \( \hat{p}_{\text{int}} \), while cost \( 1 \) is the resource cost when the factor input has been produced by a stage 1 firm at the price \( \hat{c} \), where \( \hat{c} \) is less than \( \hat{p}_{\text{int}} \). Let \( \pi_1(i) \) 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

\[
\pi_1(0) = (p_f - \text{cost } 2) \sum_{i=0}^{\infty} i \times (p_f) \frac{\hat{p}}{1 - \lambda},
\]

where \( \hat{p}(i) \) = 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

\[
\pi_1(1) = \left( \sum_{i=1}^{\infty} \left( (p_f - \text{cost } 1) + (p_f - \text{cost } 2) (i-1)(1-\lambda) \right) \hat{p}(i) - \hat{p}(0) \right) x(p_f).
\]

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 \((p_f - \text{cost} \ 1)\), and a net profit of \((p_f - \text{cost} \ 2)\) on each of the remaining customers. The term \(pr(o)\cdot c\) 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 in equilibrium \(\pi_1(o) = 0\), it follows that \(p_f = \text{cost} \ 2\), and that

\[
\pi_1(1) = \left\{ \left[ \sum_{1}^{\infty} pr(i) \right] \ (p_f - \text{cost} \ 1) - pr(0) \ c \right\} x(p_f),
\]

or

\[
\pi_1(1) = \left\{ \left[ \sum_{1}^{\infty} pr(i) \right] \ (\text{cost} \ 2 - \text{cost} \ 1) - pr(0) \ c \right\} x(p_f),
\]

or

\[
\pi_1(1) = \left\{ \left[ \sum_{1}^{\infty} pr(i) \right] \ (p_{\text{int}} - c) - pr(0) \ c \right\} x(p_f).
\]

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

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

where \(1 - Pr(o)\) = the probability that at least one customer will frequent a stage 1 firm.

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