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Abstract

The introduction of a new manufacturing system provides a unique opportunity to analyze its effects on the governance structure of vertical relationships. This paper focuses on the possible effects of lean manufacturing on the decision to vertically integrate. Transaction cost theory provides the framework for the analysis. Lean manufacturing is characterized by a high degree of mutual commitment between up- and downstream firms; this is expected to lead to the formation of contractual vertical relationships. The analysis utilizes a new data set obtained directly from U.S. automobile manufacturers. The empirical results strongly suggest that the arrival of lean manufacturing has implications for the decision on governance structure.

1. Introduction

Manufacturing has been undergoing a transition from the Fordist system of mass production to a lean production system which emphasizes quality and speedy response to market conditions using technologically advanced equipment and a flexible organization of the production process.[1] The introduction of this new manufacturing paradigm has led to widespread changes in the organization of production in the U.S. manufacturing sector (see

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Milgrom and Roberts 1990, Klier 1993). Milgrom and Roberts argue that it was only "natural to expect the characteristics of the modern manufacturing firm to be reflected in the way the firm is managed and the way it structures its relations with customers, employees, and suppliers." (p. 515) Since the early 1980s, it has become increasingly clear that the ramifications of introducing a new manufacturing system extend far beyond the shop floor. In fact, the competitiveness of companies and entire industries can be influenced by its implementation.[2]

Analyses of relationships between assembler and supplier companies in a lean manufacturing environment suggest that they are best characterized as close working relations. The introduction of lean manufacturing has brought with it an increase in outsourcing by upstream firms, a switch from multisourcing to single sourcing, a reduction in the number of suppliers, and longer term contracts with suppliers.[3] The close vertical relationships are necessary in order to facilitate frequent exchange of information during development and production and in order to involve suppliers in ongoing product design and development activities, as well as to encourage them to improve quality control (Holmes 1986, Aoki 1988, Milgrom and Roberts 1990, and Helper 1991). It has been suggested that the closer vertical relationships support the use of contractual arrangements (Aoki 1988, Coase 1988). It is therefore worthwhile to ask how transaction cost theory can explain the reported effects of lean manufacturing on the choice of governance structure for vertical relationships.

Coase (1937) introduced the concept of transaction costs in order to explain the existence of firms in a market economy.[4] Williamson (1975, 1985) developed Coase's idea into a theory of institutional choice, which suggests that transaction costs are minimized by matching governance structures with certain characteristics of transactions. Empirical work which tests Williamson's theory consistently finds that vertical relationships characterized by assets highly specific to that relationship are unlikely to be organized in the form of short-term market relationships. In these cases either long-term contractual relations or vertical integration are chosen as structures to govern the vertical relationship. Relationship-specific human capital has been shown to exert the strongest influence on the occurrence of vertical integration. This has been firmly established for both forward and backward integration, using manufacturing as well as non-manufacturing data (see Monteverde and Teece 1982a and 1982b; Anderson and Schmittlein 1984; Masten 1984; Spiller 1985; Joskow 1985; John and Weitz 1988; Masten et al. 1989 and 1991; and Liebermann 1991). However, the transaction cost theory literature has so far not considered the effects of the lean manufacturing system on the structure of vertical relationships.[5] Lean manufacturing was pioneered and successfully applied by Japanese producers. It has since been adopted by many American manufacturers in order to be able to compete effectively (see for example Helper 1991, Bechter and Stanley 1992).[6]

This study focuses on the ramifications of the introduction of lean manufacturing for the decision to vertically integrate. Does lean manufacturing affect the comparative assessment of markets and hierarchies, and thereby the choice of governance structure? Based on the framework of transaction cost theory, it explores a possible explanation of the increased usage of contractual arrangements in a lean manufacturing environment. To illustrate, examples from the U.S. auto industry will be used throughout the paper because it introduced the new manufacturing system rather quickly and greatly influenced the way many other businesses organize their factories.

The paper is organized as follows: section two develops the theoretical framework and the hypothesis regarding the effects of the introduction of lean manufacturing on the determinants of vertical integration. The model is developed in section three. Data set and variables are described in section four. The empirical results are presented in section five, a summary and conclusions follow.

2. Theoretical framework

a. Transaction cost theory and vertical integration

Transaction cost theory postulates that contracting is not a costless activity. With regard to procurement decisions it relates individual 'make-or-buy' choices to certain characteristics of the transaction. It argues that the key determinant of governance structure is the extent to which production requires large investments in durable, relationship-specific assets. Investments in these transaction-specific assets leave only imperfect market exchange alternatives to the parties of a transaction since assets which are specialized to a transaction represent a lower value in other uses; i.e. they create a stream of quasi-rents.[7]

To the extent that these quasi-rents are appropriable, they might become a matter of contention in a bilateral relationship. The more specialized the assets, the greater the incentive for agents to attempt to influence the terms of trade through bargaining or other rent-seeking activities once the investments are in place. The possibility of post-contractual opportunism creates what the literature refers to as the hold-up problem (see Goldberg 1976): one party can capture all of the appropriable quasi-rents from the other party by threatening to dissolve the relationship unless price concessions are forthcoming.

Since it is prohibitively costly to write long-term contracts which specify all obligations under all possible contingencies, the possibility of post-contractual opportunism is argued to influence the choice of governance structure. Transaction cost theory posits that, in the presence of transaction-specific investments, governance structures will emerge ex ante to reduce the incentives of either the buyer or the seller to behave opportunistically ex post, i.e. after the governance structure is chosen.[8] Specifically, governance structures are argued to be matched with asset specificity characteristics of transactions in a cost-minimizing fashion.

