

AN EMPIRICAL EXAMINATION OF TRANSACTION- AND FIRM-LEVEL INFLUENCES ON THE VERTICAL BOUNDARIES OF THE FIRM

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A large literature has successfully employed transaction cost economic theory to describe how exchange conditions affect the optimal form of organization. However, this approach has historically not accounted for the influence of firm-specific attributes on the governance decision. This paper develops a model based on insights from transaction cost economics, the resource-based view, and real options theory to examine how transaction-level characteristics, firm-specific capabilities, and product-market scope influence the governance of production. Empirical evidence derived from analysis of 469 make-or-buy decisions involving 117 semiconductor firms indicates that decisions regarding the governance of production activities are strongly influenced by both transaction- and firm-level effects. Copyright © 2003 John Wiley & Sons, Ltd.

The determination of a firm's boundaries represents a question of both theoretical and practical importance. Indeed a broad and impressive body of scholarly work has addressed the problem, including research drawn from economic (e.g., Coase, 1937; Williamson, 1975) and organizational (e.g., Lawrence and Lorsch, 1967; Thompson, 1967; Galbraith, 1977) perspectives. This work has described how the information and coordination advantages associated with integration may provide scale and scope benefits (Chandler, 1962), reduce transaction costs (Coase, 1937; Williamson, 1975), align incentives (Grossman and Hart, 1986), exploit powerful relationships (Pfeffer and Salancik, 1978), and allow an organization to reduce its dependence on buyers and suppliers (Pfeffer and Salancik, 1978).

Key words: vertical integration; transaction cost theory; resource-based view; option theory

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While a number of theoretical approaches have been put forth to analyze firms' vertical boundary decisions, existing research has largely followed the precepts put forth in transaction cost economics (TCE) and argued that the optimal form of organization is primarily a function of the characteristics underlying a given exchange. Under the assumption that economic actors are both boundedly rational and potentially opportunistic, transaction cost theory explains how unfavorable exchange conditions can increase the cost of writing enforceable contracts and create *ex post* maladaptation and hold-up problems (Williamson, 1985). Moreover, TCE asserts that in these unfavorable situations hierarchical organization will be beneficial because it aligns the interests of exchange parties, provides for the reconciliation of differences via fiat, and permits a more effective, sequentially adaptive decision-making process (Williamson, 1975). This logic has been used to argue that integration will be a more efficient form of organization than market contracting in transactions that involve either highly specific assets or high levels of uncertainty

(Williamson, 1975, 1985; Klein, Crawford, and Alchian, 1978).

Empirical research has provided strong and consistent support for the theorized relationship between transaction-specific investment and governance (e.g., Monteverde and Teece, 1982a, 1982b; Walker and Weber, 1984; Masten, 1984; Masten, Meehan, and Snyder, 1991). However, the existing literature provides almost no discussion of the role of firm-level differences and how they might influence the boundaries of the firm in existing empirical transaction-based models of the firm. Indeed, both Demsetz (1988) and Winter (1988) argue that differences in firms' productive capabilities have been suppressed in the modern economics of organization in favor of an overriding concern with incentives (see Riordan and Williamson, 1985, for an exception). This is surprising given the widespread belief that firms differ significantly in their strategies and capabilities (e.g., Wernerfelt, 1984; Barney, 1991), arguments which assert that valuable firm-specific knowledge often drives vertical boundary decisions (e.g., Conner and Prahalad, 1996; Kogut and Zander, 1992, 1996), and numerous statements in the popular business literature indicating that firms internalize activities that allow them to leverage their unique competencies (e.g., Bettis, Bradley, and Hamel, 1992; Quinn and Hilmer, 1994).

This paper contributes to the existing literature on vertical integration decisions in a number of ways. After controlling for transaction-level characteristics highlighted by TCE, this paper describes whether and how a variety of firm-specific attributes influence organizational governance. For example, governance choices may be influenced by prior firm-specific investments (Williamson 1998, 1999), contemporaneous firm-specific agreements that are interdependent with the focal transaction (Argyres and Liebeskind, 1999), or other firm-specific resources and investment opportunities (Barney, 1999). The identification of such 'shift parameters' (Williamson, 1991) promises to provide a complementary linkage between these theories of organizational governance. In addition, the paper extends existing empirical work using transaction cost analysis by jointly and interactively examining the influence of asset specificity and exchange uncertainty. Here the paper makes a subtle distinction regarding the relationship between exogenous uncertainty and governance by arguing that the primary reason

market exchange is hazardous in uncertain environments is not because it is more costly to write complete contracts in uncertain environments *per se*, but rather because uncertain environments may lead to contractual renegotiation that can be hazardous in the presence of specific investments. Thus, this research adds to evidence that disentangles the roles that uncertainty and asset specificity play in determining firms' governance decisions (Coles and Hesterly, 1998). Finally, the paper responds to calls for further empirical work on firm boundaries in high technology industries (e.g., Coase, 1992; Monteverde, 1995).

The empirical portion of this study is based upon a cross-sectional analysis of production decisions in the semiconductor industry. A cross-sectional design was chosen to facilitate comparison with the results reported in the existing vertical integration literature (e.g., Monteverde and Teece, 1982a, 1982b; Walker and Weber, 1984). The semiconductor industry was chosen as the research context for several reasons. First, given their tremendous importance in this industry, production activities are afforded a great deal of managerial attention. Second, the appearance of specialized manufacturing firms, or foundries, in the early 1990s has resulted in an increasingly heterogeneous distribution of capabilities across firms in this industry. Finally, there is considerable variation in the structure of these relationships both within and across different categories of transactions involving semiconductor production. In our work we have observed instances where production is fully internalized within the firm, is governed through joint venture relationships, and is governed through market-sourcing relationships.

The following section provides background theoretical material and develops hypotheses relating transaction- and firm-level characteristics to governance choice. Evidence from a cross-sectional sample of 469 vertical integration decisions involving 117 semiconductor firms reveals that both transaction- and firm-level effects influence firms' boundary choices. Important for transaction cost theory is our result that effects due to small numbers bargaining situations, asset specificity, and uncertainty remain significant after controlling for firm-specific effects. Consistent with the organizational capabilities view, our results further indicate that firm-specific capabilities have a

significant and independent effect on firms' vertical integration decisions. Finally, as suggested by real option theory, our results suggest that the formation of small, toe-hold, investments in multiple product-markets increases the likelihood of vertical integration. The paper concludes with a discussion of these findings and their implications for theory and research on the boundary of the firm.

LITERATURE REVIEW

Transaction cost theory and vertical integration

In contrast to the suggestion in neoclassical economics that firms' vertical boundary decisions are determined by technological factors such as economies of scale or scope, transaction cost theory asserts that these decisions may also be influenced by characteristics associated with the efficiency of the chosen form of organization. Efficiency is assumed to be inversely related to the magnitude of the costs of organizing the economic system or, more specifically, the costs of negotiating and writing contracts and the costs of monitoring and enforcing contractual performance (Williamson, 1975).

Although TCE advocates selecting a governance form that minimizes production and transaction costs, it has emphasized the importance of the costs associated with governing and monitoring transactions. Due to the economies of specialization available in the marketplace, applications of the theory generally assume that markets provide a more efficient mechanism for exchange than does hierarchy. However, in certain situations the costs of market exchange may increase substantially and surpass the technical efficiencies provided by the market. Thus, the theory focuses on identifying the characteristics of exchanges that are best suited to market and firm organization.

