DO SMALL FIRMS BENEFIT LESS FROM ALLIANCES THAN LARGE FIRMS? EVIDENCE FROM THE SEMICONDUCTOR INDUSTRY

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Abstract A good deal of academic and practitioner research argues that small, entrepreneurial firms are disadvantaged in strategic alliances. Despite this attention, little empirical work documents the factors that make collaboration difficult, whether specific organizational decisions may mitigate these reported disadvantages, or whether these considerations affect performance for these firms. Utilizing the resource-based (RBV) and transaction cost economics (TCE), this paper examines the extent to which alliance-, firm-, and partner-level characteristics affect alliance decisions and subsequent performance across small and large firms. Using a sample of 603 semiconductor production sourcing alliances and a two-stage methodology, our empirical results indicate that partner capabilities and the relative "technical distance" between firm and partner capabilities have distinct effects on small and large firms' alliance performance.

Keywords: Alliances; Firm and Partner Capabilities; Small and Large Firms; Transaction Cost Economics (TCE); Resource Based View (RBV).

INTRODUCTION

The number of strategic alliances has grown dramatically over the past two decades. By one account, more than 20,000 alliances have been formed worldwide between 1998-2000 at a 25 percent annual growth rate (Harbison *et al.*, 2002). While alliances were once thought to be restricted between large firms, alliances between small ventures and large firms represent an increasing percentage of alliance activity—particularly in high technology sectors (Rothaermel & Deeds, 2005). A 2004 National Federation of Independent Businesses (NFIB) report notes in particular that nearly two-thirds of small businesses currently hold or have held some type of alliance. This same report indicates that the type of alliance most frequently formed by small business manufacturers is a long-term production agreement.

The increased use of alliances by small firms has stimulated a growing research stream that suggests alliances create unique benefits and challenges to small firms (Park & Kim, 1997; Sarkar *et al.*, 2001; Zahra *et al.*, 2000). Alliances provide lower cost access to activities critical to the success of high technology entrepreneurial ventures (Powell *et al.*, 1996), by allowing these often resource-constrained firms to share expertise, assets and risk without incurring significant debt or equity (Baum *et al.*, 2000; Stuart, 2000). At the same time, many small firms report dissatisfaction with their alliances due to exploitation by their larger partners, with some entering bankruptcy as a result of their collaborative activities (Alvarez & Barney, 2001).

This paper contributes to this literature by examining the antecedent conditions and consequences of alliances between small and large firms. We develop and test two propositions that examine whether and why small firms might report lower overall alliance performance than large firms: (a) do they choose or are forced to ally with less technically capable alliance partners; and (b) are they less able to absorb knowledge from their more technically capable alliance partners, in comparison to large firms. More generally, by jointly incorporating the organizational alignment approach of transaction cost economics (TCE) with firm-level resources and capabilities articulated by the resource based view (RBV) of the firm, we contribute to work integrating these perspectives into a more robust theory of alliance organization and performance.

We test these propositions using a sample of 603 semiconductor technological development and production sourcing alliances using two-stage econometric analysis. The first stage examines the factors that affect firms' decisions to select equity or non-equity alliances. The second stage examines alliance performance, which we measure as the level of "technological advancement" of the focal alliance compared against the sample average of alliances in the same product market and/or year. Comparisons across small and large firms are examined in each stage of the econometric analysis.

Sample statistics indicate that small firms achieve lower technological performance in their alliances on average, in comparison to large firms. Correlation statistics indicate that technological performance varies positively with equity alliances, positively with firms' and partners' technical capabilities, and negatively with the "distance" in technical capabilities between firms and their partners. The first-stage results demonstrate both similarities and differences regarding the use of equity versus non-equity alliances between small and large firms. For instance, both small and large firms are more likely to use equity alliances as alliance scope and demand uncertainty increase and less likely to use equity alliances as the technological distance in capabilities between them and their partner firms increases. At the same time, small firms' alliance organization decisions differ from large firms' according to supplier availability and alliance difficulty, while large firms' decisions differ from small firms' according to alliance experience and relationship length. These results support the proposition that small firms face particular constraints in their alliance organization decisions in ways that large firms do not. The second-stage results analogously indicate similar and different performance effects from alliance-, firm- and partner-level factors for small and large firms. For both types of firms and both kinds of alliances, technological performance improves when partner firms possess more advanced technical capabilities but degrades as the distance in technical capabilities between firms and their partners grows. Large firms are better able to reduce the performance penalties associated with the distance in technological capabilities, however, than small firms. We conclude our analysis with a short discussion of the characteristics that lead to inappropriate alliance selection decisions on the part of small and large firms.

The next section provides an overview of the alliance literature, highlighting in particular research that examines performance and small and large firm differences in alliance organization. This discussion is followed by our theoretical context and hypotheses development around the firm- and partner-level attributes that differentially affect small and large firms' alliance organization and subsequent technological performance. The next section provides an overview of the empirical setting, the sources and characteristics of the data, and the dependent and independent variables. The following section details the econometric model, and presents the analysis and results. The final section discusses the results, makes concluding comments and offers opportunities for future research.

