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DO MAKE OR BUY DECISIONS MATTER? THE INFLUENCE OF ORGANIZATIONAL GOVERNANCE ON TECHNOLOGICAL PERFORMANCE

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This paper investigates how firms' decisions to outsource or internalize production affect their technological performance. While several popular arguments and some anecdotal evidence suggest a direct association between outsourcing and technological performance, the effects of firms' governance decisions are likely to be contingent upon several specific attributes underlying a given exchange. This paper first demonstrates how standard performance models can improperly suggest a positive relationship between firms' outsourcing decisions and their technological performance. Models that account for firm- and transaction-specific features are then presented, which indicate that neither outsourcing nor internalization per se result in superior performance; rather, a firm's technological performance is contingent upon the alignment between firms' governance decisions and the degree of contractual hazards. Copyright © 2002 John Wiley & Sons, Ltd.

INTRODUCTION

The decision to outsource or vertically integrate a value-chain activity represents one of the more complex choices facing a firm's managers. On the one hand, integration requires management to commit significant resources to a course of action, the effects of which may be costly to reverse, while forgoing numerous advantages associated with the marketplace. On the other hand, integration may be required for a firm to accumulate resources necessary to generate or maintain a competitive advantage (Dierickx and Cool, 1989). The complexity of this decision has been exacerbated in recent years by the increasing rapidity of technological change and the geographic and organizational dispersion of knowledge (Clark and Fujimoto, 1991; Teece, 1992).

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A broad variety of outsourcing arrangements has emerged in response to these environmental changes. Whereas outsourcing used to be confined to fairly specialized, repetitive tasks such as facilities management or logistics, it has now spread to more visible and sensitive functions such as customer service, R&D, and manufacturing (Greco, 1997; Liebeskind *et al.*, 1996). Moreover, this trend is expected to continue for the foreseeable future. For instance, the outsourcing market for U.S.-based corporations is expected to grow more than threefold between 1996 and 2001, from $100 to $318 billion (Anderson, 1997).

Although there is widespread consensus on the importance of firms' vertical integration decisions, it remains unclear whether or how these boundary decisions affect various dimensions of firm performance. For example, it has been asserted that outsourcing capital-intensive production activities improves a firm's ability to respond flexibly to changes in technology or demand, to accumulate external knowledge, to avoid coordination inefficiencies, and to compress product

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development cycle times (e.g., Clark and Fujimoto, 1991; D'Aveni and Illinitch, 1992; Harrigan, 1983; Helper and Sako, 1995; Nishiguchi, 1994; Womack, Jones, and Roos, 1990). However, outsourcing may also contribute to the hollowing of corporations, resulting in the depreciation of existing capabilities *vis-à-vis* actual or would-be competitors as well as in the failure to seize opportunities to develop new capabilities (e.g., Bettis, Bradley, and Hamel, 1992; Quinn and Hilmer, 1994; Reich and Mankin, 1986).

An intermediate position is that the effects of individual sourcing decisions are contingent upon features of the individual transaction and the contracting environment. In fact, a substantial body of influential research initiated in the 1970s has identified various factors that influence firms' decisions to select alternative governance structures, be they horizontal or vertical in nature (e.g., Klein, Crawford, and Alchian, 1978; Williamson, 1975). Recent extensions of this research have noted that internalization enhances coordinated adaptation across contiguous value chain activities, just as firms relying on weaker forms of governance can benefit instead from the marketplace's high-powered incentives (e.g., Chesbrough and Teece, 1996; Monteverde, 1995; Teece, 1996). In spite of the wealth of studies considering the factors influencing firms' governance choices, however, very little empirical research has gone on to examine the performance and competitive implications of firms' governance decisions in general, or their production sourcing strategies in particular (e.g., D'Aveni and Ravenscraft, 1994; Masten, 1993).

In response to the tension between the potential benefits and risks associated with outsourcing relative to vertical integration, as well as to redress the limited evidence on the actual consequences of firms' vertical boundary decisions, this study focuses on the performance effects of firms' production sourcing strategies. More specifically, we investigate the technological performance implications of production internalization versus outsourcing by firms in the global semiconductor industry. Our focus on a precise, disaggregated measure of firm performance as well as our modeling approach mitigate the potential confounding effects that impede the identification of organizational performance's antecedents (March and Sutton, 1997).

Beyond considering popular arguments concerning the absolute benefits or shortcomings of outsourcing and vertical integration, we also assess comparative perspectives on the performance implications of firms' vertical integration decisions. Specifically, we examine the fundamental 'discriminating alignment' tenet of transaction cost theory (Williamson, 1985), which focuses on the performance implications of the fit between firms' governance choices and a set of specific attributes of the transaction at hand (e.g., Anderson, 1988; Sampson, 2001; Silverman, Nickerson, and Freeman, 1997). The paper also recognizes that even after one accounts for the influence of the specific transactional features highlighted by transaction cost theory, other unobserved transactional or even firm-level attributes may shape firms' vertical boundary choices and their consequences. We explicitly account for the potential influence of unobserved heterogeneity by employing a series of two-stage, self-selection models. Relative to prior work examining the relationship between vertical integration and its antecedents or the relationship between vertical integration and its consequences, this two-stage design permits an integrative model that simultaneously captures firms' vertical integration and outsourcing decisions as well as both the observed and unobserved antecedents of these decisions and their performance implications. As a result, we are able to address a criticism of existing empirical research in transaction cost economics that focused on the effects of transactional characteristics on the choice of governance, rather than on the performance of alternative modes of organization (e.g., Masten, 1993).