In the transaction cost theories of Williamson (1975) and Klein *et al.* (1978), market inefficiencies are seen to originate from small numbers bargaining situations. While such situations may exist *ex ante*, the primary contribution of TCE has centered on its ability to describe the specific exchange characteristics that are likely to lead to *ex post* small numbers situations. Due to the bounded rationality of decision-makers, the asymmetric distribution of relevant information,

and the inability to completely specify behavior in the presence of multiple contingencies, the theory maintains that all contracts are incomplete and therefore subject to renegotiation and the possibility of opportunistic behavior. Moreover, the theory asserts that the likelihood of opportunistic behavior is most severe when an exchange requires one or both parties to make significant transaction-specific investments since such investments create quasi-rents that may be subject to hold-up (Klein *et al.*, 1978).

Williamson (1991) argues that different governance structures represent discrete solutions to various contracting problems. Specifically, markets and hierarchies are thought to support differing levels of incentive intensity and administrative control as well as to utilize different types of contract law (Williamson, 1991). Vertical integration is thought to be beneficial in contracting situations where hold-up concerns are severe because hierarchical governance aligns the interests of exchange parties, provides for the reconciliation of differences via extensive administrative rules and procedures, and permits a more effective, sequentially adaptive decision-making process (Williamson, 1975).

While providing a number of important insights regarding the most efficient means to govern a particular transaction, TCE has been developed and tested under a set of restrictive assumptions that ignore the potential influence that an extant governance form, a firm's existing portfolio of transactions, or other firm-specific asset and capability stocks may have on a focal transaction. The resulting implication is that, in equilibrium, all firms facing a given set of transactional attributes will reach similar conclusions regarding which activities to execute internally and which activities to outsource. This proposition 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 over extended periods of time. For instance, while IBM has historically been highly integrated, Compaq has outsourced a number of its component assembly processes. Thus, the optimal form of governance is likely to be contingent on both the attributes of the current transaction and the pre-existing strengths and weaknesses of the focal firm.

Firm-specific effects: resources and vertical integration

The resource-based view (RBV) of the firm provides one means to analyze the effect of firm-level capabilities on vertical integration decisions. Two basic conditions are highlighted by the RBV. The first is that firms are largely heterogeneous in terms of their resources and capabilities (e.g., Wernerfelt, 1984). The second is that some of these resources and capabilities are limited in supply or costly to imitate (e.g., Dierickx and Cool, 1989; Barney, 1991). As a result of these conditions, proponents of the RBV have argued that firms' governance choices may be directed by their attempts to leverage and protect idiosyncratic capabilities (e.g., Barney, 1999). While TCE focuses on the relationship between characteristics of isolated transactions and the likelihood of *ex post* opportunistic behavior, the RBV emphasizes how the opportunity to create competitive advantage by exploiting unique firm-level attributes affects the value of the incentives, administrative controls, and adaptation mechanisms offered by competing forms of organization.

The simplest manner in which firm-specific governance effects may arise is through prior commitments. While much of the existing TCE literature assumes that firms may effortlessly renegotiate existing contractual provisions as they adapt to changing exchange conditions, the existence of an extant governance form is likely to create switching costs that may lock a firm into a particular governance choice. Williamson (1998: 43) refers to this sort of effect when he argues that existing governance alternatives are 'privileged in relation to rival alternatives that arrive later.' This privilege is related to the level of economic and political precommitments. The political costs associated with shutting down a small-town manufacturing plant, for instance, are likely to mitigate the likelihood of deintegration, even if the component could be efficiently sourced through the marketplace. Consequently, a firm that chose to internalize an activity in the past, perhaps due to the need for high levels of transaction-specific investment, may be more likely to remain integrated in the present, even if the current levels of asset specificity and uncertainty suggest that market transaction is attractive.

A firm's governance choice may also be influenced by contemporaneous exchange relationships.

Argyres and Liebeskind (1999) introduce the notion of governance inseparability to describe situations where there are interdependencies between related governance decisions. These interdependencies are the result of formal and informal commitments embedded in the existing portfolio of contractual relationships. These commitments in turn alter the incentive structure of subsequent governance decisions by creating implementation obstacles that constrain the feasible range and types of mechanisms. For example, Coca-Cola's exclusive franchising agreements with its bottlers inhibited their attempts to forward integrate in the 1980s. More generally, the existence of extant commitments suggests that governance decisions will exhibit a significant degree of path dependence.

Firm-specific governance effects may also arise from firm-specific capability differentials. While vertical or horizontal diversification may create value in a firm by exploiting any excess valuable resource (e.g., Teece, 1980, 1982), recent conceptual (Quinn and Hilmer, 1994; Barney, 1999) and case study research (Argyres, 1996) describes situations where integration decisions seem to be driven by a firm's ability to leverage its core competencies into adjacent value chain activities. For example, Quinn and Hilmer (1994) argue that Nike's decision to manufacture components of its 'Nike Air' system while outsourcing the remainder of its shoe production was based on its desire to internalize activities associated with its 'core air technology.' Similarly, Argyres (1996) provides a case study of a manufacturing firm that chose to outsource a key component because the underlying production activity was not something they felt they could do well.

A critical task in exploring the firm-level antecedents of organizational scope is the identification of the specific firm-level commitments and capabilities that a firm may exploit through its vertical integration decisions. By relaxing the constraint that firms maintain homogeneous asset and capability stocks the RBV provides an important contribution to traditional TCE-dominated studies of vertical integration. However, even studies of vertical integration that focus on the transaction- and firm-level characteristics highlighted by these theories fail to account for the value associated with the ability to react flexibly to an uncertain future. A more complete theory of vertical governance will include a dynamic assessment of how uncertainty

in the future value of an asset affects the optimal form of governance.

Firm-specific effects: product-market strategy and vertical integration

A third stream of research that promises to shed light on firms' vertical integration decisions is the real option literature. Similar to financial options, real options are investment opportunities that confer the right, but not the obligation, to take some specific operating action in the future. These real options come into existence when existing resources and capabilities allow preferential access to future opportunities (Bowman and Hurry, 1993: 762). They may provide value by creating an asymmetry in the distribution of returns—by purchasing an option on a nonfinancial asset, the owner gains access to greater upside potential than downside exposure. This asymmetry results from the ability to terminate an investment while taking actions to fully exploit future positive outcomes. As such, real options theory emphasizes the value of investments that allow firms to manage risk proactively by confronting uncertainty over time in a flexible fashion (Kogut, 1991). To date, a number of real options have been identified, including the options to defer investment, expand or contract production, abandon operations, switch use of inputs, and grow into expanding markets (Trigeorgis, 1998).

The literature points to at least three mechanisms through which real options theory may influence a firm's governance decisions. First, conceptualizing firms as an aggregation of investment opportunities, real options theory provides one potential explanation why some firms will be able to productively undertake investments that other firms cannot without experiencing greater risk (Dixit and Pindyck, 1994; Trigeorgis, 1998). Specifically, in industries that are subject to volatile demand swings (i.e., consumer electronics), real options theory indicates that firms which have invested in assets such as excess capacity or numerically controlled machinery may benefit from the opportunity to flexibly alter the output mix of a given facility (Kulatilaka and Trigeorgis, 1994) and are therefore more likely to use integrated governance than their less flexible competitors. As such, option theory complements the RBV in explaining why firms' with heterogeneous resource profiles may

choose governance structures that are suboptimal according to standard transaction cost reasoning.