LITERATURE REVIEW

A substantial body of research suggests that alliances provide mechanisms through which competing firms with otherwise opposing interests can enter into mutually beneficial exchange. This research is broadly classified into two streams. The first describes why firms select different alliance governance forms. This research frequently conceptualizes alliances as discrete and intermediate forms of organization between the polar extremes of pure market or hierarchical organization (Borys & Jemison, 1989). Empirical research generally makes strong distinctions between non-equity and equity alliances, suggesting equity alliances afford greater control and incentive alignment through shared ownership and membership on a joint board (Chi, 1994; Pisano, 1989) and superior coordination through common administrative organization (Gulati, 1995; Gulati & Singh, 1998; Osborne & Baughn, 1990). While performance implications are often inferred, emphasis within this research stream is predominantly placed on the factors that lead influence alliance governance.

The second research stream emphasizes the motivations and performance implications associated with alliance formation, while generally downplaying issues related to alliance governance. Alliances improve firms' abilities to access, coordinate and control the resources necessary to develop, manufacture, and market goods and services (Hamel *et al.*, 1989). One principal means through which alliances create value is by bringing together firm-specific resources that are otherwise costly to trade or substitute across firms (Doz & Hamel, 1998; Kogut, 1988). Alliances facilitate innovation and technological development by improving firms' existing knowledge bases (Baum et al., 2000) and by allowing the pooling of resources and the spreading of costs and risks (Powell, 1990). Alliances enhance performance by tapping into specialized capabilities (Dyer & Ouchi, 1993; Kogut, 1988; Mowery *et al.*, 1996) and accessing new information and knowledge (Mowery *et al.*, 1998).

Empirical research that examines alliance performance is limited, however, and with generally mixed results. The majority of alliance performance research is conducted through surveys (Zollo *et al.*, 2002) or case studies (Doz & Hamel, 1998) that, while informative, potentially suffers from subjectivity, survey participant biases or other measurement difficulties. More recent research utilizes more direct measures of alliance performance. Ahuja (2000) finds a positive relationship between the number of alliances formed and firm innovation, suggesting that alliances help firms develop and absorb technology outside the firm, while Hoang and Rothaermel (2005) find a positive relationship between partner general experience and R&D project performance. Neither of the above studies explores differences among alliance types, however. Sampson (2004), by contrast, finds that alliances improve innovative performance—measured in terms of post-alliance patent productivity—when selected according to TCE hazard mitigation arguments, but this is only an indirect measure of innovative performance.

The alliance literature frequently portrays small and large firms as distinct entities with unique strengths and weaknesses. Small firms are characterized as possessing superior technologies and innovative capabilities (Deeds & Hill, 1996; Eisenhardt & Schoonhoven, 1990), while large firms are portrayed in terms of refined downstream manufacturing, distribution and marketing assets (Baum et al., 2000; Stuart, 2000). Despite the potential to improve performance by linking the complementary resources of small and large firms, it is not evident that this objective is automatically realized. In particular, alliances between differently-sized entities can lead to power imbalances that hinder success (Khanna *et al.*, 1998; Simonin, 1997). Even when an alliance is considered value enhancing, it is questionable whether small and large firms share equally in the benefits of collaboration. Anecdotal evidence suggests that small firms perceive that their larger partners appropriate a disproportionate share of the value generated through collaboration (Alvarez & Barney, 2001). Some alliance research not surprisingly suggests that firms instead seek partners similar in size and status (Bucklin & Sengupta, 1993; Harrigan, 1988; Podolny, 1994).

The existing literature thus emphasizes the benefits of alliances in providing mechanisms through which firms access complementary resources and capabilities, improve knowledge creation and transfer, and facilitate innovation. A tension nevertheless exists for small firms between the need to gain access to important resources and the requirements of achieving sufficient control and coordination to capture the information benefits of any collaborative effort. Surprisingly little empirical evidence exists regarding whether small firms experience unique shortfalls or challenges as a result of their alliance activities in comparison to large firms. Nevertheless, such an examination is critical—only by comparing empirically the conditions under which small and large firms enter into specific alliances and attain more (or less) benefit can alliance research be advanced.

THEORY & HYPOTHESES

Although alliances provide access to greater scale and a broader scope of resources than is typically available in a single firm, they also create organizational challenges. The use of alliances implies reduced control and coordination over the process by which particular activities are conducted, in comparison to internal organization (Hamel *et al.*, 1989; Kale *et al.*, 2002; Singh & Mitchell, 1996; Williamson, 1991). The observed variety of alliance arrangements moreover suggests that certain alliances are better suited for particular activities than others. Transaction cost economics (TCE) provides one characterization of how these benefits and challenges vary across different alliance arrangements. As a hybrid organizational form (Borys & Jemison, 1989), alliances are intermediate to the high-powered incentives of the market and its reliance on price and the low-powered incentives of the firm and its broader set of administrative control systems (Mahoney, 1992; Oliver, 1990; Williamson, 1991). Within this alliance taxonomy, alliances principally vary according to their ownership characteristics (Oxley, 1997). Alliances range from arm’s-length in which cash payments are exchanged for technology, know-how or capacity (Porter, 1980), to more formal where buyers enter into relationships with their suppliers (Dyer, 1996). Distinctions in this latter category are made between arrangements that involve no shared equity (i.e., technology licenses, second-sourcing contracts, reciprocity agreements and long-term contracts) and equity arrangements that either involve equity exchange or create joint ventures with separate administrative organizations (Gulati & Singh, 1998; Oxley, 1997; Pisano, 1990a).

