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Technical Change, Competition and Vertical Integration

SRINIVASAN BALAKRISHNAN
Graduate School of Management, University of California, Los Angeles, California, U.S.A.

BIRGER WERNERFELT
J. L. Kellogg Graduate School of Management, Northwestern University, Evanston, Illinois, U.S.A.

Summary
This paper starts with a survey of the received theories of vertical integration. We then extend these theories by arguing that while uncertainty in general will make integration more effective, a particular type of uncertainty, the possibility of technological obsolescence, works the other way. After making this point at a conceptual level, we build a model to study how the frequency of technological change interacts with the intensity of competition to influence the optimal level of integration. The predictions of the model are then tested and very strongly supported by data from 93 industries.

INTRODUCTION

By their 'make or buy' decisions firms decide their degree of vertical integration. The business policy literature on the topic is, however, much smaller than that on a less common phenomenon such as diversification. In this paper we will seek to analyze the vertical integration strategy from a long-term profit-maximization perspective. Our arguments for a long-term analysis rest on two premises: (a) strategy, by definition, relates to the future, which is almost always different from the present; and (b) strategic decisions imply resource commitments, few of which can be revoked without incurring some costs. A far-sighted firm, therefore, will base its vertical integration decision not only on the current technological conditions, but also on the anticipated changes in these conditions. The focus of the paper is, in short, why certain investments in the long run would be more attractive to integrated firms than to independent suppliers.

We shall apply some recent ideas from transaction cost economics to our understanding of the vertical integration strategy. Klein, Crawford and Alchian (1978), and Williamson (1979), show that an integrated firm will do better than an unintegrated competitor if there are high profits in the value-added chain. The idea is that the parties in a bilateral monopoly, involving an independent supplier and an unintegrated firm, will spend a lot of resources bargaining over these profits. With vertical integration, on the other hand, this incentive to bargain is restrained bureaucratically. Standard economic reasoning furthermore asserts that high profits arise from the existence of specialized assets (or skills) in the value-added chain. If such specialized assets are necessary to succeed in the industry, only the few firms which have these assets are able to enter. Thus protected by entry barriers one would expect these firms to make high profits based on their specialized assets. So these assets yield high profits because they are 'rare', and they are 'rare' because no other

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industries use them. Accordingly, such assets have a very low value in their secondary use, making their value drop noticeably if technical change should render them obsolete in their primary use. The expected long-run profitability of a specialized asset is therefore much lower in the presence of frequent technical change. Putting these two arguments together we would expect vertical integration to be less desirable in industries with more participants (less specialized assets, lower profits) and more frequent technical change. The purpose of the paper is to demonstrate this point in the context of a careful theoretical analysis.

The dangers of vertical integration in the presence of environmental instability have recently been the subject of much attention in the policy literature (Hayes and Abernathy, 1980; Porter, 1980: 309-315; Harrigan, 1983a,b). The argument made by these researchers is essentially that irreversible investments are vulnerable, if there is uncertainty about their future value. A difficulty with this line of reasoning is, however, that it leaves unexplained why such an investment would look more appealing to an independent supplier than to an integrated firm. In other words, why won't a supplier demand the same expected return on his investment as would an integrated firm? In order to clarify this some careful theoretical reasoning is necessary. According to the standard analysis of Williamson (1975), uncertainty will, in general, lead to *more* vertical integration. The basic argument is that an independent supplier will demand a reasonably complete long-term contract before committing to investments in an idiosyncratic asset. As the number of contingencies in the contract goes up, it becomes more expensive to write, monitor and enforce so that vertical integration becomes more attractive. The predicted positive relationship between general uncertainty and vertical integration has been demonstrated conclusively by Masten (forthcoming). For a particular type of uncertainty, the possibility of technological obsolescence, the relationship does, however, reverse. In this case more uncertainty does not increase the number of contingencies in a hypothetical contract with an independent supplier, it only makes the single contingency more likely. Furthermore, as the likelihood of obsolescence goes up, the expected profitability of the investment goes down, and with it the incentive to bargain and hence the gains from vertical integration. (We abstract from risk aversion throughout the paper.)