Second, since real options theory indicates that the decision to avoid irreversibly committing resources is most valuable under high levels of uncertainty (McDonald and Siegel, 1986), it also provides a means to explain the trade-off between the contemporaneous efficiency of competing forms of organization and the value to operate flexibly in an uncertain future. Assuming integration into production entails greater sunk costs and more irreversible investment than production through market contracting, market contracting will provide greater flexibility than integrated production. The value of this flexibility may be manifest, for instance, in the risk of owning assets that may turn out to have little value in markets that are exposed to volatility in technology or product demand (e.g., Balakrishnan and Wernerfelt, 1986). Real options theory recognizes the value associated with this latter flexibility and brings this information to bear on the initial make-or-buy investment decision. Thus, even if market contracting requires that the firm incur greater short-term marginal production costs or engage in potentially hazardous exchanges, real options theory suggests market exchange may still be the optimal form of governance if the flexibility benefits created by avoiding irreversible commitments offset the cost of these more immediate inefficiencies.

Finally, real options theory suggests that firms will be more likely to vertically integrate whenever the manufacture of one product provides a secure, preferential claim on the option to later develop a (potentially lucrative) related product. Such platform investments are particularly significant in industries where sequential learning or intergenerational spillovers of tacit knowledge are significant (Kim and Kogut, 1996). In these settings, option theory suggests that firms may internalize the manufacture of early generations of a product in order to maintain the option to participate in the production and sale of subsequent generations of that product. For instance, in the biotechnology industry, it will often be necessary for a firm to invest in an internal pilot production process in order to develop the manufacturing expertise necessary to have the option to internalize scale production at a later date. Thus, even if it is possible to efficiently contract for production in the marketplace, it may be optimal for the firm to internalize the transaction

in order to maintain the option value associated with subsequent generations of the product.

DEVELOPMENT OF HYPOTHESES

In this section, we introduce an empirically testable model grounded in concepts derived from transaction cost, resource-based, and real options approaches to vertical integration. Hypotheses 1 and 2 briefly describe a base, transaction-level model that illustrates how characteristics of the exchange influence the likelihood of vertical integration through market hazards. This model is then extended to describe how firm-level factors influence whether a firm chooses to fabricate a particular product within the firm or through a contractual (alternate sourcing) relationship. Specifically, Hypotheses 3 and 4 suggest that the switching costs and proprietary capabilities developed through a firm's manufacturing and sourcing experiences affect its chosen level of vertical integration. The fifth and final hypothesis in the model suggests that a firm's product-market diversification strategy affects its chosen level of vertical integration by creating the ability to respond flexibly when there is uncertainty regarding the future value of production assets.

Transaction-level effects

The driving factor in the 'fundamental transformation' from a large market to a bilateral monopoly is asset specificity (Williamson, 1985). Asset specificity defines the degree to which the assets in an exchange are more valuable in their current application than in their next best use. Transactions involving high levels of specific assets create the opportunity for quasi-rents to be appropriated or 'held up' by opportunistic buyers or suppliers. For instance, an automobile supplier that invests in machinery that produces a unique part for a particular assembler may be subject to hold-up since the supplier will have few alternatives if the assembler were to demand a lower price for the part. More generally, the potential for misappropriation raises the cost of market exchange by making contractual negotiations more contentious, instigating parties to invest in contractual safeguards, and by reducing investment in other efficiency-improving, relation-specific assets. Vertical integration provides a means of avoiding these inefficiencies by

aligning incentives, providing access to a greater range of administrative controls, and allowing for more frequent and cooperative adaptations to the exchange.

Hypothesis 1: The more transaction-specific the assets required to produce a given product, the larger the likelihood of vertical integration into production.

Another transaction-level characteristic that is thought to influence firms' vertical integration decisions is uncertainty. In its typical application, uncertainty refers to the degree to which unanticipated environmental changes alter the conditions underlying an exchange. Uncertainty influences the cost of governance in a number of ways. For instance, since the number of contingencies that may affect a contract increases with uncertainty, greater uncertainty raises the expected costs of writing and enforcing a contingent claims contract (Williamson, 1985). Similarly, to the extent that uncertainty hinders the coordination of linked activities, greater uncertainty may result in maladaptation costs. Moreover, as uncertainty inhibits a firm's ability to measure the contribution of any individual activity, it increases the likelihood that shirking may occur undetected (Barzel, 1982; Demsetz, 1988).

While vertically integrated governance structures are costly to set up, integration addresses many of the contracting problems associated with uncertainty. For instance, the net effect of the improved measurement and greater administrative control provided by hierarchy facilitates monitoring and therefore diminishes the likelihood of shirking. Similarly, by increasing the degree of centralized authority and administrative control, integration aligns the interests of exchange parties, provides for the reconciliation of differences via fiat, and permits a more effective sequentially adaptive decision-making process (Williamson, 1975). Consequently, firms are more likely to adopt integrated governance structures in uncertain environments.

Hypothesis 2a: The higher the level of uncertainty, the larger the likelihood of vertical integration into production.

As noted above, existing empirical tests of firms' vertical boundary decisions have largely focused

on the examination of direct relationships between governance and measures of the specificity of assets and exchange uncertainty. This work has emphasized how the costs of writing and enforcing a contingent claims contract increase with the level of uncertainty and exchange complexity. Although the relationship between uncertainty and firms' vertical integration decisions is stressed in much of the existing literature, empirical studies have yielded fragile and at times contradictory results (Mahoney, 1992; Sutcliffe and Zaheer, 1998).¹ One potential reason for these inconsistent empirical findings is that uncertainty also has a more subtle, indirect, influence on governance. This second line of reasoning suggests that renegotiation in and of itself does not lead to higher transaction costs; rather, that the market hazards that lead to vertical integration are most likely to occur when contract renegotiation takes place *in the presence of* specific assets (e.g., Coles and Hesterly, 1998). Thus, market exchange is not hazardous in uncertain environments because it is more costly to write complete contracts in uncertain environments per se, but rather because uncertain environments facilitate subsequent contractual renegotiation that can be hazardous in the presence of specific investments. Since exchanges conducted in uncertain environments are more likely to encounter unanticipated contingencies that require renegotiation than exchanges conducted in more stable environments, market failure is particularly likely in situations where both high levels of asset specificity and uncertainty are present. In these situations, the centralized authority and discretionary allocation of resources associated with vertical governance structures allow firms to avoid the inefficient haggling and costly renegotiation associated with the marketplace. This logic suggests the following hypothesis.

Hypothesis 2b: The positive effect of uncertainty on the likelihood of vertical integration into production will be larger in transactions characterized by high levels of asset specificity.

Firm-level effects

Although TCE describes how markets and hierarchies differ in their ability to respond to hold-up and maladaptation costs, it is silent on the relative influence of firm-specific capabilities. Demsetz (1988), for instance, points out that TCE downplays the importance of other costs, including firm-level production costs, which influence the optimal form of organization.² Barney (1999) argues that integration decisions are jointly determined by the expected cost of opportunism associated with accessing a factor through the marketplace as well as the expected cost of creating that factor inside the firm. Williamson (1998: 48) suggests that a key question is not what is the best governance structure available to organize a transaction of characteristics x , but rather, what is the best governance structure available to organize a transaction with characteristics x for a firm with competencies and rigidities of type y ?