More hierarchical alliances are argued to better mitigate opportunism and improve monitoring by aligning incentives, improving control and fostering coordination among partner firms. There are, however, limits to the benefits of more hierarchical alliance arrangements. In particular, excessively hierarchical alliances dull incentives and present additional bureaucratic costs. While less attention has been placed on the performance implications associated with these arguments, the concept of "discriminating alignment" suggests that less hierarchical alliances should be used to manage more straightforward exchanges and more hierarchical alliances utilized to manage more complex exchanges. Empirical alliance research is generally supportive of the discriminating alignment proposition, suggesting equity alliances are more likely in the presence of *ex-ante* small numbers bargaining situations and uncertainty (Pisano, 1989); specific investment and appropriability hazards (Oxley, 1997), and alliance scope (Oxley & Sampson, 2004). Some empirical research also suggests alliance performance varies in a discriminating way according to the alliance arrangement selected and alliance scope and difficulty (Leiblein & Macher, 2005; Sampson, 2004).

The above arguments suggest that there are organization and performance implications based upon alignment between alliance selection and exchange attributes. Utilizing this discriminating alignment approach and the capability orientation of the resource based view (RBV), we examine whether two other "attributes of exchange"—focal firm and partner firm capabilities and the technical distance in capabilities between focal firms and partner firms—influence alliance organization and performance. We also examine whether and to what extent these differences are due to any qualitative distinctions between small and large firms.

Firm and Partner Capabilities

The resource based view (RBV) of the firm suggests organizations are bundles of resources, some of which become valuable, rare, and non-substitutable (Barney, 1991; Lippman & Rumelt, 1982; Rumelt, 1984; Wernerfelt, 1984). Valuable, rate and non-substitutable (VRIN) resources can be tangible—such as specific product designs or particular production techniques—or intangible—such as brand equity; market, technological or customer knowledge; or unique management practices. Scholars have extended the RBV to examine the sources of competitive advantage by highlighting the role of capabilities, particularly in high technology environments (Teece *et al.*, 1997). Capabilities represent strategic and organizational routines and processes (Nelson & Winter, 1982) that are deeply embedded within firms (Eisenhardt & Martin, 2000). Capabilities are often based on tacit knowledge within firms, and thus subject to uncertainty concerning their efficiency and performance. In particular, differences in routines related to experience accumulation and the articulation and codification of (tacit) knowledge create differences in capabilities (Zollo & Winter, 2002), and thereby differences in performance.

The tacit and embedded characteristics of capabilities suggest that market transactions related to their sale are difficult to organize for and achieve (Pisano, 1990b), mainly due to non-trivial costs of transfer (Teece, 1977). At the same time, it is difficult for firms to develop internally all of the requisite capabilities and complementary assets required to produce a product or provide a service (Teece, 1986). The literature instead suggests that alliances represent an effective organization mechanism to acquire (Kogut, 1988) or access (Grant & Baden-Fuller, 199) organizational knowhow. Alliances not only provide access to important resources (Eisenhardt & Schoonhoven, 1996; Rothaermel, 2001) and complementary assets (Teece, 1996), but also facilitate learning and the sharing of knowledge (Dyer & Nobeoka, 2000; Kahnna *et al.*, 1998; Kale *et al.*, 2000; Mowery *et al.*, 1996) among firms.

Differences in characteristics among partner firms suggest, however, that some alliances are more effective than others. Well-connected partners offer indirect ties that act as mechanisms for knowledge spillovers (Ahuja, 2000), while more innovative partners improve focal firms' innovative efforts and outcomes (Stuart, 2000). Firms who ally with a more diverse set of partners are also more successful post-IPO than firms that ally more narrowly (Baum et al., 2000). Capability endowments within firms also influence organization and performance. Argyres (1996) shows capabilities jointly influence production and transaction costs, and subsequently, governance decisions. Leiblein and Miller (2003) find firm capabilities have a statistically and economically significant impact on outsourcing decisions, even after controlling for transaction costs. Outsourcing to partner firms is more likely if firms (Mayer & Salomon, 2006) or their partners (Hoetker, 2005) possess superior technical capabilities. In the former case firm capabilities help shape firms' governance capabilities in selecting, monitoring and sharing knowledge with suppliers, while in the latter case supplier capabilities free firms from additional investment in time and resources.