Although a negative relationship between competition and integration has been found both in economics (Tucker and Wilder, 1977; Levy, 1981), and in business policy (Harrigan, 1983c), it has, as far as we know, not been tied to the transaction cost rationale for integration. In fact the most frequent explanation for the inclusion of concentration as an exogenous varible in models of integration is that integration is a barrier to entry and thus causes concentration to go up. In our analysis the causation goes from competition to integration. The next section will contain a review of the theoretical literature on the topic, while we then present a formal model and an empirical test.

THEORIES OF VERTICAL INTEGRATION

Economies of integration

Various theories have been put forth to explain the gains firms derive from meeting their input requirements internally. Consider a technology or a production process requiring at least two complementary assets or functions to be combined. Let S_1 represent the strategy of integration when the assets are owned by the same firm and S_2 represent the strategy of separate ownership and transaction across the market. Focusing on the downstream firm's decision, profit from integration will be

$$\pi(S) = R(S) - [c(S) + d(S)] \quad (1)$$

where π denotes the profit of the downstream firm; $R(S)$ is the firm's revenue, $c(S)$ is the cost of production, and $d(S)$ denotes the transaction costs for the strategy S, including administrative costs. These functions give the R, c and d which result from optimal management of all other aspects of the business, given the integration strategy. (For a similar formulation of the problem of evaluation of alternative strategies for organizing complementary functions, see Hurwicz, 1972.) The strategy of integration S_1 will be preferred to the market strategy S_2 if

$$\pi(S_1) > \pi(S_2). \quad (2)$$

On examining the right-hand side of equation (1), we see that there can be three possible factors causing the inequality (2):

(a) *Competitive considerations*: when integration introduces entry and/or mobility barriers to competition resulting in higher revenues to the integrated firm, that is $R(S_1) > R(S_2)$.

(b) *Production economies*: when there are production economies of scope, that is $c(S_1) < c(S_2)$.

(c) *Transactional economies*: when there are transactional economies in integration, that is, $d(S_1) < d(S_2)$.

Competitive considerations

Vertical integration may serve as an entry barrier by reducing the costs of incumbent firms and thus putting entrants at a disadvantage. This mechanism therefore suggests a causal link from integration to concentration, or opposite that of the transaction cost theory which maintains that rent earnings potential, indicated by a small number of industry participants, leads to integration. We shall not be able to disentangle the two in this paper.

Integration may also provide a firm with a product differentiation advantage over other unintegrated incumbents in the industry (Caves and Porter, 1977). To the extent that such intra-industry differences persist in the long run, they are a limitation on our results, which are developed on the industry level only.

A very dramatic, and illegal, use of vertical integration can occur when an integrated firm is able to prevent nonintegrated competitors from getting certain intermediary products at any price. How frequently such practices are followed is, of course, difficult to assess. Alcoa was forced to sell aluminum ingots to independent extruders, while Bowmar failed to convince the legal system that Texas Instruments unfairly had cut off its supply of chips. Also, it may be that some firms integrate not to do this themselves, but to prevent others from doing it to them. This may be a reason for the integration into forge works by nuclear reactor manufacturers. If such illegal practices, or perceived threats of them, are common, we would again not be able to disentangle them from other causal linkages between integration and competition and vice-versa.

Production economies of integration

Economies of scope from integration could, for example, result from technological inseparabilities. Because of the underlying technology, the transfer of an intermediate product between successive stages of production may be costly. Bain (1968) stresses the role played by technological inseparabilities when he cites the example of an integrated steel plant. When the successive stages of production of rolled steel—making pig iron, converting the iron into steel ingots and then rolling them into flats, bars, and the like—are performed at the same location, neither the pig iron nor the steel ingots need to be cooled and then reheated before rolling. If they were not, fuel costs would be saved. This argument for integration does not, however, hold up under closer scrutiny. We may ask why it should not be possible for the (separate) owners of the steel plant and the rolling mill to locate their plants adjacent to each other and thus carry out the transaction under contract with temperature penalty clauses. On the other hand, balancing and sequencing of capacity may be a highly nontrivial task to include in a contract. If only market capacity has to balance, things are much easier.