The paper proceeds as follows: We first offer a brief review of the literature and present background theoretical material to motivate two research questions. The next section presents the research design, provides methodological details on self-selection, and describes the resulting two-stage models we employ in the analyses. This is followed by a presentation of results from a sample of over 700 decisions involving the production of semiconductor devices. These results imply that outsourcing positively influences firms' technological performance when one relies on standard multivariate analyses that do not address the endogeneity of firms' outsourcing and vertical integration decisions. However, models that account for self-selection indicate that such effects

are driven by unobserved firm and transactional characteristics that lead firms to choose outsourcing over vertical integration. Moreover, the findings demonstrate that the alignment between firms' governance choices and the features of exchange identified by transaction cost theory affects firms' technological performance. For example, firms that outsource production activities in the face of various contractual hazards identified by transaction cost theory tend to experience technological performance penalties. A concluding section discusses the implications of these findings and identifies a number of promising avenues for future research that integrates firms' governance choices with the antecedents and consequences of those decisions. This discussion also serves to illustrate the broader applicability of our modeling approach in research on strategic choices and their performance implications.

BACKGROUND LITERATURE AND RESEARCH QUESTIONS

Vertical governance and technological performance

Although the strategy literature has paid a great deal of attention to the factors that influence the make or buy decision, relatively little empirical work has addressed the performance implications of these decisions (e.g., D'Aveni and Ravenscraft, 1994; Masten, 1993; Rumelt, 1974, 1982). This lack of attention is surprising given that the heterogeneity of firm performance represents one of the fundamental questions in the strategy field (Rumelt, Schendel, and Teece, 1994) and that the integration decision represents a large, difficult-to-reverse investment that directly affects firms' capabilities and property rights.

Although there exists little empirical work that has rigorously examined whether integration affects performance, numerous conceptual papers have described the potential advantages associated with outsourcing and vertical integration (see Mahoney, 1992, for a review). Outsourcing not only shifts costs from the focal firm to suppliers, but it may also create economic value within the supply chain, enabling a firm to tap into specialized capabilities (e.g., Dyer and Ouchi, 1993; Helper and Sako, 1995; Mowery, Oxley, and Silverman, 1996; Nishiguchi, 1994; Womack *et al*., 1990) and to shorten product development cycles through concurrent development (e.g., Clark, Chew, and Fujimoto, 1987; Clark and Fujimoto, 1991). Teece (1992) argues that de-integrated corporate hierarchies avoid the decision making complexities typically associated with integrated concerns and are therefore better suited to competing in environments where the convergence of technologies from disparate sectors and time to market are of importance.

However, vertical integration may also enhance performance, chiefly because of the coordination benefits associated with internalization. While increased coordinative abilities may be due either to an improved flow of administrative information or to technological interdependencies, enhancements in electronic data exchange technologies suggest that the most significant coordinative advantages are based on technological interdependencies that exist between activity stages. This latter point is supported by research which suggests that locating manufacturing activities outside of the firm's boundaries can degrade a firm's capabilities by impairing cross-functional coordination (e.g., Allen, Lee, and Tushman, 1980; Chesbrough and Teece, 1996; Griffin and Hauser, 1992; Hatch and Mowery, 1998; Teece, 1996).

The opposing conclusions reached by these two groups of arguments are the result of different sets of underlying assumptions. Arguments emphasizing the benefits of outsourcing assume that many critical capabilities reside outside the boundaries of the firm and that appropriation problems are minimal. Such a situation is most likely in environments involving mature, autonomous technologies (Teece, 1984). In these settings, performance is directly tied to the ability to identify, isolate, and solve a specific set of independent technical problems. Under these conditions, contracting hazards are minimal, specialization is favored, and outsourcing will enhance performance by allowing specialized suppliers to benefit from scale economies by pooling demand and from learning economies by focusing on a limited number of well-defined activities. Recent empirical results are consistent with these arguments (e.g., Liebeskind *et al*., 1996).

In contrast, arguments extolling the benefits of integration assume that the most valuable capabilities reside within the firm and that appropriation problems are significant. As a principle advantage of internal organization is the ability to provide

enhanced information transfer and coordination across activities within the production system, this argument implies that performance is principally driven by second- and higher-order interactions among a set of value-chain activities. While the adoption of an architectural innovation may diminish the value of established information filters and communication channels (e.g., Henderson and Clark, 1990), integration is likely to remain a superior form of governance for managing technologies that require a great deal of coordinated adjustment within the production system (e.g., Chesbrough and Teece, 1996; Langlois, 1992; Teece, 1996).

Unobserved attributes, vertical governance, and technical performance

The preceding section suggests that the value of employing a particular organizational form is strongly dependent upon crucial assumptions regarding the nature of underlying resources, supplementary attributes of the focal firm, and other industry conditions. However, absent a theory of resource value, these arguments will be necessarily incomplete. While existing anecdotal (e.g., Kotabe and Murray, 2001) and some large-scale empirical evidence (e.g., D'Aveni and Ravenscraft, 1994) is suggestive of a direct relationship between vertical integration decisions and performance, this direct comparison is appropriate only if firms' governance choices are not influenced by other firm- or transaction-level characteristics.

The proposition that firms' governance choices are not influenced by various firm- and transaction-level characteristics, however, is untenable. Simple comparisons of integration decisions across firms facing similar environments—such as General Motors and Chrysler in the automobile industry or IBM and Compaq in the personal computer industry—suggest that firms differ dramatically in their sourcing decisions. For instance, while IBM is highly integrated, Compaq outsources a number of its component assembly processes. A number of conceptual articles (e.g., Quinn and Hilmer, 1994; Barney, 1999) and a limited body of case study research (e.g., Argyres, 1996) echo this point, arguing that relative firm-level capabilities affect firms' governance decisions.

It is further likely that many of the firm- and transaction-specific characteristics alluded to above also influence firms' technological performance. For instance, in a series of influential papers, Henderson and Clark (1990) and Henderson (1993) have argued that firms' ability to successfully adopt new technologies hinges on the match between the architectural requirements of the new technology and firm-specific information filters and communication channels. Recent evidence that differences in certain HR practices influence the speed and quality with which semiconductor production facilities are able to implement new process technologies paper suggests a similar conclusion (Macher and Mowery, 2001).