Any number of firm-specific resources and capabilities may affect a firm's integration decisions. For example, the existence of slack resources may provide firms with an alternative to accessing production through sourcing agreements as they may reassign production individuals, build excess capacity, and so forth (e.g., Thompson, 1967). A firm may also build up valuable plant-level HR capabilities that enhance its ability to implement and improve upon existing processes (e.g., Macher and Mowery, 2001) or develop specific information filters and communication channels that provide it with a unique ability to adapt its production technology within a stable architecture (e.g., Henderson and Clark, 1990; Henderson, 1993). The RBV suggests that a firm that owns these or similar valuable and difficult-to-imitate capabilities will be more likely to integrate than its competitors. Toyota, with its acknowledged lean production expertise (e.g., Womack, Jones, and Roos, 1990), provides an example of a firm broadly thought to

¹ For instance, empirical studies focusing on one aspect of behavioral uncertainty—measurement uncertainty—have demonstrated a positive relationship between the ability to measure an employee's productivity and the degree of vertical integration (Anderson, 1985; John and Weitz, 1988). In contrast, research focusing on technological uncertainty (e.g., Balakrishnan and Wernerfelt, 1986; Harrigan, 1986; Walker and Weber, 1984, 1987) has demonstrated a negative relationship between uncertainty and integration. Research examining the influence of demand uncertainty has illustrated both a negative (e.g., Harrigan, 1986) and a positive relationship (John and Weitz, 1988; Levy, 1985; Walker and Weber, 1987) with integration.

² While Williamson (1991) responds to Demsetz's (1988) critique by arguing for a more general notion of comparative costs, such an approach risks reducing the theory to a tautology and 'deprives transaction cost theory of any predictive content' Demsetz (1988: 147).

be exploiting its unique capabilities by integrating into production activities that are sourced by similar firms without such expertise. Collectively, these examples point out that, over time, firms develop stable, detailed, and predictable patterns of quasi-automotive behavior in their ordinary productive activities (Nelson and Winter, 1982). The existence of these and other firm-specific capabilities provides one explanation why some firms are more skilled at implementing otherwise common governance structures.

Many of the specific routines that affect firms' productive capabilities are developed experientially at the firm or plant level. These routines are neutral, but critical, constructs that generate both organizational capabilities and rigidities (Leonard-Barton, 1992). Production experience provides learning opportunities that enhance a firm's production capabilities (Arrow, 1962). Such experientially derived capabilities improve subsequent production along a given trajectory in terms of both efficiency (e.g., Rapping, 1965; Boston Consulting Group, 1968; Henderson, 1984) and technical performance (e.g., Clark, 1987; Dosi, 1988). As a result, production experience is likely to enhance the likelihood that a firm will choose internal governance along a given technological trajectory.

Hypothesis 3: The greater a firm's experience using the relevant process technology, the larger the likelihood of vertical integration into production.

Firm-specific resources and capabilities may also affect a firm's ability to mitigate transaction costs through astute management of sourcing relationships. Firms may differ in their ability to select attractive sourcing partners, negotiate and enforce supplier contracts, design systems to manage relationships outside of the hierarchy, or to monitor and enforce contractual compliance (e.g., Doz and Hamel, 1998). For example, as a result of the cost table methodology developed at Honda's Marysville, Ohio site, Honda is thought to be more efficient at monitoring the performance of its suppliers than its competitors (Laseter, 1998). Firms such as Honda that are well endowed with the necessary administrative resources and capabilities are likely to enjoy lower costs and greater benefits from outsourcing production activities than competitors with less refined contracting skills. Indeed,

the relationship between experience and the formation of subsequent sourcing partnerships is also suggested by a recent study of over 2000 joint ventures that reports evidence of large firm-level experiential effects in managing joint ventures (Anand and Khanna, 2000).

In addition to firm-level administrative capabilities, greater sourcing experience also helps build dyad- and market-level capabilities that may enhance a firm's ability to engage in a successful sourcing partnership. It is widely held that repeated transactions provide partners with an understanding of each other's cultures, management systems, capabilities, weaknesses, and so forth (e.g., Gulati, 1995, 1998; Gulati and Singh, 1998) that lead to the development of interfirm coordination skills or relational capabilities (Dyer and Singh, 1998). The learning benefits associated with experiences within a given product-market or with a particular governance form may allow firms to better judge the particular hazards associated with cooperative behavior in a specific area.

Greater sourcing experience is likely to aid in the development of organizational routines that allow firms to efficiently collaborate with a broad array of partners. These routine-based capabilities may include general capabilities such as standard contractual safeguards or mechanisms to enhance interfunctional coordination across partners as well as firm-specific relational capabilities. Experienced firms may select better suppliers, understand how to organize relationships more effectively, and better anticipate and respond to technological or market contingencies over time. Firms with greater sourcing experience are more likely to outsource their production activities.

Hypothesis 4: The greater the number of prior outsourcing relationships with suppliers of a particular process technology, the smaller the likelihood of vertical integration into production utilizing that technology.

The introduction of real options theory into the vertical integration literature provides a method to analyze the value of a firm's ability to adjust its strategy over time. In addition to potential scope economies derived from the contemporaneous sharing of activities across markets, product-market diversification also imparts the firm with a portfolio of valuable options. This is most clear in the case of small product-market investments that

provide the firm with the ability and discretion to adjust its strategy in the future. Such investments enable firms to avoid downside outcomes and take advantage of upside opportunities by shifting production in response to changes in segment demand, competitors' actions, technological development, and other environmental contingencies.

The switching options provided by small investments in multiple product-markets are likely to affect a firm's choice between internal and sourced production in two ways. First, a firm with toe-hold investments in multiple product-markets is able to invest in a given process technology, knowing that even if demand falls short of projections, the manufacturing facility may be converted for use in one of its other product-markets. Thus, greater product-market scope reduces a firm's exposure to the risk of underutilizing a production facility in markets with uncertain demand. Second, and of greater importance in industries with short technology-cycle times, firms with greater product-market scope are able to continue utilizing a technology after it becomes obsolesced in its primary product-market application by shifting its use to a less demanding application. As a result, firms with broader scope have an enhanced ability to flexibly respond to changes in market demand and are therefore more likely to internalize their production activities.

Hypothesis 5: The greater the number of product-markets into which a firm is diversified, the larger the likelihood of vertical integration into production.

The preceding hypotheses describe an empirically testable model of firms' vertical integration decisions. This model is depicted in Figure 1. The top third of the diagram depicts the traditional TCE-based approach to vertical integration. This approach focuses on the problems of opportunism inherent in market contracts and identifies the optimum governance form for a generic firm considering an exchange with a particular set of attributes. The rest of the figure relaxes the constraint of equivalence of firm-level capabilities and rigidities. Following insights derived from the resource-based approach, the model recognizes that managers will attempt to leverage those firm-specific capabilities that are costly to develop. In the figure, these capabilities are depicted as experientially

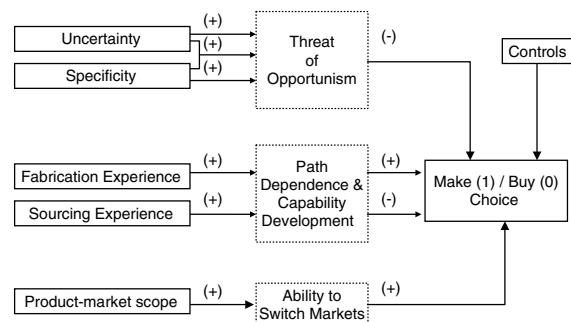


Figure 1. A model of vertical integration decisions incorporating transaction- and firm-level attributes

derived production and sourcing capabilities. Following insights derived from real options analysis, the model further acknowledges that managers of firms with greater product-market scope have a greater ability to flexibly respond to changing market conditions than their more focused counterparts. As a result, firms with greater product-market scope may be more likely to make specific investments in production activities.

In summary, the presence of firm-specific capabilities suggests a second set of considerations that need to accompany costs associated with the threat of opportunism emphasized in existing models of firms' vertical boundary decisions. That is, a trade-off exists between the expected cost of opportunism associated with a given exchange and the expected cost of acquiring or leveraging particular firm-specific capabilities. Taken together, the resource-based and real option theories provide a compelling rationale for relaxing the constraint of homogeneous resource and capability stocks inherent in traditional transaction cost treatments of vertical integration.