Similar to partner-firm capabilities, the type of alliance implemented should also influence alliance performance. Grant and Baden-Fuller (199) suggest knowledge generation alliances facilitate the transfer and absorption of partners' knowledge bases, while knowledge application alliances promote knowledge sharing in which firms access partners' knowledge bases to exploit complementarities while maintaining distinct bases of specialized knowledge. Kogut (1988) more directly suggests that equity arrangements support the transfer of technological capabilities among firms, in comparison to non-equity alliances, given the tacit nature of the knowledge exchanged. If alliance performance requires acquiring or accessing the capabilities embedded within partner firms, more hierarchical alliances improve control and foster coordination. Empirical alliance research is generally supportive of this proposition—equity alliances are more likely in the presence of *ex-ante* small numbers bargaining situations and uncertainty

(Pisano, 1989); specific investment and appropriability hazards (Oxley, 1997), and alliance scope (Oxley & Sampson, 2004). Other alliance research finds alliance performance varies in a discriminating way according to the alliance arrangement selected and level of exchange hazards (Leiblein & Macher, 2005; Sampson, 2004). We make a similar 'discriminating alignment' argument regarding technical capabilities. Equity alliances are more effective interorganizational mechanisms for transferring tacit knowledge associated with technology-based capabilities than other types of alliances. Firms retain their capabilities while simultaneously benefiting from their partners' organizational knowledge (Kogut, 1988). The following set of hypotheses that relate firm and partner capabilities to alliance organization and performance, respectively, is therefore examined:

H1a Alliances with greater ownership (e.g., equity) are more likely as the technical capabilities of firms and/or their partner(s) increase.

H1b The technological performance of alliances is, on average, positively related to the technical capabilities of firms and their partner(s).

Firm and Partner Technical Capability Differences

While it may appear attractive to ally with the most technically capable partners, organizational and technical barriers associated with different routines, resources and capabilities among partner firms suggest that such strategies can have negative performance effects. In particular, as the distance between the technical capabilities of firms and their partners increases, firms' abilities to receive and process (Hamel, 1991) or absorb (Cohen & Levinthal, 1990) partner firms' technical knowledge and information is reduced. While firms jointly pursuing collaborative technological development require some degree of overlap, empirical research that examines firms and partners with similar and different 'capability sets' is mixed. Some research suggests that alliances last longer and show greater stability over time when alliance activities with partner firms do not overlap (Dussage *et al.*, 2000). Other research suggests that greater overlap in organizational properties enhances alliance success (Lane & Lubatkin, 1998) and greater 'overlap' in technical knowledge facilitates knowhow exchange and development (Mowery *et al.*, 1998). Research in the latter category suggests that the importance of knowledge complementarities and partner-specific absorptive capacity are important determinants in the partner selection process (Cohen & Levinthal, 1990).

A tension therefore exists for firms entering into alliances with partner firms of heterogeneous capabilities. On the one hand, firms require access to and benefit from the technical capabilities of their partners. Partner firms who do not "push-the-envelope" in terms of technical acumen are unlikely to improve the technological standing of the focal firm. On the other hand, some similarity or overlap with partner firms is beneficial in order to engender communication, improve understanding and efficiently absorb technical information. But particularly acute differences in technical capabilities between firms and their partners is likely to detract more from improved technological performance than the benefits that technically-advanced or technically-lagging partners, in comparison to the focal firm, might provide. If firms do enter into alliances with significant technical distance, similar arguments as articulated above suggest that the use of equity alliances will provide some performance advantages.

Kogut (1988) more directly suggests that equity arrangements support the transfer of technological capabilities among firms, in comparison to non-equity alliances, given the tacit nature of knowledge exchanged. If alliance performance requires acquiring or accessing the capabilities embedded within partner firms, more hierarchical alliances should provide superior control and foster greater coordination. We therefore examine the following set of hypotheses that relate firm-partner technical capability distance to alliance organization and performance, respectively:

H2a Alliances with greater ownership (e.g., equity) are more likely as the technical distance in capabilities between firms and their partner(s) increase

H2b The technological performance of alliance arrangements is, on average, negatively related to the distance in technical capabilities between firms and their partner(s).

Small and Large Firm Comparisons

Size provides certain advantages to firms' R&D efforts and innovative activities (Cohen, 1995). Large firms are more likely to possess the scale, experience and financial resources required for capability development than small firms (Woo & Cooper, 1981). Large firms also have greater access to the complementary technologies and downstream capabilities that are presumed to make R&D and innovation more productive (Cohen, 1995). The limited scale, technical experience and resource constraints of small firms likely affect their abilities identifying and selecting suitable partners. Searching for the "right" alliance partners is costly, given the associated expenses of scanning the landscape, the due diligence required, and the resources consumed. Small firms have comparatively greater difficulty bearing these information and search costs in comparison to large firms. For instance, addressing differences in the administration of small and large firm international joint ventures, Buckley (1997:72) suggests that "[t]he horizons of small firms are limited by managerial constraints…therefore, when an opportunity presents itself, it is often seized without proper evaluation…consequently, small firms with inexperienced managers can behave in a naïve fashion." Particularly related to technological development, the requirements for and true value of the underlying (complementary) assets are difficult to assess. Large firms are generally in better positions to monitor the technological environment and determine which of the potential partner firms are more or less suitable.