If there are unobserved attributes that influence both governance choice and performance, then a self-selection bias will be present, and normative implications drawn from these analyses may be incorrect (e.g., Heckman, 1979; Maddala, 1983; Masten, 1993; Masten, Meehan, and Snyder, 1991). The presence of unobserved heterogeneity in performance models potentially biases parameters for indicator variables used to measure the influence of a firms' governance choices since firms select governance forms based on their own maximizing analyses rather than on a random basis. Thus, in standard ordinary least squares models, the effects of these decisions can be confounded by unobserved factors that prompted the firm to choose one vertical integration approach over another in the first place. This leads us to state the following research question:

> *Research Question 1: Do unobserved attributes underlying firms' vertical integration decisions influence the governance-technological performance relationship?*

Governance misalignment and technical performance

While any number of unobserved transaction-, firm-, or industry-level characteristics may give rise to a self-selection problem, a theoretical discussion of firms' boundary choices and their implications requires researchers to identify these factors and their causal relationships. Transaction cost economics (TCE) helps in this effort by elucidating specific transaction-level characteristics that influence the efficiency of alternative forms of governance. More specifically, a fundamental tenet of

transaction cost theory, the notion of discriminating alignment, is that efficiency will be enhanced when a fit exists between the chosen governance arrangement and the underlying attributes of that transaction and the broader contracting environment (e.g., Williamson, 1985, 1991). For example, TCE holds that vertical integration is beneficial under small numbers situations in aligning the interests of exchange parties and providing administrative rules and procedures to adjudicate differences, thereby facilitating sequential adaptation (Monteverde and Teece, 1982; Walker and Weber, 1984; Williamson, 1975). However, these benefits must be weighed against the greater administrative costs associated with internal governance.

Based on this line of reasoning, it follows that the performance implications of outsourcing versus vertical integration should hinge upon the alignment between the chosen governance structure and the attributes of the transaction and its contracting environment. For example, for complex exchange relationships involving transaction-specific investments, a firm that selects a simple governance structure lacking adequate safeguards will be exposed to moral hazard and hold-up risks. By contrast, the potential consequences of adopting an excessively complex governance structure for a simpler relationship include a loss in flexibility and decision-making speed due to the imposition of bureaucratic controls (Williamson, 1985, 1991). The bureaucratic decision making processes implied by hierarchy may also dull incentives for innovation (Chesbrough and Teece, 1996; Teece, 1996). Thus, in contrast to contentions that governance has an absolute effect on performance, transaction cost theory proposes that the fit between a governance arrangement and the transaction's attributes influence the efficiency of these intra- and interorganizational exchanges. Given these theoretical arguments and the paucity of research on the alignment-performance relationship (e.g., Anderson, 1988; Silverman *et al*., 1997), we address the following research question:

> *Research Question 2: Does the fit between firms' vertical governance decisions and relevant transactional attributes highlighted by TCE influence technological performance?*

METHODOLOGY

Data

The empirical setting for this paper is the production of semiconductor devices. Such transactions are interesting to focus on for several reasons. First, production capabilities are of tremendous importance in this industry. The ability to produce semiconductor devices using advanced processes is directly tied to both improved end-product performance and reduced cost. As a result, there is a strong incentive for all industry participants to incorporate advanced processes into their products. Second, while many semiconductor firms remain integrated into both design and production, a number of firms have focused their operations solely on design and have outsourced their production needs. Thus, despite the importance of production activities, there is no single, universally accepted method for the organization of these transactions. Finally, even in instances where semiconductor production is internalized within the firm, production usually takes place in a location that is physically separated from design and other upstream activities. Consequently, in this industry, the potential influence of geographic proximity does not confound the effects of firms' governance decisions on performance. These considerations suggest that the semiconductor industry provides an ideal setting in which to examine the relationship between organizational governance and a set of competitively important technical capabilities.

The data for this paper were derived from a 1997 report of firm-level activity within the semiconductor industry published by the Integrated Circuits Engineering Corporation (ICE). This document summarizes the responses to surveys conducted in 1996 regarding the corporate, production, and alliance activities of 176 global integrated circuit manufacturers. The portion of the report utilized in this paper described 192 instances where these firms managed production externally through sourcing (i.e., buy) agreements and 367 instances where these firms managed production in wholly-owned production facilities. Preliminary data analysis indicated that the necessary product-market and process-technology information was available for 174 of the 192 (90.6%) sourcing agreements and 220 of the 367 (60.0%) internal production lines in the sample. Since a firm may access production for multiple products

and processes through a single sourcing agreement or fabrication line, we record a separate observation for each product market-process technology combination.[1] For example, a firm may sell memory devices using 1.0 micron technology, memory devices using a 0.8 micron technology, and application-specific integrated circuits (ASICs) using a 1.0 micron technology. These product-market, process-technology combinations would be recorded in our sample as three separate observations. Upon disaggregation to the product market-process technology level of analysis, our final sample consisted of 714 production decisions.