Two general types of governance structures are offered as solutions to the condition of asset specificity: vertical integration and contracts. They differ in terms of their ability to accommodate asset specificity conditions; the desirability of vertical integration is argued to be higher, the higher the cost of conducting transactions via market-based relationships.

The role of **contracts** is to prevent opportunism by stipulating acceptable behavior at the beginning of a relationship between two parties. Their use allows for market incentives to work in that relationship. A particular relationship between two firms is limited by the length of the contract. Consequently, it is possible for the downstream company to switch supplier companies once the contract expires. But contracts incur expenses in both specification and enforcement that limit their usefulness. Efforts to suppress opportunism contractually are limited by the costs of writing and enforcing explicit contractual agreements. **Vertical integration**, on the other hand, offers the possibility of making decisions in an adaptive, sequential manner. This reduces the need to enumerate all possible contingencies at the outset of the relationship. But these benefits of integration are limited by the loss of high-powered incentives and the increasing costs of managerial oversight as firms incorporate more activities. Accordingly, organization within the firm necessitates greater investments in monitoring and administration.

Transaction cost theory distinguishes three main forms of specific assets: specific human capital, specific physical capital, and site-specific capital. Specific human capital arises due to investment in and accumulation of education and skills that are specific to a particular relationship, embodied for example in accountants, designers, and engineers needed to produce a particular product. Specific physical capital includes buildings and machines that can be used for one customer or a small number of customers only. Suppose that in order to produce a particular part for one buyer, specific dies are needed for a machine press to turn out that part; in that case the dies represent specific physical capital. Finally, if successive stages of a production process are located adjacent to each other, they involve site-specific capital. Obviously, in order for location to lead to specificity, some transportation costs are required.

These three asset specificity conditions are argued to influence the choice of governance structure in the following way. If a firm uses outside contractors rather than its own employees, opportunistic behavior is possible. For example, a contractor who knows that a firm is facing a deadline may demand more money or lower the quality of its output to meet its own deadline. Since quasi-rents accrue to transaction-specific *human capital*, the cost of transacting across the market increases and makes it necessary to integrate production within the firm (Williamson 1985, p.96). Accordingly, an increase in the degree of human asset specificity is expected to lead to an increase in vertical integration.

The presence of specific *physical capital* can also lead to post-contractual opportunistic behavior, for example, if a company that produces stampings owns not only the machine press but also the dies needed to produce a particular part. That company might decide to raise the price of its product because its customer may find it prohibitively expensive to switch suppliers in the short run. If the relationship between these two companies is dominated by specific physical assets, ownership of these assets can eliminate the hold-up problem by internalizing the quasi-rents, the object of opportunistic behavior. However, that does not require production itself to be integrated; the buyer may own the dies and have stamping companies bid for provision of the machine press services. Such a case of ownership of a specific physical asset in combination with a contractual relationship is referred to as quasi-integration (or quasi-vertical integration). A higher degree of physical asset specificity is not expected to lead to an increase in vertical integration, but to an increase in quasi-integration.

Investments in immobile *site-specific assets* can also give rise to opportunistic behavior. For example, if the downstream company stops demanding the input provided by the closely located supplier, that company might have to relocate in order to find alternative business; but that can be extremely costly in the case of long-lived and immobile assets. Once such assets are located, the parties operate in a bilateral exchange relationship for the useful life of the assets. Hence, an increase in site specificity is expected to favor vertical integration over autonomous contracting since it reduces potential for opportunistic behavior (Williamson 1985, p. 95).

One also needs to pay attention to the frequency with which transactions occur. The costs of setting up a vertically integrated organization, i.e. investments in monitoring and administration, suggest the following relationship. As a transaction recurs more frequently, integration is expected to become more desirable since potential losses from not integrating, i.e. losses from opportunism and the relative disadvantage of being able to make decisions adaptively, outweigh the costs of integration (Anderson and Schmittlein 1984, p. 388; Williamson 1985, p. 60). Frequency of transaction is therefore a relevant dimension in determining the choice of governance structure; an increase in the frequency is expected to lead to an increase in the probability of vertical integration.

b. Hypothesis: effect of mutual commitment

With the introduction of the lean manufacturing paradigm in the United States, the relationships between assemblers and supplier companies have begun to change. This paper argues that the introduction of lean manufacturing is able to reduce the propensity for opportunistic behavior by increasing the extent of mutual commitment present in vertical relationships.

Compared to Fordist manufacturing, lean manufacturing is characterized by a relatively high level of underlying mutual commitment between up- and downstream firms; it becomes visible with an increase in the degree of communication and interaction between manufacturers and suppliers, resulting in more closely-knit relationships. Both parties undertake credible commitments in support of their relationship and in order to promote exchange (Williamson 1983, p. 519). The supplier company changes the organization of its production such that it can produce "just-in-time", otherwise it will end up carrying large amounts of inventory for the downstream customer. In addition, it takes on responsibility for quality control and, often, research and development, both activities that were traditionally undertaken by the auto assembler. Accordingly, suppliers invest in quality control training and equipment, and maintain their own product-design staff. Furthermore, suppliers are found to locate (or relocate) their operations close to the downstream customer. The assembler, in turn, uses single suppliers for a particular automobile platform as opposed to dealing with multiple suppliers per part. In addition, it commits to longer-term relations through both longer-term contracts and the extension of informal contract-renewal promises, given continuous quality improvement by the supplier.[9]

Successfully implemented lean manufacturing sourcing relationships enable both parties to benefit from the incentive advantages of contracts. The assembler company is able to save monitoring costs and to cut down on inventory; the supplier company is no longer exposed to annual contract bidding in its longer-term relationship with the auto assembler. This was not the case in a Fordist manufacturing environment: short-term, arms-length relationships with multiple suppliers generally were not designed to reward commitment. There was no incentive for sourcing relationships to continue over time.