At the same time, partner firms most likely find large firms represent more desirable collaborators, in comparison to small firms. Large firms generally offer less risk and larger upsides to partner firms' own technological development and financial advancement goals. Small firms are less desirable partners due to their level of technical acumen, and revenue, growth and profit potential. Given the resource and informational constraints described above, it is therefore likely that small firms are subject to more acute adverse selection problems in comparison to large firms. Partner firms' incentives to establish ownership arrangements via equity alliances with small firms are therefore less in comparison to large firms. As a result, and given that they have no or at least more limited options in going it alone, small firms are forced into alliance arrangements with less capable partners in comparison to large firms. If small firms ally with less capable partners they are systematically disadvantaged in their abilities to achieve superior levels of performance. We therefore examine the effect of firm size and partner firms' technological capabilities on alliance organization and performance, respectively:

H3a Small firms are less likely to establish alliance arrangements with greater ownership (e.g., equity) as the technical capabilities of their partner firm(s) increase, in comparison to large firms.

H3b Small firms realize worse performance in their alliance arrangements as the technical capabilities of their partner firm(s) increase, in comparison to large firms.

The managerial, organizational and technical constraints of small firms have a secondary effect on their abilities to extract value from their established alliance arrangements. Small firms typically possess smaller capability endowments and thus lag behind the technical capabilities of their larger counterparts. Even if small firms establish alliances identical to large firms in terms of partner firms' technological capabilities, these arrangements represent a greater stretch for small firms because they are more technologically distant in comparison. The larger managerial and organizational challenges of small firms associated with absorbing new information (Cohen & Levinthal, 1990) further limit the success of small firms' alliances with more technically capable partners.

As mentioned above, small and large firms also differ in their capabilities in managing alliances. These capabilities include general routines that enhance inter-functional coordination across partners, as well as firm-specific processes that aid in facilitating communication and anticipating and responding to technological or market contingencies (Nelson & Winter, 1982). Firms' abilities to codify and disseminate the knowledge that results from the alliance improves from the formation of formal alliance functions (Kale *et al.*, 2002) and the repeated use of certain types of alliance arrangements (Anand &

Khanna, 2000). For small firms, an alliance function is unlikely while alliance experience is more limited. Small firms lack the resources that facilitate the effective filtering through and codification of knowledge that results from their alliances. Small firms are less likely to hire experienced specialists who directly manage corporate development and alliance activities and less likely to invest in and develop skills in managing multiple partnerships. Given the associated challenges of managing alliances above and beyond the technical distance between firms and their partners (Deeds & Hill, 1996), the lack of managerial and administrative skills and supporting resources of small firms suggests that they benefit less from alliances more technologically-distant in comparison to large firms.

At the same time, partner firms that possess superior technological capabilities are likely to find small firms less desirable collaborators in comparison to large firms for the reasons articulated above. Especially for equity alliances, partner firms have "nothing to gain" and "everything to lose" from entering into alliances with small firms in comparison to large. We therefore examine the effect of firm size and technical capability distance on alliance organization and performance, respectively:

H4a Small firms are less likely to establish alliance arrangements with greater ownership (e.g., equity) as the technical distance in capabilities with their partner firm(s) increases, in comparison to large firms.

H4b Small firms realize worse performance in their alliance arrangements as the technical distance in capabilities with their partner firm(s) increases, in comparison to large firms.

RESEARCH DESIGN

Industry Setting

The empirical setting for this paper is alliance arrangements for the development and production of semiconductor devices. These exchanges are interesting to examine for several reasons. First, production capabilities are of tremendous importance in the semiconductor industry. The ability to produce semiconductor devices using advanced process technologies is directly tied to improved end-product performance, increased revenue and reduced cost. Industry participants therefore have strong incentives to incorporate advanced process technologies into their products. Second, there has been a trend toward disintegration in the industry exhibited in the organizational separation of product design and process manufacturing (Macher & Mowery, 2004). As semiconductor firms increasingly do not possess all of the requisite value chain activities in-house, they instead rely on partner firms. Third, the industry is intensely competitive, exemplified in price declines of 25-30 percent per year (Smith & Reinertsen, 1991), short product lifecycles and rapid technological advancement. Semiconductor firms introduce new products quickly in order to capture the economic rents that accrue to those firms that are fast to market and able to meet demand. It is often only through collaborative alliances that firms can effectively compete in light of these stringent competitive conditions. Finally, there is no single, industry-accepted method for organizing design and production activities. Semiconductor firms typically first decide whether to make or buy, and then given the latter choose whether or not to include shared equity as part of the arrangement. These considerations suggest that the semiconductor industry provides an ideal setting in which to add to existing research by highlighting comparatively the organization and performance implications of alliance-, firm- and partner-level characteristics.

Data

Data for this paper were obtained from annual editions of Integrated Circuit Engineering's (ICE) Profiles of IC Manufacturers and Suppliers. ICE is a market research firm that specializes in the global semiconductor industry. One section of the Profiles market research reports details the governance decisions made by firms in the industry. In particular, alliance arrangements by semiconductor firms are profiled in terms of partner firms, product markets and process technologies covered, among other factors. We utilize reports that describe the instances where semiconductor firms manage technological development and production externally through sourcing agreements.