Measures

Technological performance

The measure of technological performance used in this paper is defined as a function of the focal transactions transistor density provided by the focal transaction. Transistor density is the fundamental driver of both cost and product performance in the industry and represents a universally valued success factor (e.g., Hazewindus and Tooker, 1982; Gruber, 1994). Prior research has measured technological performance as a function of a primary indicator of transistor density, the line width, or feature size, at which information is etched onto a semiconductor circuit (e.g., Eisenhardt and Schoonhoven, 1996; West and Iansiti, 1998). Since the average feature size varies across product-market applications, we transformed the raw feature size value by standardizing it with respect to the mean and standard deviation for all other observations within the same product-market subfield. Further, since smaller feature size implies better technological performance, we take the negative of this standardized value (i.e., technological performance $= -(x - \bar{x}_j)/(s_j)$, where x is the focal transaction's feature size, $\bar{x}_j$ is the average feature size in product-market j, and s_j is the standard deviation of feature sizes in this product-market).[2]

Thus, a positive value for technological performance implies a company is using a technology that is more advanced than the average technology used by its immediate competitors. In contrast, a negative value indicates that substandard technology is being utilized. The magnitude of the measure indicates the degree to which the technology is ahead or behind the technology curve for its product-market subfield. Data on firms' technological performance in 1996 were obtained from the 1997 edition of Integrated Circuit Engineering's *Profiles of IC Manufacturers and Suppliers*.

Explanatory variables

In order to examine the proposition that technological performance differs across transactions over which different levels of managerial control are maintained, we define the variable *Governance Choice (Buy)* to be equal to one for transactions where a firm engages in a contractual relationship for its production activities, and equal to zero for transactions where a firm maintains full ownership over its production activities.

The primary argument put forth in this paper is that technological performance is influenced by the degree to which each particular transaction is appropriately governed. To test this proposition, we develop a measure, *Governance Misfit*, that captures the probability that another governance form is more appropriate given the contractual hazards surrounding the exchange. In developing this measure, we follow Anderson (1988) and Silverman *et al.* (1997) in estimating the likelihood that a particular governance form will be chosen as a function of transaction-level attributes derived from TCE. Specifically, we estimate the most likely value for *Governance Choice (Buy)* for a given transaction, using the following probit model:

$$\text{Prob}(Y_i = 1) = \Phi(\beta' X_i) \qquad (1)$$

where Y_i is the governance choice variable for the ith observation, X_i is a vector of characteristics surrounding the transaction that determine the contractual hazards, β is a vector of estimated coefficients for these characteristics, and $\Phi(\cdot)$ is the standard normal cdf. The degree of *Governance*

[1] Following industry practice, we distinguish seven product markets: analog devices, application specific integrated circuits (ASICs), discrete devices, digital signal processors (DSPs), memory devices, microprocessors, and telecommunications devices. The primary process technologies in use as of 1996 included 1 micron, 0.8 micron, 0.5 micron, 0.35 micron, and 0.25 micron technology.

[2] Although smaller semiconductor feature sizes support superior performance, to ease interpretation of our results, we reversed the sign of our technological performance measure so that positive values indicate supernormal performance, and negative values indicate substandard performance.

Misfit is then defined as $1-\Phi(\beta' X_i)$ when *Governance Choice (Buy)* is equal to one (i.e., when a transaction is outsourced) and as $\Phi(\beta' X_i)$ when *Governance Choice (Buy)* is equal to zero (i.e., when a transaction employs internal governance). Thus, governance misfit measures the probability that too much governance is employed for transactions that are internally governed and the probability that too little governance is employed for transactions that are outsourced.

The vector of characteristics used to determine the level of contracting hazards in the first stage probit model includes transaction-level measures for the *ex ante* number of suppliers, the specificity of the assets exchanged, and the uncertainty of product demand, as well as controls for firm industry tenure and firm size. The measure of *ex ante* number of suppliers accounts for the effect that shifts in bargaining power due to the number of available suppliers will have on firms' make or buy decisions (e.g., Pisano, 1990). This measure is obtained by counting the number of firms that supplied production for the relevant process technology during our sample time frame.[3] Following Levy (1985), the measure of product market demand uncertainty captures unanticipated shifts in the demand for a specific type of semiconductor device by calculating the variance surrounding a forecasted trend in demand for products within the relevant product-market subfield. Specifically, demand uncertainty is measured as the sum of squared errors from a regression of the relevant product-market's historical demand rates for the years 1990– 96.

While a direct measure of asset specificity was not available for this research, we were able to utilize a previously developed industry-specific construct that captures the conditions likely to give rise to high asset specificity. The logic supporting this measure is based on cross-product-market differences in the need for coordination and mutual adaptation across value chain activities. These differences account for factors such as the number of design attributes that need to be specified, the reliability with which those attributes can be measured, and the degree to which these attributes influence the performance of other elements of the product (e.g., Chesbrough and Teece, 1996). Such adaptation is, in turn, facilitated by the development of specialized resources (e.g., reporting structures, information systems, and common language) that promote technical dialogue (Henderson and Clark, 1990; Henderson, 1993; Monteverde, 1995). In the semiconductor industry, coordination requirements are thought to be particularly heavy in analog and leading-edge memory product markets.[4] Consequently, we identify high asset specificity conditions as those where the exchange involves either analog or memory products (asset specificity = 1). Asset specificity is coded as zero for all other transactions.

Control variables

Although our interest is in developing a parsimonious model of the relationship between the governance mechanisms used to manage production activities and technological performance, other firm- and transaction-specific characteristics may influence our results. For instance, larger firms may face a degree of institutional insulation and bureaucratization that decreases their responsiveness to shifting industry conditions (Haveman, 1993). In contrast, larger organizations often have superior financial and human resource endowments that enable them to internalize production and invest in state-of-the-art production equipment. Large firms may also have greater market power or positional advantages compared to their smaller rivals that affect their incentives and abilities to adapt to changing environments (e.g., Delacroix and Swaminathan, 1991; Baum and Oliver, 1991; Baum and Mezias, 1992). Similarly, firm age may influence both a firm's performance and its choice of a particular governance form. For instance, the liability of newness concept suggests that older firms benefit from accumulated experience (e.g., Amburgey, Kelly, and Barnett, 1993; Carroll and Delacroix, 1982), but others have countered that firms become increasingly ossified as they age (e.g., Barnett, 1990; Ranger-Moore, 1997).