The central question of this paper is how the introduction of mutual commitment affects the decision to vertically integrate. Anecdotal evidence seems to suggest it reduces the transaction cost of contractual arrangements. How can we explain its impact within the framework of transaction cost theory?

The introduction of lean manufacturing brought with it a relatively high level of mutual commitment in sourcing relationships.[10] It has the effect of protecting contracts against expropriation. The presence of high degrees of mutual commitment strengthens the ability to enforce contractual agreements by making hold-up threats less credible: mutual commitment affects the symmetry of the hold-up threat. The above-mentioned investments in the vertical relationship by assembler and supplier, such as investment in R&D and quality control as well as the use of longer-term contracts and the extension of contract renewal promises, make a potential bargaining situation over the appropriable quasi-rents more symmetric.[11] That is different from Fordist supplier relationships, where bargaining leverage tended to be asymmetrically distributed in favor of the automobile assembler. To put it differently, a mutual reliance relation strengthens the mechanism of implicit contract enforcement. A so-called implicit contractual agreement is not enforced through a third agency (ultimately the presence of government) but merely by the threat of termination of the transactional relationship and communication of the contractual failure to the market place. Coase (1988, p. 44) points out that the implementation of long-term contracts is commonly accompanied by informal arrangements not governed by contract. A defrauding firm may realize immediate gains by breaking the contract, but if it can be identified, it will lose future business. Longer term vertical relationships, typical for lean manufacturing, reinforce the effectiveness of contractual agreements by increasing the present discounted value of the quasi-rent stream attributable to a particular vertical relationship relative to the one-time gain from severing that relationship by breaking the contract.

From the theory outlined above it follows that the introduction of lean manufacturing can effectively reduce the propensity for opportunistic behavior by increasing the extent of mutual commitment present in vertical relationships. Therefore, the increase in mutual commitment is expected to result in a decrease in the probability of vertical integration.

3. Model

The objective of this paper is to assess how the introduction of lean manufacturing affects the decision to vertically integrate. According to transaction cost theory, governance structures are chosen in order to minimize transaction costs. Transaction costs are assumed to be determined in the following way:

$$T_i = \alpha + \beta X_i + \varepsilon_i \tag{1}$$

where i denotes a transaction, X represents a vector of independent variables, $\varepsilon_i \sim N(0,1)$, and ε_i and ε_j ($i \neq j$) are independent.[12] The actual transaction costs [T_i], however, are unobserved. Instead, one can observe the governance structure chosen [Y_i]. A binomial probit model distinguishes two different categories in the dependent variable; in the case at hand they are "vertical integration" and "contractual relation".[13] The two categories of governance structure are related to the unobserved variable, i.e. the level of transaction costs, in the following way:

$$Y_i = 1 \text{ [vertical integration] if } T_{i,\text{vertical integration}} < T_{i,\text{contract}} \tag{2}$$

$$Y_i = 0 \text{ [contractual relation] if } T_{i,\text{vertical integration}} \geq T_{i,\text{contract}}$$

Accordingly, the binomial qualitative choice model estimates

$$Y_i = \alpha + \beta X_i + \varepsilon_i. \tag{3}$$

The parameters of the independent variables can be estimated by the maximum likelihood method using the loglikelihood function:

$$L = \sum_{i=1}^{n} Y_i \log F(\alpha + \beta X_i) + \sum_{i=1}^{n} (1-Y_i) \log[1 - F(\alpha + \beta X_i)] \qquad (4)$$

where F represents the cumulative distribution function of the standard normal distribution. The binomial probit model estimates the probability of vertical integration as

$$\text{Prob } (Y_i = 1) = \text{Prob } (T_{i,\text{vertical integration}} > T_{i,\text{contract}}) = \Phi(Y_i) \qquad (5)$$

where Φ denotes the standard normal distribution.[14]

In interpreting the estimation results it is important to note that the estimated coefficients in a qualitative choice model are not meaningful by themselves. Hence the marginal effects of the independent variables on the choice of governance structure are calculated and analyzed.[15]

The binomial probit model to be estimated has the following general form:

Prob(vertical integration) = $\alpha + \beta_1$ human asset specificity + β_2 physical asset specificity + β_3 site specificity + β_4 mutual commitment + β_5 frequency + $\sum \gamma_i$ control variables + ε