Transactional economies: advantages of hierarchies

Williamson (1975, 1979) argues that transactional considerations, rather than technological inseparabilities, determine whether a firm integrates or not. Williamson's analysis is a significant extension and elaboration of the arguments of Commons (1934) and Coase (1937). According to the transactional view a transaction will take place in the institutional framework, market, or hierarchy which allows it to be executed most efficiently. Of particular relevance here is the contrast between situations with many well-informed buyers and sellers and situations with only a few buyers and sellers. In the latter case each individual may profitably use resources on various bargaining efforts, thus increasing the total cost of executing the transaction in a market. In the case of more competition, on the other hand, nothing can be gained from individual bargaining efforts and the market is an efficient medium for the transaction. Thus if the profits are likely to be low, there is little to bargain over and no advantage of an internal structure. Conversely, we would expect to see integrated firms around transactions with potentially high profits. (See Naert, 1971, and Crocker, 1983, for examples of more formal analysis of strategic interaction in intermediary markets.)

The superior efficiency of administrative hierarchies has been the subject of several studies by Chandler and others, on the historical role played by the 'visible hand', in the evolution of the modern corporation (Chandler, 1962, 1977; Chandler and Daems, 1980). Chandler concludes from his investigation that

> [the modern business enterprise] began and expanded by internalizing activities and transactions previously carried out by a number of separate businesses. It emerges at the point when the businesses or units could be operated more profitably through a centralized hierarchy than by means of decentralized market mechanisms. (Chandler and Daems, 1980:11)

The continuing growth and expansion of the size, span and the scope of business enterprises is well documented in the business policy literature (see for example, Chandler, 1962; Rumelt, 1974; and Wrigley, 1970). Firms such as General Motors, Mitsubishi, and Philips have complex administrative structures which surpass even many large national governments in their size and intricacy. Their success and growth attest to the gains that could be realized from administrative control over the flow of resources.

Transactional economies: limits to corporate span

Williamson qualifies the advantages of the hierarchy over the market with the caveat that there are nontrivial costs in administering transactions within the integrated firm as well. These costs, it is argued, increase with the size and span of the firm. Administrative coordination consumes managerial time and effort and this is a scarce commodity in the organization. Because the integrated firm is involved in several stages of production and marketing, there is a greater need for administrative coordination, allowing managers less time for strategic functions which are critical for the firm's future growth and survival. Chandler has identified this as a basic weakness in the organization structures adopted by many large U.S. enterprises in the early stages of their growth (1962:295-296). While decentralization might relieve top management from the burden of day-to-day administration, it introduces the problem of control loss. Shirking and opportunistic behavior by, for example, the divisional managers can result in substantial costs within the organization.

Thus, internal administration of transactions also becomes costly and the span of the firm may be optimally chosen at the margin where the incremental cost of administering an additional transaction internally is equal to the marginal savings in the external transaction costs. Coase's insightful analysis of the nature of the firm (Coase, 1937) results in precisely the same conclusion.

Investments in specialized assets and technological change

A major incentive for vertical integration, as we have noted earlier, arises from the desirability of eliminating or attenuating costly bargaining over profits from specialized assets deployed in the industry. It follows that vertical integration implies investment with low salvage value and hence it increases the size of the capital loss, if a major innovation occurs. Specialized assets, suitable only for the now obsolete technology, may have to be scrapped and replaced with machinery embodying the new technology. Porter cites the following example in this connection:

> Imasco, a leading Canadian cigarette producer, backward integrated into packaging material used in the manufacturing process. However, technological change made this form of packaging inferior to other varieties, which the captive supplier could not produce. The supplier was eventually divested after many difficulties. (Porter,1980: 310)

It is possible that the change in the packaging technology was entirely *unanticipated* by Imasco's planners. However, if the initial integration into packaging and the subsequent divestiture were the results of a myopic vertical integration strategy attributable to behavioral or accounting factors, we may interpret this example as direct support for our argument in the introduction. The investment in the packaging technology was less valuable because of its short life. There were therefore fewer profits to bargain over and fewer incentives to integrate. If also the next technology was expected to be relatively short-lived, the decision to deintegrate was correct.

It is not necessarily the reduced flexibility itself which diminishes the incentive to integrate. The services of an asset subject to obsolescence should always be priced higher than those of a more robust asset to compensate for the difference in life expectancy. Presumably this price increase is the same whether a given firm or its suppliers make the investment. Instead, it is the effect of the reduced life expectancy on the expected industry profitability which reduces the incentive to bargain and thus to integrate. At the limit, where the industry profitability goes to the competitive rate of return, there is no incentive to integrate since there are no profits to bargain over and thus no transaction costs to save. The risk of technological obsolescence would consequently moderate the incentives to integrate, *ex ante*. A highly volatile industry characterized by frequent technological changes, therefore, will be unattractive for high levels of integration.