In order to ensure that our estimated relationships are not unduly influenced by such factors,

[3] A squared term is included to improve model fit.

[4] Although the production of both analog and digital memory products requires heavy transaction specific investment, the underlying cause of the specific investment varies between the two markets. While the production of analog devices may not require state-of-the art production technology, heavy customization requirements necessitate a high degree of adaptation across design and production activities. The production of digital memory devices, in contrast, generally requires that design and production engineers develop state-of-the-art processes (Monteverde, 1995).

all models include a series of control variables. We defined *Firm Size* as the log of the firm's average domestic sales for the period 1994 through 1996. *Firm Tenure* was measured as the number of years that had passed since the firm was first founded or, for conglomerates, the number of years since the firm first began selling semiconductors. We accounted for differences in sourcing strategy that may simultaneously influence governance form and performance through two additional controls. The variable, *Governance Duration*, is defined as the number of years that the focal sourcing agreement or production line has been active. This control captures effects due to the depth of external relationships or internal experiences. Similarly, the variable, *Buy Portfolio*, accounts for differences attributable to the breadth of a firms' sourcing network and is defined as the number of contemporaneous production sourcing transactions managed by the firm.

Descriptive statistics

Table 1 provides summary and zero-order correlation statistics for the entire sample. While the positive correlation between technological performance and the use of buy transactions is consistent with the popular contention that outsourcing provides the flexibility to access superior technical capabilities, the large and significant intercorrelations between technological performance, firms' governance choices, and a number of the control variables indicate the need for multivariate analyses to partial out the influence of each variable on technological performance.

Technological performance model specification

As noted above, a complication arises when analyzing the influence of governance form on performance in that firms are able to willfully choose the form of governance they use to manage a particular transaction. Since firms are able to self-select the observed form of governance based on their own performance maximizing analyses, it is likely that the observed level of technological performance is conditional upon unobserved factors that influence firms' governance choices. To correct for these potential biases, we employed a two-stage technique derived from work in labor economics (e.g., Heckman, 1978, 1979; Lee, 1982, 1983; Lee, Maddala, and Trost, 1980). This modeling approach can be summarized as reestimating regression coefficients by introducing an adjustment term, called the inverse Mills ratio, to the performance model.

The starting point for this procedure lies is the realization that the regression model is misspecified if a selection process underlies the sampling procedure. Heckman's original examples included the study of market wages for women (Heckman 1976, 1979). He recognized that the sample of working women is likely not random since the decision to participate in the labor force is an outcome of unobserved factors (e.g., the presence of small children in the family). In the context of semiconductor production, a similar problem arises because firms may select to outsource or vertically integration production of semiconductor devices based on unobserved characteristics associated with the firm or transaction. Failure to address this selection process leads to the possibility that performance differentials may be incorrectly attributed to firms' governance decisions, when they are in fact due to unobserved factors associated with the governance decision.

Heckman (1976, 1979) proposed a way to deal with this self-selection problem. In the present study, the intuition is that the estimates in the performance model need to be corrected by controlling for the propensity of the firm to choose a particular form of governance. Technically, one first estimates a first-stage probit model to specify a selection equation (Equation 1) and then calculates the inverse Mills ratio, which is used as a control variable in the second-stage performance model. The inverse Mills ratio, λ_{ji}, is given as $\lambda_{1i} = (\phi(\beta' X_i))/(\Phi(\beta' X_i))$ for observations that are outsourced (i.e., $j = 1$) and $\lambda_{0i} = -\phi(\beta' X_i)/([1 - \Phi(\beta' X_i)])$ for observations that are produced in-house (i.e., $j = 0$). In both cases, ϕ $(\cdot)$ is the standard normal pdf, and $\Phi(\cdot)$ is the standard normal cdf. Second-stage models that incorporate this correction provide consistent and unbiased estimates (e.g., Maddala, 1983; Greene, 1997). An existing application of this technique in the management literature can be found in Shaver (1998).

RESULTS

First-stage governance choice estimates

Table 2 presents the results from three potential first-stage governance choice models. The probit

Table 1. Descriptive statistics and correlation matrix for performance model[a]

Variable	Mean	S.D.	1	2	3	4	5	6	7	8
1. Technological Performance	0.000	0.996								
2. Firm Industry Tenure	22.941	13.720	−0.068†							
3. Firm Size	5.968	2.818	−0.008	0.398***						
4. Governance Duration	8.492	9.102	−0.243***	0.381***	0.255***					
5. Buy Portfolio	2.499	3.458	0.228***	−0.318***	−0.276***	−0.386***				
6. Asset Specificity	0.458	0.499	0.000	−0.100**	−0.045	−0.147***	0.085*			
7. Governance Choice (Buy)	0.335	0.472	0.289***	−0.403***	−0.409***	−0.475***	0.750***	0.122**		
8. Governance Misfit	0.455	0.138	0.367***	−0.348***	−0.324**	−0.457***	0.633***	0.112**	0.843***	
9. Correction for Self-Selection (λ)	1.443	0.938	−0.507***	0.627***	0.553***	0.516***	−0.481***	−0.225***	−0.604***	−0.669***

[a] $N = 714$. $^{\dagger}p < 0.10$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$

Table 2. Probit estimates for first-stage governance choice model[a,b]