As indicated above, transaction cost theory predicts that an increase in the degree of *human asset specificity* has a positive effect on the probability of vertical integration; β_1 is expected to be > 0. Potential hold-up problems in the presence of *specific physical assets* can be attenuated by internalizing the associated quasi-rents through ownership of the specific assets rather than through the integration of production. Hence physical asset specificity is expected to lead to quasi-integration. In the binomial probit model that case is included in the category "contractual relation", therefore β_2 is expected to be < 0.[16] The introduction of lean manufacturing is expected to change the standard transaction cost theory argument of a positive effect of the degree of *site specificity* on the incidence of vertical integration. Today, geographically close location of assembler and supplier operations is frequently a sign of mutual commitment between the two firms. Consequently, one could argue that site specificity would decrease the probability of vertical integration. However, since relocation is a long-term decision it is unlikely for it to have occurred to a large extent within the last decade. Site specificity is therefore expected to have no significant effect on the choice of governance structure; β_3 is expected to be ≤ 0. The degree of *mutual commitment* present in a vertical relationship is argued to curb the potential for opportunistic behavior. An increase in mutual commitment is therefore expected to reduce the probability of vertical integration, $\beta_4 < 0$. An increase in the *frequency of transaction*, on the other hand, is expected to reduce the costs of vertical integration relative to contractual arrangements, $\beta_5 > 0$. Transactions conducted more frequently will be governed within the firm, i.e. the probability of vertical integration increases.

4. Data and variables

The empirical analysis is based on a set of cross-section data obtained directly from U.S. automobile manufacturers between September 1991 and March 1992 via questionnaire.[17] Once contacts were established with each of the car assemblers, data were collected for one particular size of car, compact cars, in order to control for possible scale effects.

The compact car platforms in the sample correspond to the following car models:[18] General Motors assembles the N-car at its Lansing, Michigan, plant. This platform is the basis for the Pontiac Grand Am, the Buick Skylark, and the Oldsmobile Achieva. Ford assembles its Tempo/Topaz cars at two locations: Kansas City, Missouri, and Oakville, Ontario. Chrysler assembles its two A-body cars, the Dodge Spirit and the Plymouth Acclaim, at its Newark, Delaware, plant.

The questionnaire was designed to collect information on a sample of parts and components that constitute an automobile.[19] The sample used consists of 30 automotive parts; its size was chosen to restrict the questionnaire to manageable size. The 30 parts in the sample were selected in order to represent the 12 subsystems as well as a range of asset specificity characteristics (see Appendix).[20] The decision to focus on parts (vs. subassemblies) eliminates possible bias toward in-house production that exists for data at the more aggregate level of subassemblies (see Luria 1990b).[21]

The data set consists of 89 observations; 41 parts (46.1 %) represent contractual relationships and 48 parts (53.9 %) fall in the category vertical integration (see Table 1).

The degree of **mutual commitment** cannot be observed directly. Proxied by the variable DEVELOP, it is measured as the number of years during which assembler and supplier work together on producing a part prior to the start of production.[22] Before a part goes into production, supplier and assembler need to come to an understanding about its technical features, quality standards, price, delivery schedules, etc. In order to work out an answer to the relevant questions, a significant amount of cooperation between assembler and supplier takes place in lean manufacturing relationships. For example, Chrysler Corp.'s new JA platform is supposed to go into production in 1995. Yet by 1992 every major system of that platform was already sourced (1992 Ward's Automotive Yearbook, p. 53). Often the supplier has to contribute its own R&D efforts to fill in the specifics of production and design of a so-called 'black box' part. It is argued that the resulting coordination efforts signal the extent of underlying mutual commitment to a vertical relationship. The more time is spent on pre-production communication between assembler and supplier, the larger is the extent of mutual commitment to that relationship.

The **frequency of transactions** between assembler and supplier is measured by the variable DELIVERY INTERVAL. It measures the time interval between deliveries of a part from the supplier to the assembler's consuming plant according to the following six-point scale: delivery every 0-2 hrs [1]; every 2-8 hrs [2]; every 8-24 hrs [3]; every 24-72 hrs [4]; every 72 hrs - 1 week [5]; longer than one week [6]; shorter intervals represent a higher frequency of transaction.[23]

The degree of **human asset specificity** is also not directly observable. Following Monteverde and Teece (1982a) and Masten et al. (1989), this variable is measured as the engineering effort, i.e. engineering cost, that went into the development of a part. The larger the engineering effort, the greater the expected magnitude of appropriable quasi-rents. Since data on actual engineering costs are of a proprietary nature, an engineering cost rating, based on a five-point scale, is used instead: [1] represents low and [5] high engineering effort.

As in Masten et al. (1989), the degree of **physical asset specificity** is measured by the extent to which the physical assets used to manufacture a given part are specific to a particular automobile manufacturer. This variable is also measured in terms of a five-point scale: [1] indicates a low and [5] a high degree of physical asset specificity.

Table 1
Means and standard deviations,* vertical integration data

INDEPENDENT VARIABLES	CATEGORY OF THE DEPENDENT VARIABLE		
	Contractual relation	Vertical integration	ENTIRE SAMPLE
Import	0.15 (0.36)	0.02 (0.14)	0.08 (0.27)
Generic	0.46 (0.50)	0.25 (0.44)	0.35 (0.45)
Human asset specificity[a]	2.34 (1.11)	3.23 (1.02)	2.82 (1.14)
Physical asset specificity[a]	2.10 (1.04)	2.75 (0.89)	2.45 (1.01)
Delivery Interval[a]	3.66 (1.33)	3.15 (0.74)	3.38 (1.08)
Distance[a]	3.02 (1.19)	2.73 (1.01)	2.87 (1.10)
Develop[a]	2.61 (0.56)	2.74 (0.72)	2.68 (0.65)
Number of observations	41	48	89

* Standard deviation in parentheses.
[a] Variables are based on ordinal rankings of each part in the sample relative to the others; the means refer to the scales of the variables as defined in the text.