A VERY SIMPLE MODEL

Following the above, a firm's integration strategy should depend on

1. competitive considerations,
2. market transaction costs,
3. bureaucratic diseconomies,
4. technological instabilities.

We will aim to show that the optimal level of integration in an industry increases with transactional economies and decreases with bureaucratic diseconomies, competition and technological instabilities. For simplicity of exposition we assume that all investments are completely irreversible. We further assume the pool of potential suppliers to be sufficiently large for the firms in our industry to set the level of integration and expect the suppliers to adjust accordingly.

A representative firm has one unit of capital of which it allocates a fraction v to selected parts of the value-added chain in its industry. The remaining part of the firm's capital, $1-v$, is invested elsewhere at the rate i. The firm has a market share s in the consumer market and a change in v will change the level of integration, but not s. In any period the firm's profitis given by

$$\pi(v) = vps\,[1 - m(1 - v) - bv]$$

where ps is the 'basic' level of profitability in the industry reflecting the entry barriers associated with integration as well as the specificity of the involved assets, m measures the fraction of the profits lost in market transactions, and b the fraction lost in bureaucratic transactions. So ps reflects our first point, whereas m and b reflect the second and third points, respectively. To interpret this, note that we postulate a linear relationship between market share (or asset specificity) and profits similar to that found in for example the PIMS studies (Buzzell, Gale and Sultan, 1975). Furthermore, external or market transaction costs increase with $(1 - v)$, the fraction of the value-added chain outside the firm's control, whereas internal or bureaucratic transaction costs increase with v, the size of the firm. So vps is the available profits and the factor $1 - m(1 - v) - bv$ measures the transaction costs of realizing these profits. In some sense the transaction costs are the total organizational costs where the organization can be either market or hierarchy. All transaction costs are given as fractions of the total profit. Without profit there is no incentive to bargain or shirk and transaction costs disappear. (To bound the optimal level of integration, we have to assume that $m < b$, since the firm otherwise would find it optimal to grow to an infinitely large scope. Effectively this means that bureaucratic diseconomies grow larger than market diseconomies after a certain size.)

Let us assume that a technological innovation which will wipe out the investment v, can arrive at any time. If the expected time to the innovation, T, is the same at all times given that the innovation is not yet in place, the annual process is of the Poisson type. In this case we get a particularly simple formula for the expected net present value of all future profits of the firm given a value of v:

$$\mathrm{NPV} \equiv \int_0^\infty \mathrm{e}^{-rt}\,\mathrm{e}^{-t/T}\,\pi(v)\,dt + \int_0^\infty \mathrm{e}^{-rt}(1-v)i\,dt$$

where we assume the discount rate $r > i$, such that the firm faces a nontrivial decision. (Note that no risk aversion is involved, the firm is maximizing expected profits.) If we integrate this with respect to time we get

$$\mathrm{NPV} = \frac{1}{r+1/T}\,\pi(v) + \frac{i}{r}(1-v)$$

We find the optimal level of integration, v^*, by substituting $\pi(v)$ from above and performing a simple maximization of NPV with respect to v:

$$v^* = \beta_0 + \beta_1 \frac{1}{s} + \beta_2 \frac{1}{T}\frac{1}{s} \tag{3}$$

where

$$\beta_0 \equiv \frac{1-m}{2(b-m)} > 0$$

$$\beta_1 \equiv \frac{-i}{2p(b-m)} < 0$$

$$\beta_2 \equiv \frac{-i}{2p(b-m)r} < 0.$$

To interpret this, it is helpful to consider three separate cases: (1) $v^* = 0$, (2) $v^* = 1$, and (3) $0 < v^* < 1$. In the first case the firm prefers not to participate in the industry, in the second case it wants to participate as much as possible, and in the third case the optimal level of integration is between these two extremes.

(1) If $i(r + 1/T) > rps(1 - m)$, the industry is so unattractive relative to alternative investments that the firm would prefer a negative level of participation, implying that the existing investments in the industry, if any, will be divested. This can, for example, be due to very small values of p and s or a very large i. In this case, and when the two expressions above are equal, the firm will set $v^* = 0$ and earn zero profits from not participating in the industry while making i elsewhere. While it is difficult to judge the actual size of all the individual parameters in our model, it seems fair to conclude that the case $v^* = 0$ is very common in practice at least in some sense. After all, no firm participates in all industries and can thus be said to have decided against participation in some industries. On the other hand, all industries have some players so some firms set $v^* > 0$ in any industry. The decision about whether or not to enter obviously depends on the projected s as seen from the above inequalities.