Independent variables	Model I	Model II	Model III
Intercept	1.175***	0.160	−0.236
	(0.136)	(0.441)	(0.465)
Firm Tenure	−0.035***	−0.028***	−0.031***
	(0.005)	(0.005)	(0.005)
Firm Size	−0.153***	−0.175***	−0.163***
	(0.021)	(0.024)	(0.025)
Ex Ante Number of Suppliers		0.223***	0.220***
		(0.047)	(0.047)
Ex Ante Number of Suppliers Squared		−0.010***	−0.010***
		(0.001)	(0.001)
Demand Uncertainty		0.088	0.465*
		(0.126)	(0.187)
Asset Specificity		0.271*	1.264***
		(0.134)	(0.381)
Demand Uncertainty*Asset Specificity			−0.728**
			(0.261)
N	714	714	714
Log likelihood	−361.12	−279.88	−275.93
$-2[L(c) - L(\beta)]$[c]	188.08(2)***	350.56(6)***	358.46(7)***
$-2[L(\text{Model I}) - L(\beta)]$		162.48(4)***	170.38(5)***
$-2[L(\text{Model II}) - L(\text{Model III})]$			7.90(1)**

[a] Positive coefficients indicate a greater probability of external governance (i.e., buy).
[b] †$p < 0.10$; *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$
[c] Log likelihood for null model was −455.161. Appropriate degrees of freedom are reported in parentheses.

model utilized in this first step is fit using all observations in the sample and differentiates firms that outsource from those that internalize production. Model I presents a baseline model that consists of an intercept term and measures of firm tenure and size. Models II and III introduce measures derived from transaction cost theory that are widely held to affect governance choice. In particular, Model II introduces measures of the *ex ante* number of available suppliers, the level of product demand uncertainty, and the level of specificity in the assets used in production. Since uncertain environments may lead to contractual renegotiation that can be hazardous in the presence of specific investments, Model III introduces an interaction term between demand uncertainty and asset specificity.

The results from the first-stage governance choice models are largely consistent with expectations and results published in the literature. The negative coefficients associated with the measures for firm tenure and firm size are compatible with observations regarding the production decisions of firms within the semiconductor industry. The advent of specialized manufacturing firms (i.e., foundries) has allowed recent entrants to the industry to utilize vertical sourcing agreements for their production needs (e.g., Macher, 2001). Given the increasing importance of foundries as well as the observation that the construction costs of semiconductor fabrication plants often reach well over $1 billion, it is not surprising to find that smaller, potentially resource-constrained, firms tend to utilize vertical sourcing relationships. Consistent with previous academic research, the significant positive coefficient associated with the *ex ante* number of suppliers indicates that firms in the semiconductor industry internalize production when small numbers bargaining problems are severe and outsource as the number of available suppliers increases (e.g., Pisano, 1990). At first glance, the positive coefficients associated with the measure for asset specificity might seem surprising. However, the negative interaction effect observed in Model III is consistent with the basic predictions of transaction cost economics (Coles and Hesterly, 1998; Mahoney, 1992). Specifically, firms internalize transactions when it is likely that they will need to renegotiate supplier contracts under conditions of high asset specificity.

The robustness of the estimated coefficients across model specifications suggests that the transaction- and firm-level effects included in our

models uniquely influence firms' make or buy decisions for our sampled transactions. Given the stability of the estimated coefficients across specifications as well as the results of the log-likelihood ratio tests presented at the bottom of Table 2, the results obtained in Model III are used in the formulation of the inverse Mills ratio for the multivariate regression estimates presented for the second-stage performance model.

Second-stage performance estimates

Table 3 provides the results of our performance models. Model I presents a baseline specification that consists of an intercept term, our control variables, and a dichotomous variable for the direct effect of governance. While Model I does not control for self-selection, and is therefore likely to be misspecified based on our arguments, we present these results to demonstrate how the correction for self-selection affects the coefficient for governance choice. Model II adds the correction for self-selection (λ). However, the estimated coefficients in Model II remain restricted to be equivalent across make and buy transactions. Model III addresses this restriction by providing unrestricted estimates for each of the covariates across transactions utilizing internal production ('Make' models) and vertical outsourcing agreements ('Buy' models). Model IV introduces the measure for governance misfit and provides separate estimates for each of the different modes of governance choice. As expected, F-tests of the null hypothesis that all of the coefficients are jointly zero are strongly rejected in all models ($p < 0.001$). The estimated coefficients for lambda are also negative and strongly significant in all models ($p < 0.001$), indicating that firms have self-selected the most favorable form of governance.

The significant intercorrelations between a number of the variables in our models, and in particular between governance misfit and the self-selection correction (i.e., λ), led us to investigate potential multicollinearity problems through variance inflation factors (VIFs), conditioning indices, and variance decomposition proportions. The maximum VIF obtained in the four models is 5.32, which is substantially below the rule-of-thumb cut-off of 10 for multiple regression models (Neter, Wasserman, and Kutner, 1985: 392). The maximum conditioning indices for these models was 34.15. The variance decomposition proportions associated with this index indicated that the underlying dependencies involved the intercept term

Table 3. Estimates for second-stage technological performance models[a]

Independent variables	Model I	Model II	Model III		Model IV	
			Make	Buy	Make	Buy
Intercept	0.175	0.140	−0.149	0.413**	−0.049	1.625***
	(0.129)	(0.101)	(0.115)	(0.141)	(0.372)	(0.406)
Firm Industry Tenure	0.004	0.028***	0.028***	0.026***	0.028***	0.021***
	(0.003)	(0.003)	(0.003)	(0.006)	(0.003)	(0.006)
Firm Size	0.045**	0.131***	0.146***	0.113***	0.148***	0.088***
	(0.014)	(0.012)	(0.015)	(0.023)	(0.017)	(0.024)
Governance Duration	−0.018***	0.002	0.001	−0.010	0.001	−0.010
	(0.005)	(0.004)	(0.004)	(0.018)	(0.004)	(0.018)
Buy Portfolio	0.002	−0.014	−0.000	−0.025+	0.001	−0.028*
	(0.015)	(0.012)	(0.023)	(0.013)	(0.023)	(0.013)
Governance Choice (Buy)	0.597***	0.149				
	(0.124)	(0.100)				
Governance Misfit					−0.247	−1.908**
					(0.870)	(0.600)
Correction for Self-selection (λ)		−0.998***	−0.984***	−1.118***	−1.004***	−0.838***
		(0.048)	(0.053)	(0.143)	(0.087)	(0.166)
N	714	714	475	239	475	239
Model F	18.86***	97.67***	80.00***	12.79***	66.55***	12.75***
Adjusted R^2	0.111	0.449	0.455	0.199	0.454	0.229