Table 2
Correlation matrix (89 observations)

	Human asset sp.	Physical asset sp.	Distance	Delivery Interval	Generic	Import	Develop
Human asset specificity	--						
Physical asset specificity	.57	--					
Distance	-.12	-.13	--				
Delivery Internal	-.09	-.07	.58	--			
Generic	-.32	-.26	-.04	-.17	--		
Import	-.06	.08	.53	.25	-.38	--	
Develop	.35	.27	-.14	-.11	-.17	-.11	--

This study proxies **site specificity** by the actual distance [DISTANCE] between the supplier plant and the consuming plant of the auto assembler.[24] A smaller distance corresponds to a higher degree of site specificity. It is measured in road miles on a five-point scale. The five categories correspond to the following distances: 0-50 miles [1], 51-300 miles [2], 301-550 miles [3], 551-800 miles [4], and greater than 800 miles [5].[25]

In addition, the sample includes a set of **control variables**: In order to eliminate a possible spurious correlation between imports and the degree of site specificity an IMPORT dummy was included; it is set to one if a particular part is imported. The data set contains three dummy variables that indicate the auto manufacturer [FORD, GM and CHRYSLER]. Two of these dummies are included as right-hand side variables in the estimated models; they are expected to pick up existing differences in the scaling of the qualitative variables as well as differences in corporate strategy. Some auto parts are not specific to a particular automobile manufacturer or a particular automobile.

For these components market relationships are expected to operate quite well (see Monteverde 1981, p.106). Therefore a GENERIC dummy variable is included to indicate the parts that are not attractive to integration because they are common across auto manufacturers. The variable is set to one if a part is not specific to a particular auto manufacturer (see Appendix).

5. Results

Table 3 reports the results for two specifications of the binomial probit model.[26] The χ^2-tests indicate that the vector of independent variables is highly significant. The explanatory power of a qualitative choice model can be calculated by the so-called R^2-analogue. The marginal effects of the independent variables on the decision to vertically integrate are reported in Table 3 below the standard deviations. They are evaluated at the mean of all the independent variables. For example, specification 2 reports that, ceteris paribus, a 1 point increase in the degree of human asset specificity at its mean would increase the probability of vertical integration by .17.[27] An evaluation of the probit model at the means of the independent variables renders 0.52 and 0.43 as the probabilities of vertical integration for specification 1 and 2, respectively. I attribute the relatively large partials for the IMPORT dummy to the skewedness of that variable; the reported results remain virtually unchanged when the seven observations relating to the imported parts are dropped.

Both the degree of human asset specificity and the degree of mutual commitment as measured by DEVELOP are consistently significant in explaining the occurrence of vertical integration. The condition of human asset specificity significantly increases the incidence of vertical integration. Interestingly, the marginal effect of the degree of human asset specificity corresponds almost exactly to the finding in Monteverde and Teece (1982a).[28] Their analysis, however, was performed with data that were collected prior to the introduction of lean manufacturing to North America. This strongly suggests that the introduction of lean manufacturing has not altered the way in which human asset specificity influences the choice of governance structure. As expected, an increase in DEVELOP, i.e. in the length of pre-production interaction between assembler and supplier, leads to a significant decrease in the probability of vertical integration. These two effects are robust across specifications. Specification 1 provides evidence for a reversal of the effect of site specificity on the probability of vertical integration. A decrease in the distance between supplying and consuming plant, i.e. an increase in the degree of site specificity, leads to a reduction in the probability of vertical integration.

DELIVERY INTERVAL measures the frequency of transactions between the parties. An increase in the number of interactions was argued to increase the probability of vertical integration. Specification 1 provides strong evidence for that influence. However, in specification 2 a significant nonlinear effect of DELIVERY INTERVAL on the probability of vertical integration is found to exist.[29] This is shown in Figure 1; it plots the estimated quadratic relationship for DELIVERY INTERVAL for the scale of that variable. Starting with a low frequency of transactions, which is represented by the value 6 - a delivery interval of longer than one week - and moving to higher frequencies, the probability of vertical integration increases as expected. However, as the DELIVERY INTERVAL falls to less than 8-24 hours (category 3), this relationship breaks off: further increases in frequency no longer increase the probability of vertical integration. Multiple daily deliveries are generally reported to be one of the stylized facts of lean manufacturing.[30] Even though it is argued that an increase in the frequency of delivery is necessary but not sufficient to indicate a change in the assembler-supplier relationship (see Helper 1991), the results of specification 2 seem to indicate that for very high frequencies of transaction the variable DELIVERY INTERVAL captures the mutual commitment between assembler and supplier present during production relationships.[31] Accordingly, the break in the standard linear relationship between frequency of transaction and probability of vertical integration can be explained by the presence of mutual commitment which works as a restraint on opportunistic behavior. This restraint becomes effective in the case of multiple daily deliveries.

To sum up, the results of the binomial probit model support the hypothesis of an increase in contractual vertical relationships brought on by the introduction of lean manufacturing. The importance of the degree of mutual commitment as a determinant of governance structure is established. Its proxy variable, DEVELOP, is found to be negatively related to the probability of vertical integration. Longer term, mutual reliance relationships between assembler and supplier, characteristic of lean manufacturing, result in a lower probability of vertical integration. The influence of the degree of human asset specificity on the choice of governance structure is found to be unaffected by the introduction of lean manufacturing. In fact, the marginal effect of that variable does not differ statistically from that established in previous related studies. As expected, evidence cannot be established for a positive effect of site specificity on the probability of vertical integration.