Information on product-market and process-technology information is available for the majority of the production sourcing arrangements in the sample. Since a semiconductor firm may access production for multiple products and multiple processes through a single sourcing agreement, we record a separate observation for each product market-process technology combination.[1] For example, a semiconductor firm that sells 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 is recorded as three distinct product market-process technology observations. At the product market-process technology level of analysis, our sample consists of 603 production sourcing decisions.

Dependent Variables

Sourcing Alliance Type – We distinguish technological development and production sourcing arrangements on the basis of equity exchange. Non-equity alliances are those in which the focal firm or its partners give or receive cash and/or design license rights or involve codevelopment agreements for development technology and/or production services. Cash and license-based alliances approximate arm's-

[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.

length contracts in which the transacting parties specify the terms of trade and repercussions for noncompliance, while codevelopment agreements involve some personnel interaction between parties. Equity alliances are those in which the focal firm and its partner firm(s) either take equity positions in each other (e.g., minority equity partnerships) or establish independent entities (e.g., joint ventures) to manage technological development and production. Equity partnerships and joint ventures offer greater residual claimancy and control rights and superior monitoring in comparison to non-equity alliances.

Technological Performance – We utilize two measures of technological performance as dependent variables in our analysis, each of which is defined as a function of the transistor density provided by the focal alliance arrangement. Transistor density is the fundamental driver of both cost and product features and represents a widely accepted measure of technological performance in the semiconductor industry. The primary indicator of transistor density is the linewidth or feature size with which information is etched onto a semiconductor device. As average and state-of-the-art linewidths vary across product markets and over time, we transform the linewidth of the focal alliance by standardizing it with respect to the mean and standard deviation identified from all other observations in the sample within the same product market and/or same time. As smaller linewidths imply superior technological performance, we take the negative of this standardized value to ease interpretation. The first technological performance measure is defined as $TechPerf_1 = -\frac{x_{j,t} - \bar{x}_{j,t}}{s_{j,t}}$, where $x_{j,t}$ is the focal alliance arrangement linewidth in product market j at time t, $\bar{x}_{j,t}$ is the average linewidth in product market j at time t, and $s_{j,t}$ is the standard deviation of linewidths in product market j at time t. The second technological performance measure is defined as $TechPerf_2 = -\frac{x_t - \bar{x}_t}{s_t}$, where x_t is the focal alliance arrangement linewidth at time t, $\bar{x}_t$ is the average linewidth in time t, and s_t is the standard deviation of feature sizes in time t. The second performance measure represents a robustness test of the first, as it compares technological performance of all alliances in all product markets in a given year as opposed to technological performance more narrowly within a given product market and given year. A positive value for either performance measure indicates semiconductor firms are developing more advanced technology than their most relevant (defined by product market or over time) competitors, while a negative value indicates less advanced technology. The magnitude of this measure indicates the degree to which the technology being developed by the firm and its alliance partner firms(s) is ahead or behind competitors.

Small Firm – We distinguish between small and large firms using a popular industry categorization based on firm revenue (Angel, 1991). The dichotomous variable *Small Firm* equals one if annual industry revenues are less than US$200 million, and is zero otherwise. Small semiconductor firms tend to be more focused around a single innovative product design or technological application. While the vast majority of these firms report annual revenues substantially below the imposed revenue threshold (i.e., median US and worldwide revenue in the sample is below $25 million and $33 million, respectively), the $200 million cutoff value is used to capture all firms that focus their operations more tightly around a single innovative product design or technological application.[2]

Independent Variables

We argue that alliance arrangement decisions and technological performance via non-equity and equity alliances by small and large firms varies according to the *ex ante* number of available partners, the *ex-post* demand uncertainty surrounding the development effort, own- and partner-firm technical capabilities and technical capability distance, among other factors.

Supplier Availability – Our measure of supplier availability is defined as the number of firms who offer production services and have the ability to manufacture semiconductor devices at the relevant process technology in a given year. This measure captures small numbers bargaining conditions, and is similar in intent to Pisano's (1990a) measure of the number of new biotechnology firms with R&D programs in particular therapeutic areas.

Demand Uncertainty – Our measure of product market demand uncertainty captures managers' perceptions regarding unanticipated shifts in the demand for a specific type of semiconductor device. Following Levy (1985), we argue that demand uncertainty is ascertained by the variance surrounding a trend in the demand for similar products. Demand uncertainty is measured as the sum of squared errors from a regression of the relevant product market's historical unit demand for the five years preceding the focal alliance arrangement. The segment-level demand data is from quarterly reports of units delivered, provided by the Semiconductor Industry Association (SIA). These data are indexed based on the starting value and regressed on a quadratic time trend, controlling for seasonality.