(2) Conversely, if $i(r + 1/T) < rps(1 + m - 2b)$, the firm would prefer to invest more than the maximum feasible amount in the industry. Such extreme industry attractiveness

can, for example, be due to very high profit levels and transaction costs associated with the industry, and very low yield on risk-free investments and low administrative costs. In such circumstances, and when the two expressions immediately above are equal, the firm will set $v^* = 1$. In contrast to $v^* = 0$, the case $v^* = 1$ seems to be very rare, although some petrochemical firms may approximate this level of integration.

(3) In the range $0 < v^* < 1$ we can do a comparative static analysis of v^* to see how each of the parameters in the model influence the optimal level of vertical integration. By differentiating the right-hand side of (3) with respect to s, T, r, p, i, and b we find the following results. First, as we argued earlier, the optimal level of integration is lower in more competitive situations where the firm's market share is low. Secondly, the logic of the model agrees with our main hypothesis, that higher technological instability, $1/T$, leads to lower levels of integration, especially when market shares are low. (Interestingly, this is exactly the result which puzzles Walker and Weber, 1984, when it shows up in a study of an automobile manufacturer.) Thirdly, we see that it is optimal to integrate more if the industry is more profitable, r and p, and if alternative investments are less rewarding, i. Integration is finally less appealing if the associated bureaucratic costs, b, are high. So the model conforms to intuition and the analysis in the preceding section.

EMPIRICAL TEST

On testing

We will now proceed to test (3) on the industry level. In particular, we want to analyze the effect of $1/T$, technological instability, and s, the market share of a representative firm. Fortunately, it seems reasonable to assume that s and T capture most relevant interindustry differences. In particular, we argue that p, b, m, r and i are similar across industries, such that v^* can be estimated from s and T. First, capital markets presumably equalize r and i across industries. Also, the linear relation between equilibrium market share, s, and profitability ps may be reasonably valid across different industries. The same should be true for the fraction lost in market bargaining $m(1 - v)$. It is harder to justify that b, the fraction of profits lost in bureaucractic administration, is constant across industries. Data limitations do, however, force us to make this assumption. Given this, however, β_0, β_1 and β_2 will be identical across industries and (3) can be estimated with cross-sectional data.

A further comment is in order to explain the type of test we perform. While it would be ideal to test the performance implications of different strategies, this is infeasible in a study at the industry level. We therefore have to presume that any firm which has survived does roughly what is optimal, such that the optimality of a strategy can be tested by seeing whether firms on the whole behave accordingly.

Measures

Before estimating (3), we need to develop operational measures for the theoretical constructs v, s and T.

The often contradictory and inconclusive results obtained in previous empirical studies on *vertical integration* are at least partly attributable to the prevailing confusion over its meaning and measurement. In this paper we have adopted the view that vertical integration signifies internal manufacture of the firm's input requirements. Porter has provided a useful definition of vertical integration from the point of view of this paper. He defines vertical integration as

> the combination of technologically distinct production, distribution, selling and/or other economic processes within the confines of a single firm . . . a decision by the firm to utilize internal or administrative transactions rather than market transaction to accomplish its economic purpose. (Porter, 1980:300)

To operationalize this definition, we adopt a vertical integration index (VI) which measures the proportion of economic processes carried out within the firm. While there is more than one such measure, the value-added/sales ratio has proved to be robust and convenient for cross-sectional analysis. The advantages of this measure lie in its simplicity and the easy availability of the data required for its construction. Criticisms of this measure have been based on three grounds. First, it is often argued that the measure is 'naturally' higher for the upstream industries, because value-added is more, in primary industries. The critics do not offer an acceptable explanation, however, why this must be so. It is conceivable, after all, that a mine may be owned by a firm and leased to the mineral processing firm. Further, we have excluded from our sample all non-manufacturing industries like mining and extraction industries and retailing, thereby avoiding much of the bias that may arise out of this. A more serious criticism is that the value-added to sales ratio is distorted by the differences in the profitability of the industries. While this criticism cannot be easily dismissed, the real difficulty is in constructing an alternative index of vertical integration that is less distorted without having to face insurmountable data problems in cross-industry studies. The vertical industry connection index suggested by Maddigan (1981), for example, requires extensive data on the activities of individual firms. The availability, and more importantly the reliability, of these data from public sources is extremely doubtful. Finally, in the past, the value-added measure was constructed from the Census data. This measured vertical integration at the plant of establishment level and not at the firm level. This problem has been largely overcome by using the Line of Business Data which consolidates vertically related establishments owned by the same firm into a single line of business.