RESEARCH DESIGN

Sample

The data used for the empirical portion of this study were derived from a 1996 survey of 176 global integrated circuit manufacturers conducted by the Integrated Circuits Engineering Corporation (ICE, 1997). Direct responses regarding production activities were provided by 117 (66%) of the 176 firms contacted in original ICE survey. Comparisons of the firms included in the final sample with those that were excluded because of incomplete

information indicated that no significant differences existed in either size (revenue) or tenure (semiconductor industry experience).

The unit of analysis for our study is the production decision. Following industry practice, we distinguish seven product-markets: analog devices, application specific ICs (ASICs), discrete devices, digital signal processors (DSPs), memory devices, microprocessors, and telecommunications devices. A number of process technologies are utilized in the manufacture of products for these product-markets with the primary process technologies in use as of 1996 including 1 micron, 0.8-micron, 0.5-micron, 0.35-micron, and 0.25-micron technology. Since a semiconductor fabrication line must be tailored to a particular process technology and (to a lesser extent) to a particular product, we record a separate observation for each process technology–product-market combination. 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 process technology–product-market combinations would be recorded in our sample as three separate observations. Complete information was available for 358 internal production (i.e., make) decisions and 111 external production-sourcing relationships. Thus, our final sample includes 469 production decisions of which 20 (17.1%) of the firms were observed using both internal fabrication and outsourcing methods to meet their production needs, 25 (21.4%) firms had only outsourcing recorded, and 72 (61.5%) firms were coded with solely internal production.

Model specification

The make vs. buy literature has often employed binary choice models to assess the relationship between a set of covariates and the make-or-buy decision (Monteverde and Teece, 1982b; Pisano, 1990; Poppo and Zenger, 1998). We follow this literature in specifying an index function model, in which the difference between benefit and cost of market and internal organization is an unobserved variable explained by several regressors. Thus, we observe a firm's choice to make or not to make, and assume that this choice indicates whether the value of the unobserved variable exceeds a threshold value. The resulting multivariate statistical

model takes the following basic form:

Vertical integration

$$\begin{aligned}
 &= \beta_0 + \beta_{1-6} \text{ Controls} + \beta_7 \text{ Asset specificity} \\
 &+ \beta_8 \text{ Demand uncertainty} + \beta_9 \text{ Asset specificity} \\
 &* \text{ Demand uncertainty} + \beta_{10} \text{ Fabrication experience} \\
 &+ \beta_{11} \text{ Sourcing experience} + \beta_{12} \text{ Product} \\
 &- \text{ Market diversification} + \varepsilon
 \end{aligned} \tag{1}$$

While our interest lies in developing a parsimonious model to assess the joint influence of transaction- and firm-level attributes on firms' vertical boundaries, other factors may influence our results. For instance, larger firms may have both greater levels of fabrication experience and the financial resources and scale necessary to invest in internal production than their smaller counterparts. Firms with longer tenure in the industry may be more diversified and more willing to integrate into production. Control variables for firm size and tenure are thus included to ensure that the observed relationships between our theoretical variables and governance choice are not unduly influenced by these factors.

The economic environment may also affect the governance of firms' production activities. When the number of available suppliers is few, creating a low level of rivalry in the contracting environment, firms may prefer backward integration (e.g., Porter, 1980; Pisano, 1990). Moreover, firms may face different macroeconomic factors such as access to low-cost capital, advanced technology, or a stable political environment. The empirical analyses include measures for the *ex ante* number of suppliers to control for differences in cost of market exchange as well as a series of geographic and time indicator variables that account for the macroeconomic conditions in the year in which the observed process–product combination was introduced.

Measurement of theoretical variables

Asset specificity

A variety of forms of asset specificity have been identified in the literature, including property whose value is specific to a particular site or location, customized physical assets, and human capital that is tailored through learning

or technology transfer to a particular application (Williamson, 1983). Specificity also arises when timely and coordinated responses are critical to the completion of a project (Masten *et al.*, 1991). In the case of semiconductor production, the most relevant specific assets are the specialized reporting structures, information systems, and technical dialogue required to achieve the necessary level of coordination and adaptation between product design and manufacturing activities (Monteverde, 1995). These coordination requirements are thought to vary with 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. As the production of analog and some customized ASIC devices requires a very flexible process, a high degree of coordination is required between design and production engineers as they formulate numerous changes to the standard process. In contrast, the need for design and production engineers to develop entirely new, state-of-the-art processes creates heavy coordinative demands in the production of digital memory devices. Consequently, we identify high asset specificity conditions as those where the exchange involves analog, memory, or customized ASIC products, and zero otherwise.

Demand uncertainty

Our measure of product-market demand uncertainty is designed to capture managers' perceptions regarding unanticipated shifts in the demand for a specific type of semiconductor device. Following Levy (1985), we argue that such unpredictability in demand may be ascertained by the variance surrounding a trend in the demand for similar products. Specifically, demand uncertainty is measured as the sum of squared errors from a regression of the relevant product-market's historical unit demand for the 5 years preceding the integration decision (i.e., 1991 through 1995). The segment-level demand data are from quarterly reports of units delivered, provided by the Semiconductor Industry Association. The units data are indexed based on the starting value, and regressed on a quadratic time trend, controlling for seasonality.

Fabrication experience

Our measure of fabrication experience is designed to indicate if a firm has the skills and resources necessary to internally fabricate the product in question. Following prior empirical studies of production learning curves that have been published in both the economic (e.g., Gruber, 1994) and management (e.g., Lieberman, 1989) literature, we measure fabrication experience as the natural log of the cumulative number of similar products manufactured by the firm. The cumulative number of similar products manufactured is estimated as the firm's cumulative production capacity in the relevant process technology for the prior 5 years (1991–95).

Sourcing experience

A firm's ability to identify attractive sourcing partners and to mitigate potential contracting hazards is likely to be related to a number of different types of experience. Personal experiences between individuals that share a professional affiliation may provide access to valuable information regarding potential partners (e.g., von Hippel, 1988; Powell, Smith-Doerr, 1993). Institutional experiences may allow organizations in a particular field or industrial district to observe firms that have previously engaged in successful partnerships (e.g., Saxenian, 1994). Prior contractual experiences may develop skills that aid in the identification of trustworthy partners and the ability to effectively negotiate, monitor, and enforce terms of exchanges (e.g., Reuer, Zollo, and Singh, 2002). The relative influence of personal and institutional experiences is likely to be muted by our focus on a single industry where there is a great deal of publicly available information. Thus, under the assumption that hazard-mitigating sourcing capabilities are primarily determined by experience with similar contracting situations (Delios and Henisz, 2000), we define sourcing experience as the number of unique sourcing relationships over the last 5 years (outside the current observation) with firms that have the ability to produce at the relevant process.

Diversification strategy

This variable is designed to measure the extent to which a firm is able to hedge against demand uncertainty and technological obsolescence by

switching the use of its existing production technology across product-markets. While a number of alternative measures have been introduced in the diversification literature, including Rumelt's categorical measures, continuous variables such as Herfindahl and entropy indices, as well as count measures based on the number of product-markets in which a firm is active, the logic underlying our hypothesis suggests that any material presence in a market can provide the firm with a preferential claim (or toe-hold) to switch its technology into that market. For this reason, we measure a firm's product-market diversification strategy as the number of product-market subfields in which the firm sells semiconductor devices. The data for this measure are obtained from the 1996 ICE Profiles report.