Firm Capability – Firms' technical capabilities are calculated according to their demonstrated development and production capabilities in product market j at time t versus all other firms that offer production capabilities in product market j at time t. The variable *Firm Capability* is defined as $\frac{MIN(FIRM_{i,j,t})}{MIN(OTH\_FIRM_{k,j,t})\forall k}$, where $FIRM_{i,j,t}$ represents the smallest demonstrated linewidth of firm i in product market j at time t, $OTH\_FIRM_{k,j,t}$ is the smallest demonstrated linewidth of firm k in product

2 We performed robustness analyses that identified entrepreneurial firms as those in the lowest quartile of our sample in terms of annual worldwide sales. The revenue threshold implied by this criterion was $39 million. The lowest annual revenue reported was $1.3 million and the average annual revenue in the quartile was $9 million.

market j at time t and the *MIN(·)* function in the denominator selects the smallest linewidth over all other firms. This scaling produces a variable that ranges from 0.1 (technologically-lagging firms) to 1.0 (technologically-leading firms).

Partner Capability – We measure partner capabilities in a manner similar to the measure for firm capabilities. For each alliance arrangement, partner capabilities are calculated according to the demonstrated technical capabilities of all partner firms in a product market j at time t versus all other potential partner firms that offer development and production capabilities in product market j at time t. In particular, we define *Partner Capability* as $\frac{MIN(POT\_PART_{i,j,t})\forall i}{MIN(CUR\_PART_{k,j,t})\forall k}$, where $POT\_PART_{i,j,t}$ represents the smallest demonstrated linewidth of potential partner i in product market j at time t, $CUR\_PART_{k,j,t}$ is the smallest demonstrated linewidth of current partner k in product market j at time t and the MIN(·) functions in the numerator and denominator select, respectively, the smallest linewidth over all potential and all current partners. This scaling procedure produces a variable that ranges from 0.1 (technologically-lagging partners) to 1.0 (technologically-leading partners).

Technical Capability Distance – While it may seem attractive to ally with the most capable partners, managerial and technological barriers suggest that such strategies can have detrimental effects on performance. Communication and coordination challenges are likely to increase as differences in technological capabilities between alliance partners increases due to firms' reduced abilities to absorb (Cohen & Levinthal, 1990) or receive and process (Hamel, 1991) information necessary to achieve desired performance. We determine relative "technical distance" according to the demonstrated technological capabilities of firm i in product market j at time t relative to current partner firms. *Technical Capability Distance* is defined as $LN\left(\frac{FIRM_{i,j,t}}{MIN(CUR\_PART_{k,j,t})\forall k}\right)$, where $FIRM_{i,j,t}$ represents the smallest demonstrated linewidth of focal firm i in product market j at time t, $CUR\_PART_{k,j,t}$ is the smallest demonstrated linewidth of current partner k in product market j at time t. The *MIN(·)* function selects the smallest linewidth over all current partners, while the natural log improves scaling. This measure that ranges from 0.12 (technologically-advanced focal firms relative to partner firms(s)) to 10.0 (technologically-advanced partner firm(s) relative to focal firms). Measures near 1.0 indicate that the focal firm and its partner firm(s) have similar technical capabilities.

Control Variables

We include several alliance-, firm- and partner-level control measures for other factors that may influence alliance selection and technological performance.

Firm Size – Larger firms may face institutional insulation and bureaucratization that decreases responsiveness to shifting industry conditions (Haveman, 1993). At the same time, larger firms may possess superior financial or human resource endowments that allow them to more readily invest in new technologies, or enjoy greater market power or positional advantages that affects their incentives and improves their abilities to adapt to changing environmental conditions (Baum & Mezias, 1992; Baum & Oliver, 1991). A number of variables have been used to measure firm size in the management literature, including number of employees, total assets and firm revenue. Since variables based on assets or employees are directly dependent upon the decision to internalize production activities, we utilize two other measures. *Firm Revenue* is defined as the log of the focal firm's average domestic sales for each year of the dataset. *Firm Production Experience* is defined as the log of the focal firm's cumulative production capacity overall all process technologies.

Firm Age – The age of the firm may similarly influence organization decisions and subsequent performance. The liability of newness suggests that older firms benefit from accumulated experience, whereas the liability of senescence suggests firms increasingly become ossified as they age (Barnett, 1990; Carroll & Hannan, 2000). The variable *Firm Age* measures the number of years since firm founding or the number of years since the firm began selling semiconductors, respectively, for merchant manufacturers and systems houses (e.g., conglomerates).

Firm Alliance Experience – Firms differ in their abilities to select attractive sourcing partners, to negotiate and enforce supplier contracts, to design systems to manage relationships, and to monitor and enforce contractual compliance (Doz & Hamel, 1998). Firms' abilities to identify partners and to mitigate potential contracting hazards are in part a function of prior alliance experience. Alliance experience helps firms develop the skills that aid in the identification of trustworthy partners and the ability to effectively negotiate, monitor, and enforce terms of exchanges (Zollo & Singh, 2004). *Firm Alliance Experience* is defined as the number of unique alliances that the focal firm has established over the last five years.

Relationship Length – Differences in the depth of the relationship between the focal firm and partner firm(s) may influence alliance selection and technological performance. We therefore define *Relationship Length* to control for the number of years that the focal alliance has been active. This variable is meant to capture any organizational or performance effects that are due to the depth of the relationships or internal experiences associated with the focal firm and its partner firm(s).