[a] $+ p < 0.10$; $* p < 0.05$; $** p < 0.01$; $*** p < 0.001$

and the misalignment variable. While the maximum value moderately exceeds the value of 30 used to identify underlying near dependencies with borderline tightness (Belsley, Kuh, and Welsch, 1980: 112), it is well-below the cutoff value of 100 used to identify substantial variance inflation and 'potential harm to regression estimates' (Belsley *et al*., 1980: 153). Thus, we conclude that the regression estimates presented in Table 3 are not biased by the presence of multicollinearity.[5,6]

The highly significant and positive coefficient on governance choice presented in Model I suggests that semiconductor production transactions managed through outsourced relationships exhibit superior technological performance characteristics as compared to those managed internally by vertically integrated concerns. Model I also suggests that the performance of all transactions diminishes over time. These findings are consistent with the popular argument that outsourcing provides access to suppliers' specialized capabilities.

The results presented in Model II stand in stark contrast to those presented in Model I. Model II provides no evidence that governance choice influences technological performance. Moreover, the highly significant coefficient for the self-selection correction term (λ) in Model II indicates that unobserved characteristics underlying a decision to make or buy strongly influence the technological performance of that transaction relative to equivalent transactions where the alternative governance form was chosen. The negative parameter estimate for the self-selection term further indicates that the greater the firm's propensity to buy based on its unobserved characteristics, the higher its technological performance (see Dolton and Makepeace, 1987, for details on the interpretation of the self-selection coefficient term). These results suggest that the influence of governance choice on technological performance observed in Model I is largely driven by a self-selection process and that firms' governance choices for production in this industry are appropriately treated as endogenous.

While the specification presented in Model II facilitates comparison with Model I, it is limited to the extent that the estimated coefficients are restricted to be equivalent across the two governance choices. Model III relaxes this constraint by separately estimating models for 'make' and 'buy' transactions in the presence of the self-selection correction.

Model III also provides the information necessary to assess whether, on average, firms that chose to 'make' perform better than if they had chosen to 'buy', and whether firms that chose to 'buy' perform better than if they had chosen to 'make.' The average expected technological performance for each of these four contingencies is obtained by multiplying the coefficient estimates in Model III by the vector of firm attributes for the relevant sub-sample of make or buy transactions. The results of these calculations indicate that the expected technological performance for the 475 transactions that were conducted within a firm is -0.204 and the technological performance that one would predict if these same transactions were outsourced is -0.299. Similarly, while the expected technological performance for the 239 transactions that were outsourced is $+0.405$, the technological performance that one would predict if these transactions were internalized would be only $+0.281$. These results indicate that firms in this sample that internalized their production decisions performed better than they would have been expected to if they outsourced these transactions, and that firms in our sample that chose to outsource their production activities perform better than if they had chosen to internalize these activities.

An alternative, but related, means of testing the discriminating alignment proposition is to

[5] Even if the correlations between the variables in our models included an underlying near dependency, this would not necessarily imply that our estimated parameters are biased. As stated by Belsley *et al*. (1980: 115) 'Near dependencies among the variables may degrade parameter estimates (e.g., inflate standard errors) without necessarily harming them for the purposes of hypothesis testing.' Thus, while the resulting confidence intervals obtained under these conditions may be wider, the parameter estimates are not biased. Given that the examined effect is statistically significant and in the hypothesized direction across models that contain relevant combinations of the collinear variables, we conclude that our estimates have not been biased by excessive collinearity.

[6] A second potential complication in the analysis is the nonindependence of the observations. The models reported in this paper assume that each of the observations in our sample are equally weighted and independent. However, a few firms appeared multiple times in our sample. While the transactions employed by these firms were certainly not identical, we suspected that there might have been common elements across the transactions involving each firm. In the regression analyses we addressed this concern by calculating heteroskedastic-corrected standard errors. Such an approach provides a robust estimator for clustered data where observations are assumed to be independent across firms, but not independent within firms. The results using these alternative methods are consistent both in magnitude and significance with those reported in this paper.

examine whether the degree of governance misfit directly influences firms' technological performance. Incorporating a measure of governance misfit directly into the analysis provides a test regarding the performance of firms that 'bought', but had good reasons to 'make' and firms that 'made', but had good reasons to 'buy.' The results in Model IV indicate that governance misfit does have a negative impact on technological performance for buy transactions ($p < 0.01$); however, the corresponding parameter estimate does not reach significance in the 'make' performance model. These findings indicate that firms' technological performance is reduced by governance underfit—when the firm fails to implement adequate safeguards to offset hazards in the contracting environment. While the excessive bureaucracy associated with governance overfit may penalize other dimensions of performance (e.g., excessive administrative costs), our models provide no evidence that excessive governance reduces technological performance.

Finally, the findings associated with our control variables deserve comment. For instance, after controlling for governance selection, both firm industry tenure and firm size are associated with greater technological performance of both make and buy transactions (both $p < 0.001$). No evidence is found to suggest that the expected level of technological performance varies with the duration of either type of transaction. There is evidence of a weak negative relationship between the size of a firm's sourcing portfolio and technological performance, suggesting that technological performance is enhanced when firms limit the breadth of their sourcing transactions.