Measurement of control variables

Ex Ante small numbers

We measure the number of available suppliers by counting the number of firms that supplied production and had capacity to manufacture at the relevant process technology during our sample time frame. This variable is similar to the one used by Pisano (1990), which measured small numbers bargaining situations by identifying the number of new biotechnology firms with R&D programs in the relevant therapeutic area.

Firm size

A number of variables have been used to measure firm size in the managerial literature, including number of employees, average assets, and average sales. Since variables based on assets or employees are directly dependent upon the decision to internalize production activities, we utilized a measure based on firm sales as our proxy for firm size. In order to limit the influence of external shocks, firm size is measured as the log of average sales over the past 3-year period, 1993–95.³

³ Data on firm sales were not available for 14 firms, representing 39 observations. The preferred method for handling situations where there is missing data on a particular variable for a subset of the sample population is mean value replacement (Roth, 1994). We replaced the sales value for the 14 firms with the sample mean for firm sales. To verify the integrity of our results, we reanalyzed the data after list-wise deleting observations dealing with these 14 firms. In addition, utilizing information obtained in a separate published study (Angel, 1995: 93) which indicated

Firm tenure

This measure is the number of years since the firm entered the IC industry.

Geographic region

Four indicator variables were created to specify whether the focal firm is headquartered in the United States, Japan, Southeast Asia, or in the rest of the world. The excluded category for our multivariate analyses is the rest of the world category. Firms included in the rest of the world category are primarily headquartered in Europe, Africa, and the states of the former Soviet Republic.

Year

A series of indicator variables designate the year in which the focal production or sourcing agreement started. The excluded category includes all years prior to 1988.

Statistical methodology

Two additional methodological issues deserve attention. First, since our measure of diversification strategy represents a choice variable that is not randomly assigned across the sample, our analysis is susceptible to self-selection bias. To assess the potential for self-selection bias in our analysis, we employed one of several two-stage techniques that have been used to identify and treat self-selection (e.g., Heckman, 1978, 1979; Lee, 1982, 1983; Lee, Maddala, and Trost, 1980). Each of these techniques uses a probabilistic choice model to describe the self-selection decision in the first stage and then 'corrects' for self-selection in the second stage by incorporating these predicted probabilities (via the inverse Mills ratio) into the focal analysis. Since the dependent variable in the second-stage model is discrete, we used the two-step probit procedure outlined by Van de Ven and Van Praag (1981) and Shaver (1998). The resulting estimation revealed that the inverse Mills ratio (i.e., lambda) was insignificant.⁴ Moreover, neither

that these 14 firms were among the smallest in the industry, we replaced the sales value for these firms with the mean value for similar 'small' firms. Our results were robust to each of these approaches.

⁴ Specifically, we split the sample into two subsamples: one for firms active in multiple markets ($N = 347$) and the other for

the estimated coefficients nor their statistical significance changed substantially from the initial model to the second-stage models. Thus, we conclude that our analyses are not affected by self-selection.

A second complication arises due to the potential simultaneity between our dependent variable and our measures for fabrication experience and sourcing experience. While few strategy variables are truly exogenous, the irreversible nature of investments in fabrication or external sourcing agreements suggests that a portion of these measures is quite likely to be simultaneously determined with our dependent variable. To address this issue, we employed a procedure suggested by Greene (1997: 763–764) that compares the results from a base model using the possibly endogenous measures with models using instrumental variables via a Hausman test.⁵ This procedure provides a Wald test statistic that indicates whether the variables assumed to be exogenous are, in fact, uncorrelated with the structural disturbances. Rejection of the null by the Wald criterion suggests that the corresponding variables are endogenous and, thus, the desirability of reestimating the model utilizing instrumental variables. The resulting tests on each variable in our base model indicated that the fabrication experience variable was endogenous ($p < 0.001$), as was the sourcing experience variable

($p = 0.025$). These results led us to conservatively estimate models using instrumentalized variables for both fabrication experience and sourcing experience. As our models exhibit no evidence of endogeneity in the presence of the time control variables, we report results for the unadjusted measures of fabrication experience and sourcing experience in models that include the year controls.

RESULTS

Correlations and descriptive statistics for all variables included in the models are presented in Table 1. All explanatory variables except asset specificity exhibit a strong zero-order correlation with the dependent variable (make). The zero-order correlation between make and demand uncertainty is negative, opposite in direction to that predicted in Hypothesis 3a. The control variable firm size is highly correlated with fabrication experience ($r = 0.45$), sourcing experience ($r = 0.25$), and diversification strategy ($r = 0.66$). The same three variables are positively correlated with firm tenure and are significantly related to at least one of the three variables controlling for geographic region. The strong intercorrelation between these variables indicates the need for multivariate analyses to partial out the independent influence of each variable on the make-or-buy decision.

Table 2 summarizes the coefficient estimates and goodness-of-fit measures for the logit models used to test our hypotheses. By construction, our models estimate the effects of the theoretical covariates on the probability that the fabrication activity will be organized internally. Thus, a positive coefficient indicates the variable is positively related to the probability of internal production. The left-hand column lists the independent variables included in each of the models. We report results from six separate models to illustrate the consistency of these estimates across various specifications. Model I serves as a baseline model by including only the control variables. Model II adds our measures of transaction-level effects for *ex ante* small numbers bargaining situations, asset specificity, and demand uncertainty to our baseline model. Model III includes the interaction term to test Hypothesis 3b. In Model IV A, we include our original firm-level measures for fabrication experience and sourcing experience capability. Model IV B estimates a similar model using instrumentalized variables for fabrication experience

firms active in only one market ($N = 122$). Measures of firm size, firm age, and dummy variables for regional headquarters were used as regressors in the first-stage model. The output from this first-stage model was used to calculate a predicted probability that a firm with a given set of attributes would choose to diversify. Estimation of the second-stage performance models revealed that lambda was insignificant for both the single and multiple markets subsamples. Moreover, neither the estimated coefficients nor their statistical significance changed substantially from the initial model to the second-stage models. Thus, we conclude that our analyses are not affected by self-selection.

⁵ The first instrument, fabrication experience hat, was estimated by regressing fabrication experience on the set of exogenous variables (i.e., firm size, firm tenure, geographic location, *ex ante* small numbers, asset specificity, demand uncertainty, and diversification strategy) along with the instrumental variable 'other fabrication,' which is defined as the sum of the firm's fabrication capacity at all processes other than the one in the observation. The second instrument, sourcing experience hat, was estimated by regressing sourcing experience on the exogenous variables listed above and three instrumental variables: 'generic alliances' (the sum of nonproduction partnerships over the past 5 years), and two 'entry wave' variables that capture unspecified institutional, economic, and industry factors that may influence firms' vertical boundary decisions at inception. The most recent wave of entry into the semiconductor industry was defined as from 1990 to 1996. The next previous wave of entry was defined as from 1976 to 1990.