Finding a measure of the *market share for a representative firm* in an industry is more difficult because of the prevalence of intra-industry differences in market shares. A further complication is that very few firms want to publish data about their market shares. The PIMS data are not linked to firms or industries and the EIS data are only estimates by outsiders. Only for those few industries where law cases have taken place can one get reliable market share figures. Following standard practice in economics, we therefore decided to use the minimum economic scale (MES) which can be constructed from the 4-, 8-, 20-, and 50-firm concentration ratios. MES is defined as the average size of the largest firms in the industry which account for 50 percent of the total value of industry shipments. In computing this measure we have assumed equal sales for all firms within each concentration group, because individual firms' sales figures are not available. Thus, for any industry, if the 4-firm and 8-firm concentration ratios are 0.35 and 0.60 respectively, then the MES for the industry is found from linear interpolation:

$$\begin{aligned} \text{MES} &= 0.5 \div \left(4 + \frac{0.5 - 0.35}{0.60 - 0.35} \times 4\right) \\ &= 0.0783 \end{aligned}$$

It is recognized that the resulting measure is only approximate, but for want of a feasible alternative we will have to be satisfied with this approximation.

We will finally develop a measure for T in our model. From the previous section we know that T is *the mean life of the process technology* adopted in the industry. This suggests that we measure T by the average 'age' (AVAGE) of plant and equipment in use. While this measure disregards human assets, it is again the best we can do.

Data

The model was estimated with data on a sample of 93 SIC-4 digit level manufacturing industries. The sample was randomly selected from among the 261 industries included in the *FTC Annual Line of Business Reports* for the period 1974—76 (see Appendix). The main drawback of this data source is the very aggregate industry definition which was used in the compilation. Because of the usual conflict between what is desirable and what is obtainable, we did, however, proceed with these data. The procedure adopted for selecting the sample was as follows: the 261 industries in the LB (line of business) reports were first randomly assigned to two subgroups of 131 and 130 industries. The first group of 131 industries was then selected for the study. While missing data reduced the sample size somewhat, we constructed three sets of data for these industries, one each for 1974, 1975, and 1976.

The MES for each of the 93 industries in the sample was computed for 1972 and 1977, the two years in the neighborhood of 1974–76 for which concentration ratios were available from Census Reports. In the regression we use the reciprocal of the average of those two figures called NOFRM (note that $1/s$ in some sense measures the number of significant competitors). The LB reports carry data on the percentage value of plant and equipment acquired by the company, during four consecutive periods: more than 20 years ago, 10–20 years ago, 5–10 years ago, and during the past 5 years. The percentages are reported for each line of business. We computed the average age of the plant and equipment used by the industry from these basic data. If technology were changing frequently, then the plant and equipment used by the industry would be relatively new and hence the average age of the equipment would be lower than for an industry in which technology changes more slowly. In the regression, we multiplied the reciprocal of this measure by NOFRM, to get INNFRM.

Estimation

We now proceed to estimate the cross-sectional model, (3). The model is restated below:

$$v_i = \beta_0 + \beta_1 \frac{1}{s_i} + \beta_2 \frac{1}{T_i}\frac{1}{s_i} + e_i$$

where for the ith industry:

v_i = level of integration,
s_i = market share of a representative firm,
$1/T_i$ = innovation rate,
e_i = random error.