DISCUSSION

The field of strategic management is interested in describing why firms differ in their investment choices and subsequent performance (e.g., Rumelt *et al.*, 1994). Indeed, much of the work in the field can be categorized into studies that have examined factors that influence one element of strategic choice, organizational governance, and those that have examined how firms' choices affect performance. Much of the research in the first group estimates governance choice models rather than examining performance directly. Normative implications are often drawn from such models under the implicit assumption of the presence of a selection environment that ensures that observed governance choices are efficient. While the second group of studies examines the performance implications of strategic decisions, a complication commonly arises when such decisions are closely linked to underlying firm, transaction, and environmental attributes, and these decisions are made based on firms' performance expectations. In such situations, correlation or ordinary regression analyses are likely to produce misleading empirical results.

In order to obtain unbiased results in these settings, empirical models must simultaneously address firms' governance choices as well as their drivers and consequences. We believe that the two-stage modeling approach used in this study has wide applicability in the field of strategy research. This is nicely illustrated in a recent study on modes of foreign market entry conducted by Shaver (1998), which demonstrated how self-selection bias could influence normative implications drawn from studies on the performance implications of firms' foreign market entry decisions. More generally, the procedure has the benefit of allowing researchers to build integrated models of firms' strategic choices as well as the drivers and performance implications of those choices (cf. March and Sutton, 1997). It therefore has potential applications in any research design that examines the implications of managerial choice. At the level of business strategy, notable topics include the influence of first-mover effects, competitive engagement, or strategic group decisions. At the corporate level, this technique could be applied to diverse topics such as market entry decisions, diversification strategies, or the design of governance structures.

This study examines the relationship between governance choice and technological performance while controlling for selection biases. Two main findings are presented. First, in contrast to popular arguments suggesting that vertical integration or outsourcing will lead to superior technological performance, this study shows that governance decisions per se do not significantly influence technological performance directly. Rather, observed differences in the performance of transactions governed by different organizational forms are driven by factors underlying governance choice. While the increasing rapidity of technological change and the increasing dispersion of knowledge suggest

an increased role for outsourcing in the economy (e.g., Teece, 1992), the relationship between governance choice and performance is dependent on the distribution of relevant capabilities and the degree to which performance is driven by autonomous or systemic innovation (Chesbrough and Teece, 1996; Teece, 1996). The results presented in this study caution against drawing universalistic normative implications for firms deciding on whether or not to internalize or outsource their value-chain activities and point to the value of contingency-based theoretical approaches. They also suggest that, absent a fundamental change in transactional characteristics in this industry, outsourcing may well continue but will not completely displace vertical integration.

Second, following TCE's fundamental tenet of discriminating alignment, we find that deviation from the optimal form of governance, as dictated by transactional attributes associated with various contracting hazards, may have a detrimental effect on performance. Specifically, we find that one element of performance, technological performance, is diminished when contractual safeguards are inadequate for the hazards present in a given exchange. These hazards can arise due to hold-up problems in market-mediated exchange (e.g., Klein, Crawford, and Alchian, 1978) as well as the need for coordination across value-chain activities when innovation is driven by system-level needs rather than performance at the component level (Chesbrough and Teece, 1996; Monteverde, 1995; Teece, 1996). While other elements of performance, such as administrative efficiency, may be adversely affected by the presence of excessive governance, this finding contests the notion that governance under-fit and governance over-fit symmetrically affect performance.

The paper also offers some interesting implications for future research. While the significance of our measure of governance misfit supports TCE-based arguments regarding the influence of transactional characteristics on both governance choice and performance, the continued significance of the self-selection term suggests that other factors that influence governance choice are also influencing technological performance. This is in line with Williamson's recent arguments which suggest that the optimal form of governance is likely to be contingent on both attributes of the transaction and the preexisting strengths and weaknesses of the focal firm (Williamson, 1998: 48; see also Williamson, 1999). Thus, future work may contribute to this stream of research by identifying some of these unobserved transaction- and firm-level attributes, possibly employing insights from other theoretical perspectives such as the resource-based view of the firm or real option theory. For instance, it would be useful to explore how the use of specific information filters and communication channels (e.g., Henderson, 1993) or HR practices (Macher and Mowery, 2001) influence firms' governance decisions and subsequent technological performance. Similarly, it would be productive to examine whether and how firm-level differences in absorptive capacity influence firms' vertical integration decisions (Cohen and Levinthal, 1990). Research along these lines might also inform the relative importance of firm- and transaction-level factors as they relate to firms' performance.

Another attractive opportunity for research would be to extend this framework by analyzing whether and how other dimensions of governance influence technological performance. Although markets and hierarchies share some common features, they exhibit many distinct strengths and weaknesses that may differentially affect performance (Williamson, 1985). Thus, it would be productive to specifically examine the relationships between degree of ownership, various dimensions of coordination, and performance. For instance, it has been suggested that geographic agglomerations such as those present in the Silicon Valley provide a degree of coordination that improves a firm's ability to successfully introduce new products (Eisenhardt and Schoonhoven, 1996). More generally, Teece (1996) argues that various organizational archetypes (i.e., the virtual, alliance, multiproduct, and Silicon Valley types) may be more or less suited to systemic and autonomous innovations. As firms employ a wide range of different types of vertical sourcing arrangements, future research might differentiate these alternative forms of governance and investigate their performance implications (e.g., Dyer, 1996, 1997; Oxley, 1997).

Finally, the study's findings indicate how firms' vertical governance decisions influence one specific dimension of performance. Extensions might consider how firms' boundary decisions influence other performance dimensions such as overall firm profitability, excess cash flow, or risk. Efforts to isolate and catalogue the drivers of firms' governance choices, to explore other forms

of governance, and to examine other dimensions of performance will provide the foundation for more integrative research on the implications of organizational governance and the roles played by theories emphasizing different levels of analysis (e.g., transaction cost theory, the resource-based view, and real options). Such work may also offer a basis for more sound normative guidelines for practitioners. We suspect that research in directions such as these will continue to be of great importance as corporate de-integration remains a central concern for strategy research.

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