Table 1. Descriptive statistics and correlations^a

Variable	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11
1. MAKE	0.76	0.43											
2. FIRM SIZE	6.32	2.08	0.36***										
3. FIRM TENURE	22.87	13.22	0.37***	0.49***									
4. US FIRM	0.55	0.50	-0.20***	-0.22***	-0.04								
5. JAPANESE FIRM	0.18	0.39	0.17***	0.28***	0.29***	-0.52***							
6. OTHER ASIAN FIRM	0.09	0.28	0.05	0.15*	-0.23***	-0.34***	-0.15**						
7. EX ANTE SMALL NUMBERS	17.50	7.21	0.25***	-0.09	0.11*	-0.05	-0.11*	-0.06					
8. ASSET SPECIFICITY	0.75	0.43	-0.09	-0.19***	-0.25***	-0.05	-0.04	0.11*	-0.07				
9. DEMAND UNCERTAINTY	0.04	0.03	-0.11*	-0.11*	-0.13**	0.02	-0.01	-0.02	0.01	0.01			
10. FABRICATION EXPERIENCE	6.34	5.30	0.46***	0.45***	0.37***	-0.03	0.16***	-0.11*	0.34***	-0.06	-0.14**		
11. SOURCING EXPERIENCE	2.25	2.99	-0.20***	0.25***	0.18***	0.22***	-0.04	-0.21***	-0.10*	-0.10*	-0.17***	0.13**	
12. DIVERSIFICATION STRATEGY	3.27	1.90	0.41***	0.62***	0.62***	-0.31***	0.33***	-0.06	0.20***	-0.24***	-0.14*	0.51***	0.05

^a N = 469

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 2. Results of logistic regression analyses for vertical integration^a

Independent variables	Estimated parameter coefficients						
	Model I	Model II	Model III	Model IV A	Model IV B	Model V	Model VI ^e
INTERCEPT	-1.194*	-1.067	-0.273	0.924	2.381	0.433	3.847
	(0.465)	(1.070)	(1.136)	(1.318)	(1.426)	(1.574)	(1.978)
FIRM SIZE	0.239**	0.324***	0.318***	0.214	0.130	0.260	0.174
	(0.075)	(0.086)	(0.088)	(0.112)	(0.120)	(0.136)	(0.168)
FIRM TENURE	0.075***	0.069***	0.077***	0.076***	0.074***	0.065**	0.034
	(0.014)	(0.016)	(0.017)	(0.020)	(0.019)	(0.020)	(0.027)
US FIRM	-0.771*	-0.246	-0.240	-0.367	-0.435	-0.643	-1.533*
	(0.326)	(0.363)	(0.369)	(0.483)	(0.430)	(0.475)	(0.657)
JAPANESE FIRM	-0.006	0.832	0.733	-0.092	-0.004	0.038	0.440
	(0.522)	(0.561)	(0.564)	(0.632)	(0.607)	(0.634)	(0.820)
OTHER ASIAN FIRM	0.216	0.700	0.812	0.219	0.445	-0.194	0.295
	(0.548)	(0.600)	(0.607)	(0.718)	(0.741)	(0.808)	(0.926)
EX ANTE SMALL NUMBERS	—	-0.320**	-0.359**	-0.342**	-0.431**	-0.452**	-0.511**
		(0.115)	(0.122)	(0.132)	(0.153)	(0.165)	(0.171)
SMALL NUMBERS SQUARED ^b	—	0.013***	0.014***	0.012**	0.013**	0.013**	0.014**
		(0.003)	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)
ASSET SPECIFICITY	—	0.420	-0.936	-1.159	-1.610*	-1.713**	-1.198
		(0.363)	(0.557)	(0.599)	(0.638)	(0.658)	(0.761)
DEMAND UNCERTAINTY	—	-3.483	-15.305**	-16.795**	-17.924**	-19.890**	-19.869*
		(4.161)	(5.570)	(6.254)	(6.579)	(6.477)	(7.795)
ASSET SPECIFICITY × UNCERTAINTY	—	—	28.837***	30.886**	34.146***	37.612***	35.693**
			(8.720)	(9.817)	(10.199)	(10.815)	(13.080)
FABRICATION EXPERIENCE	—	—	—	0.187***	—	—	0.184***
				(0.039)			(0.049)
SOURCING EXPERIENCE	—	—	—	-0.269***	—	—	-0.223**
				(0.058)			(0.075)
FABRICATION EXPERIENCE HAT ^c	—	—	—	—	0.275***	0.315***	—
					(0.043)	(0.049)	
SOURCING EXPERIENCE HAT ^c	—	—	—	—	-0.315*	-0.388**	—
					(0.135)	(0.148)	
DIVERSIFICATION STRATEGY	—	—	—	—	—	1.889***	2.886***
						(0.509)	(0.651)
DIVERSIFICATION STRATEGY SQUARED ^b	—	—	—	—	—	-0.306***	-0.406***
						(0.073)	(0.092)
Log-likelihood	-203.24	-177.21	-171.49	-145.16	-144.81	-135.29	-97.57
Correctly classified	81.0%	85.5%	86.4%	89.4%	89.1%	90.2%	96.0%
Max-rescaled R ^{2d}	0.31	0.43	0.46	0.57	0.57	0.61	0.74

^a N = 469. For each variable, the estimated coefficient is given with the standard error below it in parentheses.
^b We introduce 'squared' terms to account for observed nonlinear relationships between governance choice and small numbers bargaining situations as well as product-market diversification.
^c Instrumental variables have been used in a two-stage process to correct endogeneity problems with this variable.
^d This variation of the general coefficient of determination, generated in the SAS logistic regression procedure, comes from Nagelkerke (1991). It is based on the log-likelihood, and can reach a maximum value of 1.
^e Model VI includes nine dummy variables for the years 1988 -96. Seven of the coefficients are significant with $p < 0.05$. Estimates obtained from analyses that added the time controls to Models I-IV were similar to those presented here without the time controls.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

and sourcing experience. Model V reports the results from our full model, which includes the transaction and capability level variables as well as our measure for product-market diversification strategy. Finally, Model VI adds the controls for time. Likelihood statistics and measures of overall model fit are included at the bottom of the table.

The robustness of the estimated coefficients across model specifications suggests that the transaction- and firm-level effects uniquely influence firms' make-or-buy decisions in the semiconductor industry. Likelihood ratio test statistics comparing each model to its immediate predecessor are all significantly different from zero ($\rho <$

0.001). Similarly, the percent of observations correctly classified and the max-adjusted R^2 improve substantially when the firm-level variables are included. As shown at the bottom of the column, Model VI correctly classifies 96 percent of the observations, and has the highest max-adjusted R^2 (0.74). Given the stability of our results across specifications, our discussion focuses solely on Model VI.

Consistent with transaction cost theory, Hypotheses 1 and 2a predicted that both asset specificity and demand uncertainty would increase exchange hazards and therefore increase the likelihood that firms would integrate their production activities. Hypothesis 2b argued that the likelihood of market failure was most severe in exchanges that exhibited both high degrees of asset specificity and demand uncertainty. Contrary to our expectations, the results presented in Model VI fail to support the existence of a significant direct effect between asset specificity and integration and suggest a weakly significant negative effect between demand uncertainty and the likelihood of integration ($p < 0.05$). As anticipated in Hypothesis 3b, the combination of asset specificity and demand uncertainty is strongly associated with vertical integration of production.

Our results provide strong support for Hypotheses 3–5. Hypotheses 3 and 4 argued that a firm's past experiences, be they embodied in past production expertise or in familiarity with suppliers of a particular production technology, would affect firms' vertical boundary choices. The results reported in Model VI indicate that fabrication experience ($p < 0.001$) and sourcing experience ($p < 0.01$) affect firms' vertical integration decisions as expected.

Hypothesis 5 argued that greater diversification across product-markets would correspond to a higher probability of internal production. The significant and positive coefficient on the product-market diversification variable provides strong support for this hypothesis. The associated quadratic term indicates that the hedging effect provided by a presence in additional product-markets has diminishing returns.