Table 3
Binomial probit analysis: probability of vertical integration

	Specification 1	Specification 2
Constant	1.20	-3.81
	(1.33)	(2.16)
Import	-2.58**	-2.56**
	(1.00)	(1.08)
	(-1.03)	(-1.01)
Generic	-0.97**	-0.83*
	(0.40)	(0.42)
	(-0.38)	(-0.33)
Human asset specificity	0.39**	0.44**
	(0.18)	(0.20)
	(0.16)	(0.17)
Physical asset specificity	0.28	0.23
	(0.22)	(0.25)
	(0.11)	(0.09)
Distance	0.44*	0.29
	(0.25)	(0.27)
	(0.18)	(0.11)

Table 3 (continued)

Binomial probit analysis: probability of vertical integration

	Specification 1	Specification 2
Develop	-0.51*	-0.67*
	(0.31)	(0.34)
	(-0.20)	(-0.26)
Delivery Interval	-0.58***	3.26**
	(0.21)	(1.59)
	(-0.23)	(-0.29)[a]
(Delivery Interval)^2	--	-0.59**
		(0.25)
Log-likelihood	-40.24	-35.37
χ^2	42.34***	52.08***
df=	9	10
χ^2 (vs controls)	17.35***	29.18***
df=	5	6
R^2-analogue	0.34	0.42

Values under each coefficient are the standard error and the partial derivative evaluated at the mean, respectively. Company dummies are not reported.

[a]Includes effect of quadratic term.

*significant at the 90% level; **significant at the 95% level;

***significant at the 99% level.

6. Conclusion

This study focussed on the possible effects of the introduction of the new manufacturing paradigm on the choice of governance structure. Effects of manufacturing on the structure of the firm are generally not analyzed by the industrial organization literature, which is probably related to the low frequency with which paradigm shifts in manufacturing occur. Yet, the widespread application of a new manufacturing system raises important questions about the structure of the manufacturing sector.

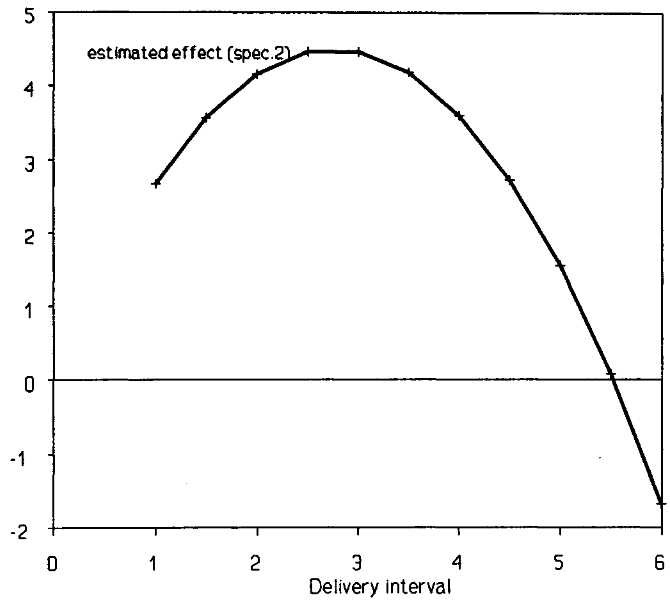
The central question of this study was how the introduction of lean manufacturing affects the decision to vertically integrate. In order to address it, this study referred to the mechanisms of contract enforcement. The presence of high degrees of mutual commitment, a characteristic of lean manufacturing, was shown to strengthen the ability to enforce contractual agreements by making hold-up threats less credible. In doing so, it increases the self-enforcing range of contracts. It was proposed that the introduction of lean manufacturing leads to a change in the relationship between up- and downstream firms and, as a result, in a relative reduction of the transaction costs of contractual arrangements.

The results of the binomial probit model show the degree of mutual commitment to be a statistically significant determinant of governance structure. Its proxy, DEVELOP, measures the number of years during which assembler and supplier work together before the actual start of production of a car model. It indicates the level of mutual commitment sustaining the longer-term contractual relationships. This greater degree of mutual commitment is found to reduce the probability of vertical integration by the constraints it places on the potential for opportunistic behavior. Lean manufacturing introduces mutual commitment into vertical relationships to a degree that is sufficient to curb the potential for opportunistic behavior. This result is not reconcilable with the maintained null hypothesis of no effect of the new manufacturing system on the choice of governance structure.

The results presented in this study suggest the following general conclusion: lean manufacturing influences the choice of governance structure by introducing mutual commitment into vertical relationships. It serves as a constraint on the potential for post-contractual opportunism and increases the probability of contractual arrangements between companies. The traditional influence of human asset specificity on the choice of governance structure is unaffected.

That insight has broader implications as the reported effects are not likely to be restricted to the U.S. automobile industry. It strongly suggests the need to consider characteristics of the manufacturing system in a theory of vertical integration. Understanding the structural effects of the new manufacturing system is key to the ability to interpret evidence as well as to plan the direction of future research. This paper adds information towards understanding the effects of the lean manufacturing system. Its implications are widespread and reach from issues of regional economic development policy and firm's location decisions to questions of plant management and manufacturing productivity.