Given the empirical measures we have developed for the theoretical constructs, the estimation of this model is straightforward and poses no special problems. With the classical assumptions about the error term, ordinary least-squares can be applied to estimate the model. Four regression equations of the form (4) were estimated, one each with 1974, 1975 and 1976 data sets and the last with the data set obtained by pooling all the three years' data.

$$\mathrm{VI}_i = \beta_0 + \beta_1 \mathrm{NOFRM} + \beta_2 \mathrm{INNFRM} + \varepsilon_i \tag{4}$$

Since a Chow test failed to reveal problems with pooling the three years, we concentrate on the pooled data. Descriptive statistics and a correlation maxtrix are given in Table 1 and the regression results in Table 2. The results are consistent with the theoretical expectation. All coefficients are highly significant, as is the F statistic. The constant β_0 is positive as predicted. The negative β_1 reflects a decrease in vertical integration as the degree of competition goes up. As earlier mentioned, this can be due to the lowering of the entry barriers inherent in integration or to a decrease in the incentives to bargain as profits are competed away. The negative β_2 supports the hypothesis that integration levels are lower in industries characterized by frequent technological changes. Note further that the importance of technological instability increases as the degree of competition increases. If there are low profits in the first place, further disincentives matter that much more. Note also that the Pearson product moment correlations of NOFRM and INNFRM with vertical integration were negative and significant at the 0.05 level. So our individual variables have a strong impact on integration. While it may be partially due to our very noisy data, and in particular the broad industry definitions, the relatively low R^2 presumably suggests that other factors, not in the model, contribute significantly to the determination of integration strategies.

Table 1. Cross-sectional analysis; descriptive statistics and correlation matrix, pooled data

Descriptive Statistics

Variable	N	Min	Max	Mean	STD dev
MES	279	0.00025	0.22737	0.08737	0.06594
VI	279	0.36858	0.85554	0.61641	0.09203
AVAGE	275	4.68750	14.32300	8.82640	1.85620

Correlation matrix
$N = 275$; $DF = 273$; $R@.05 = 0.1246$

	VI	NOFRM	INNFRM
VI	1.0000		
NOFRM	−0.3064	1.0000	
INNFRM	−0.3162	0.6877	1.0000

MES: Minimum economic scale or market share of representative firm
VI: Vertical integration index
NOFRM: (Minimum economic scale)$^{-1}$
INNFRM: (Minimum economic scale)$^{-1}$ (average age of P and E)$^{-1}$

Table 2. Cross-sectional analysis: regression results for pooled data

Equation	Constant	NOFRM	INNFRM	R^2	F-Stat	N
(4.1)	0.626 (116.1) ***	−0.000063 (−2.358) ***	−0.00018 (−2.659) ***	0.139	21.93 ***	275

t - statistics in parentheses.
*** Significantly different from zero at the 0.01 level.

CONCLUSION

We have sought to analyze the vertical integration strategy from a technological and competitive perspective. Our two main results are that:

1. especially if the degree of competition is high, integration is affected negatively by the frequency of technological change;
2. the optimal level of integration depends negatively on the degree of competition in the industry.

While these results are very strongly supported by both theory and evidence, one must caution that vertical integration strategy is a complex and controversial topic. While we will draw some tentative managerial implications below, we feel that our main contribution lies in establishing the difficulty of the issues and the potential usefulness of careful theoretical analysis and transaction cost economics for strategic analysis. It is our expectation that this framework can be fruitfully applied to study several aspects of strategy formulation. In terms of the topic at hand, it would be interesting to extend the theoretical model to disequilibrium situations allowing for intertemporal developments in competition and interfirm differences in market share. Finally, it would be satisfying to replicate the empirical study on a group of single business firms.

Judging from the recent bulge of papers on the topic, the relationship between vertical integration and strategic flexibility is finally getting the attention it deserves. While much of the alleged advantage of the Japanese may lie in their use of structures between market and integration, it is nevertheless an important first step to understand the pros and cons of vertical integration. The main message of the paper is that simple-minded rules of thumb are dangerous and potentially misleading. While uncertainty in general should favor integration, technological uncertainty works the opposite way. So you cannot decide on integration levels for all your components simply by looking at demand fluctuations. The likelihood of technological obsolescence must be assessed for each component, and the specificity of each investment must be judged. Across-the-board analysis is not sufficient.

APPENDIX: THE LINE OF BUSINESS DATA

The *Line of Business Report* is an annual publication of the Bureau of Economics, the Federal Trade Commission. Its author is William F. Long, Manager, Line of Business Program. These reports contain aggregate financial and statistical data for the lines of business of 437–70 companies surveyed by the FTC. The lines of business correspond to approximately SIC-4 digit level industries. This data source was preferred to the Census of Manufactures, because it provided firm-level data as compared to the plant-level data published by the latter. For a complete description of the LB data, see *FTC Statistical Report: Annual Line of Business Report*, 1974. We acknowledge, with thanks, FTC's help in providing us this data in computer tape form.

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