DISCUSSION

This paper develops and tests a model of governance behavior that generalizes existing TCE

studies of vertical integration that have held capabilities and strategies constant across firms. The main findings indicate that firm-level capabilities and strategies independently and significantly influence firms' vertical boundary choices. Consistent with qualitative arguments suggesting that firms' make or buy decisions are conditioned by their core competencies (e.g., Quinn and Hilmer, 1994; Argyres, 1996; Barney, 1999), we find that firms having greater experience with a particular process technology are more likely to internalize manufacturing activities than firms lacking such production experience. Similarly, firms with high levels of sourcing experience are more likely to outsource their production than firms that do not have such experience. Consistent with option theoretic arguments, we also find that a measure of firm strategy, product-market diversification, is associated with a greater likelihood of internalizing production. Firms' boundary decisions are influenced by their ability to adjust their strategy over time in response to changing market conditions. Taken together, these results lead us to conclude that there is benefit both to economizing and strategizing (Williamson, 1991).

The practical importance of these findings is illustrated by the economic significance associated with our firm-level measures. Holding the value of all other variables constant, a one standard deviation increase in sourcing experience decreases the probability that a transaction is internalized by 8.8 percent. Similarly, increasing the level of fabrication experience one standard deviation from its mean increases the probability that a transaction is conducted internally by 6.9 percent. While the large number of firms in our sample without any internal production suggests that the economic significance of the fabrication experience variable should be interpreted with caution, these results provide compelling evidence of the practical importance that firms' experiences have on their subsequent vertical integration decisions.

While our conceptual model argues that greater uncertainty leads to integration for transactions involving both high and low values of asset specificity, our empirical results indicate that, in the semiconductor industry, uncertainty only leads to integration in the presence of high asset specificity—uncertainty is associated with increased outsourcing for products that do not require transaction specific investment. Consistent with real option theory, this finding suggests that the reduced

commitment associated with market contracting for nonspecific resources enables firms to switch suppliers, adjust production scale downward, or change technology at less cost in the future than if they had invested in their own production. In this instance, the ability to flexibly respond to uncertainty in the value of production assets overwhelms the benefits of the reduced transaction costs brought on by the uncertainty that a supplier will behave opportunistically. In practical terms, the increasing cost of semiconductor fabrication facilities, reaching over \$1 billion in many cases, may make the abandonment option even more valuable in the future.

This paper also examined the extent to which transaction-level variables affect firms' vertical boundary choices. Our results indicate that firms in the semiconductor industry internalize production when *ex ante* small numbers bargaining problems are severe and increasingly outsource with the number of available suppliers. Although there has been some prior empirical support for the small numbers hypothesis (Pisano, 1990), our results are important in that they show that *ex ante* small numbers bargaining situations continue to influence the make-or-buy decision after controlling for the influence of a variety of firm-level effects.

The paper further examined the influence of the two main transaction-level predictors of *ex post* opportunistic behavior: asset specificity and uncertainty. At first glance, the nonsignificant direct effect between asset specificity and integration might seem surprising. However, the positive interaction between asset specificity and demand uncertainty is consistent with the basic predictions of transaction cost economics (e.g., Coles and Hesterly, 1998). Specifically, firms internalize transactions when it is likely that they will need to renegotiate supplier contracts under conditions of high asset specificity.

The present study's results and limitations have several implications for future theoretical and empirical research on the determinants of vertical integration. The statistical significance of our firm-level variables as well as the fact that many firms in our sample tend to follow an internalization or an outsourcing production strategy suggests that firms do have distinctive asset stocks, resources, or capabilities that lead them to marginally prefer one form of governance over another. In this paper we assert that these differences arise from past experiences; however, we do not describe the initial

conditions that lead to these differences. Future research may examine the extent to which today's firm-level effects are the result of a path-dependent process initiated by past exchange conditions (e.g., Williamson, 1999), constraints imposed by a firm's portfolio of production agreements (e.g., Argyres and Liebeskind, 1999), or other past imperfections in the market for production expertise (Barney, 1986).

The paper also presented some preliminary evidence suggestive of the role that real options may play in firms' vertical integration decisions. However, the real options approach to vertical integration suggests a much broader array of potential strategies than explored in this paper. For instance, one way to create a real option to manage uncertain demand for products or technologies is to invest in flexible technology (Kulatilaka and Trigeorgis, 1994). Another approach to manage these uncertainties is to invest more in worker education so employees are cross-trained. Alternatively, a simple and often low-cost approach to managing demand uncertainty is to hire temporary workers. The cost of this latter option includes fees paid to temporary agencies, potentially lower productivity, or the loss of morale, but the temporary employment contract gives the firm the right to switch employee skills sets without paying severance fees or renegotiating union contracts. To the extent that these tactics affect a firm's exposure to demand or technological uncertainty, they represent a critical source of unobserved heterogeneity that may partially explain the fragile nature of existing empirical results regarding the effect of uncertainty on governance (e.g., Mahoney, 1992). Moreover, given the multidimensional nature of the uncertainty construct (Sutcliffe and Zaheer, 1998), these approaches may allow managers to tightly focus their actions to mitigate the affects of specific types of uncertainty.

Although the robustness of the coefficients in our models across multiple specifications suggest that transaction- and firm-level effects play significant and largely independent roles in firms' vertical boundary decisions, we are unable to test for the relative magnitude of these effects with this data. Given the distinctions inherent in the TCE, RBV, and real option approaches to vertical integration, it would be fruitful for future empirical research to examine the extent to which firm- and transaction-level factors influence firms' boundary decisions. For instance, tests for a fixed effects or random

effects model vs. a pooled cross-sectional model will reveal the existence and the relative magnitude of firm effects.

A cross-sectional research design was chosen for this paper in order to provide comparability with extant research on the vertical boundaries of the firm (e.g., Monteverde and Teece, 1982a, 1982b; Walker and Weber, 1984; Masten, 1984; Masten *et al.*, 1991; Poppo and Zenger, 1998). The stability of the relationships between attributes of a given transaction, relevant capabilities, and governance decisions over time remains an untested area deserving of attention. In the semiconductor industry, the evolution of specialized manufacturing firms, or foundries, is likely to alter the traditional hazards associated with market contracting by increasing the number of potential suppliers and increasing the modularity of production. More generally, one might conjecture whether technological improvements in CAD/CAM, electronic data interchange, and other information technologies have reduced the traditional coordination problems associated with outsourcing. Given the apparent trend toward the disintegration of design and manufacturing in many industries, future studies may examine whether changes in the value of the transaction- or firm-level factors highlighted by existing theory have led to the recent deintegration of formerly integrated firms.

This paper emphasized insights derived from the organization economics literature on governance structures. As noted in the introduction, however, a number of other theoretical perspectives comment on the factors that influence an organization's boundaries. For instance, the resource dependence perspective describes how factors such as control, influence, and power may influence organization boundaries (e.g., Pfeffer, 1978). Consistent with this stream, future research may examine whether low-status firms adopt vertical integration in an effort to reduce interdependencies with exchange partners (Pfeffer and Salancik, 1978: 114) or as response to institutional pressures to create legitimacy. Alternatively, noting that the increased interdependence implied by integration decreases an organization's ability to adapt to environmental change, future studies may examine the performance of integrated and deintegrated firms in stable and volatile environments (e.g., Sorenson, 2002).

The study's findings indicate a number of opportunities that exist for management scholars to study

the similarities and differences between transaction cost, organizational capability, and real option approaches to vertical integration. Future research may address specific contexts in which these different theories are most informative, specific areas of agreement and disagreement between these theories, and the positive and normative boundaries of these theories. As firms increasingly search for ways in which to create and appropriate economic value through cooperative agreements, these research directions will likely take on greater importance.

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