Figure 1
The effect of "delivery interval"



Appendix
A Stylized Compact Car

Subsystem:	**Part:**
ENGINE	Engine Assembly
	Cylinder Block
	Crankshaft
	Pistons
	Connecting Rods
	Balance Shafts
	Camshafts
	Cylinder Head*
	Valvetrain Components
	Water Pump
	Oil Pump/ Lubrication
	Intake Manifold*
	Exhaust Manifold
	Flywheel
	Piston Rings*
	Other
DRIVETRAIN	Transaxle Assembly
	Clutch Assembly
	Torque Converter*
	Transmission Case*
	CV Joint*
	Rear Differential
	Drive Shafts
	Gear Sets*
BODY STRUCTURE	Cowl, Dash Stampings
	Body Exterior*
	Bumper Assemblies
	Small Stampings
	Windshield*
	Frame
	Weather Stripping*
SEATS, TRIM	Seat Frames, Mechanicals
	Seat Covers* [G]
	Instrument Panel

Appendix (continued)
A Stylized Compact Car

Subsystem:	**Part:**
	Interior Finish Trim
	Headliner/ Carpeting
	Rough Hardware* [G]
	Grille Panel
	Exterior Trim
	Mirrors* [G]
	Occupant Restraint* [G]
STEERING AND SUSPENSION	Steering Wheel
	Steering Column*
	Power Steering Pump
	Steering Gear*
	Front Wheel Knuckle
	Suspension Control Arms
	Springs
	Struts
	Shock Absorbers
	Stabilizer/ Torsion Bars
	Trailing Axle
FUEL DELIVERY	Fuel Tank
	Fuel Lines
	Fuel Pump
	Fuel Injection*
	Carburetor
	Turbocharger
	Engine Control Module*
	Gas Cap/ Filler* [G]
ENGINE ELECTRICAL	Spark Plugs
	Engine Wiring Harness*
	Distributor/ Coil*
	Ignition Module
	Starter Motor
	Alternator* [G]
	Cruise Control

Appendix (continued)
A Stylized Compact Car

Subsystem:	Part:
EXHAUST/ EMISSION CONTROL	Exhaust Pipes
	Catalytic Converter* [G]
	Muffler* [G]
	Other Exhaust Parts
BRAKES/ WHEELS/ TIRES	Caliper Assembly*
	Drums
	Discs
	Shoes and Linings
	Master Cylinder
	Brake Tubes and Hoses
	Wheels* [G]
	Hub Caps
	Tires
HEATING/ VENTILATING	Condensor
	Compressor*
	Radiator
	Heater Core
	Tubing/ Hoses
	Engine Fan* [G]
CHASSIS/ ELECTRICAL	Battery* [G]
	Main Wiring Harness
	Small Electric Motors
	Electrical Inst. Controls
	Lamps
	Audio*
	Fuses, Switches

Source: Luria (1990b); Andrea et al. (1988)
* Parts in the sample
[G] Generic part

Footnotes

[1]The Fordist system is named after Henry Ford who introduced the use of interchangeable parts and the moving assembly line to the manufacturing process. Lean manufacturing is also frequently referred to as just-in-time manufacturing.

[2]For example, the remarkable recent success of Chrysler Co. in terms of developing cars quickly and efficiently is reported to be the result of reorganization efforts that were patterned on development and production techniques employed by Honda Motor Corp.

[3]For example, Ford Motor Co. currently contracts with about 1400 supplier companies for about 55% of the costs of an automobile. That compares to 2400 supplier companies and 48% of the costs in the year 1980. The company plans to reduce its supplier base to 1000 companies by the year 2000. For the recently introduced CDW27 world car, called the Mondeo in Europe and scheduled to replace the Tempo/Topaz in the US in the summer of '94, 58% of its parts are single sourced, the remainder is dual sourced. (Fleming 1993)

[4]Transaction costs include most costs associated with conducting economic activity other than actual production costs; e.g. costs of coordinating interdependent activities, exchange of information and of writing, monitoring, and enforcing contracts.

[5]The business strategy literature, notably studies conducted under the guidance of the International Motor Vehicle Project at MIT (Womack et al. 1990 and references cited therein) analyzes the difference between Fordist and lean manufacturing in great detail. However, it focuses on issues of competitiveness and corporate strategy rather than on the effects of a change in the manufacturing paradigm on the determinants of vertical integration.

[6]The recent gains in market share by the Big Three may well be related to strong gains in manufacturing productivity that occurred during the last few years. In addition to the automotive industry, applications of lean manufacturing are reported for consumer and electronic goods, metal products, aircraft, aerospace, and computer industries (see Hollingsworth 1991).

[7]Asset specificity refers to a situation where one or both parties to a transaction have made investments such that the value of an exchange is greatest when it occurs between these two firms rather than with other firms (Perry 1989). Quasi-rent is the value of an asset in excess of its value in its next best use (Klein et al. 1978).

[8]For example, appropriable quasi-rents exist in specialized assets of oil refineries, pipelines, and oil fields. This leads to shared ownership in the pipeline by oil-field owners and refinery owners to remove the possibility of a separate owner capturing the rent associated with the pipeline (Klein et al. 1978).

[9]For example, in the five years between 1983 and 1988, average written contract length doubled for sourcing contracts in the U.S. auto industry (Helper 1991).

[10]The increase of mutual commitment in vertical relationships is treated as exogenous to the governance decision of the firm. Mutual commitment is a characteristic of the lean manufacturing system and as such assumed to be outside the scope of analysis of this paper. Williamson (1983, p.528) refers to a "mutual reliance relation" where both the up- and downstream company invest in relationship-specific capital. Such relationships are characteristic for lean manufacturing.

[11]Monteverde (1981, pp. 64-75) shows in a simple game-theoretic model that under symmetric conditions a player attempting to exploit the trading partner is not assured of being able to make himself unambiguously better off. Hence it is in the interest of both firms to find some way of achieving the cooperative solution which promises each party a certain payoff. "Both parties will realize that covert opportunism is impossible and will likely settle, instead, into mutual cooperation where there exists symmetry in bargaining leverage."

[12]There are numerous minor effects that are excluded from the analysis; e.g. design requirements, quality control, production and transportation costs, and negotiating strength of potential suppliers relative to those of the producer. By the central limit theorem these combined effects are assumed to be normally distributed.

[13]The category contractual relation includes both purely contractual and quasi-integrated relationships.

[14]It estimates the probability of vertical integration since Y_i is set to 1 for every vertically integrated transaction.

[15]This is a useful procedure for continuous variables; the scaled qualitative variables, human asset specificity, physical asset specificity, delivery interval, and develop, are treated as continuous variables (see Monteverde and Teece 1982a, Masten et al. 1989 and 1991).

[16]See Masten et al. 1989.

[17]Data sources were the U.S. Big Three: Chrysler, Ford, and General Motors. Saturn Corporation declined to participate in this project.

[18]'Platform' refers to the structural underbody of a car; it is a concept that defines vehicles with common wheelbase and other dimensional characteristics that would make them relatively simple to produce on a common line (Luria 1990a, p.143).

[19]Data were collected at the level of the individual car assembler-supplier relationship. Accordingly, each datapoint represents a particular assembler-supplier relationship. That way cases of multiple sourcing are represented by separate datapoints. The questionnaire allowed for a maximum of five assembler-supplier relationships per part. Data used in previous studies did not allow for a distinction between different suppliers for a particular part.

The data were obtained from purchasing and engineering staff responsible for the relevant platforms. In order to check for their accuracy, I arranged for a screening of the returned questionnaires by an independent expert on the automobile industry. The ratings for the variables human and physical asset specificity as reported in the questionnaires indicate a high degree of consistency in the data; for both measures the correlation of rankings ranges between .93 and .98 across auto assembler.

[20]I am indebted to Dan Luria for invaluable advice.

[21]Luria (1990b) measures the degree of in-house production in two different ways: by means of a 'value shipped' variable that gives the car assembler credit for 'make' as if all of the parts and assemblies shipped from its parts plants were added in those plants; and by means of a 'value added' variable that gives the car assembler credit only for the proportion of value added in its own parts plants. In both cases he finds the degree of in-house production to be greater at the level of subassemblies than at the level of parts and components.

[22]See Helper (1991) on the importance of measuring characteristics related to the organization of production in order to adequately capture the mutual commitment between assembler and supplier.

[23]Since this scale is inversely related to the frequency of transactions, β_5 is expected to be < 0.

[24]Quantitative measures of location are likely to be influenced by the potential endogeneity of the location decision. In order to account for that, a measure similar to the one used by Spiller (1985) was created. It included information on the location of the closest potential supplier and was calculated as the ratio of distance to the closest supplier and distance to the actual supplier. However, it was not found to contribute information beyond what DISTANCE already measured. Alternatively, a qualitative measure of the "importance" of close location of subsequent stages of production could have been used (see for example Masten et al. 1989). However, such a proxy could not distinguish several suppliers for a particular part.

[25]Since the scale of DISTANCE is inversely related to the concept of site specificity, β_3 is expected to be > 0.

[26]The coefficients for the company-dummies are not reported due to confidentiality reasons. The pattern of influence on the decision to integrate reported in Table 3 is robust with respect to the scaling of the qualitative independent variables; both quadratic and logarithmic transformations of these variables were tested.

[27]The degree of human asset specificity is measured on a five-point scale; the sample mean is 2.82.

[28]Monteverde and Teece (1982a) estimated a binomial probit model of vertical integration with data from U.S. auto manufacturers. Since Kirk Monteverde kindly provided access to his data, I was able to calculate the unpublished partial derivative for the human asset specificity variable (significant at the 95%-level) -- it is +.12 -- and use it as a benchmark value. However, several caveats apply to such a comparison. For example, different sampling procedures were used across studies. Monteverde and Teece left it up to the automobile manufacturers to supply them with information; in my study I sampled information on a given set of automobile parts across manufacturers. In addition, each of the studies probably received its information from a different set of respondents at the automobile companies. However, the robustness of the rankings of the qualitative independent variables was established for both studies.

I find no evidence for a statistical difference in the marginal effect of the degree of human asset specificity on the probability to vertically integrate between my own and the results of Monteverde and Teece. Their partial derivative was found to lie within two standard deviations from the slope of human asset specificity as estimated in my model. This finding is robust across specifications. The standard deviation was obtained by calculating the asymptotic variance of the slope of human asset specificity.

[29]A χ^2-test on (DELIVERY INTERVAL)^2 yields a value of 9.74; $\chi^2_{.99}(1) = 6.635$.

[30]See for example Linge (1991).

[31]Helper (1991) reports that supplier companies are able to increase the frequency of delivery without changing their production system. However, when a supplier has to deliver very frequently, e.g. in the case of seats which are now commonly delivered every hour to the assembly plant, she will have to make adjustments in her own production operation in order to assure timely delivery of defect-free parts (see also section 2b).

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