Alliance Scope – Alliance scope has previously been measured in terms of the number of functional areas (Oxley & Sampson, 2004), technologies (Oxley, 1997), or alliance partners (Pisano, 1989) in the alliance arrangement. Our control measure captures the number of product markets, process technologies, and partner firms involved in the alliance. The variable *Alliance Scope* is defined as $CUR\_PART_i(PROD\_MKTS_i + PROC\_TECH_i)$, where CUR_PART_i represents the number of partners involved in focal alliance *i*, and $PROD\_MKTS_i$ and $PROC\_TECH_i$ represent, respectively, the number of product markets and process technologies that focal alliance *i* covers. The intent of this variable is to capture the complexities, interdependencies and uncertainties associated with both the extensiveness (e.g., horizontal dimensions of alliance scope) and monitoring requirements (e.g., number of alliance partners) of the technological development and production sourcing effort.

Alliance Difficulty – Our measure of alliance difficulty captures both the structure and complexity of technological development and production sourcing problems related to the focal alliance. Problem structure is operationalized according to semiconductor product type. Semiconductors are either analog or digital devices, with the latter further defined by their principal operations as either storage (e.g., memory) or function (e.g., logic). Analog (more so) and memory (less so) products present ill-structured technological development problems, with solutions often based more on art than on science (Monteverde, 1995). Product design and process manufacturing play repeated games of trial-and-error and give-and-take, modifying either the product design or the manufacturing process (or both) in order to figure out what works. Significant disagreements are commonplace in determining the most efficient approach, as there are no formalized processes in place that facilitate solution search (Simon, 1973). A lack of codified knowledge and an inability to predict performance *ex ante* suggests multiple potential directions for solution search for these types of products. Problem complexity is measured as a function of process linewidth, or minimum size of the smallest circuit on a device. More complex problems are presented when technological development is at the leading-edge (e.g., smaller linewidths) because of incomplete understanding of and unexpected interactions between product and process parameters. The tasks of learning the physical limits of the manufacturing process are compounded by the need to understand the functional limits of the product design and how these factors interact with each other. For both ill-structured and complex problems, extensive experimentation, information exchange and rich communication between product design and process manufacturing is required (Macher, 2006). Equity alliances should realize performance advantages when the focal alliance involves ill-structured or more complex technological development and production sourcing problems. The variable *Alliance Difficulty* equals one if the manufacturing process fabricates analog products or advanced memory products,[3] and is zero otherwise.

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[3] Our measure of *Alliance Difficulty* pools the problem structure (analog and memory products) and complexity (technological sophistication) dimensions. Our alliance difficulty classification is: (1) any analog product; and (2) any memory product whose process linewidth is less than the average linewidth of all memory products in the sample in a given year. We tested the robustness of this measure, and can confirm that significant changes to the results do not obtain.

Geographic Region – Four indicator variables are created to specify whether the focal firm is headquartered in Europe, Japan, Southeast Asia, or North America. Firms in the Southeast Asia category are primarily based in China, Korea, Singapore and Taiwan. The excluded category is the North America category in the analysis.

Year – A series of indicator variables that designate the year in which the focal production or sourcing agreement started are included. The excluded year is 1990 in the analysis.

EMPIRICAL RESULTS

Econometric Approach

Two complications arise when analyzing the alliance organization and performance. First, actual alliance performance data is limited. Gulati et al. (2000) in particular notes "[t]hough we have many answers to the question: 'Why do alliances…exist?' we have fewer answers to the question: 'Do alliances…really matter when it comes to firm performance?'" As mentioned above, alliance research that examines performance is limited and with generally mixed findings. The nature of our data allows us to examine the performance implications of distinct alliance arrangements and firms size comparatively, using direct performance measures that represent important dimensions of competitiveness in the semiconductor industry.

Second, the performance of alliance arrangements not chosen are not observed (Poppo & Zenger, 1998). Firms' decisions between different alliance arrangements result in only one of several possible outcomes observed, raising the question of how to estimate the performance difference between the collaborative alliance arrangement selected and the counterfactual (Hamilton & Nickerson, 2003). Earlier empirical studies circumvent this problem by examining only the alliance arrangement decision using qualitative choice estimation techniques, and then making predictions of efficiency based on the observed characteristics. The results of these models are intuitively appealing, but possess certain limitations. Qualitative choice coefficient estimates present interpretation difficulties by making it impossible to determine how an attribute independently affects the performance of each collaborative alliance type. Because firms select alliance arrangements based on their own performance maximizing analyses, it is likely that the observed level of performance is conditional on the alliance arrangement selected. We instead employ a two-stage modeling approach to determine the influence of alliance selection on technological performance (Heckman, 1979). In the first stage, a dichotomous model estimates the influence of alliance-, firm- and partner-level characteristics on the alliance decision. In the second stage, ordinary least squares with robust standard errors also adjusted for clustering estimates the influence of these characteristics on technological performance.

Econometric Results

Table 1 provides summary statistics of the dependent and independent variables used in the analysis for the entire sample and disaggregated by small and large firms. Table 2 provides descriptive and correlation statistics for the entire sample. Preliminary analyses of these tables provide some insights regarding the relationships among equity and non-equity alliances, technological performance and firm size. Table 1 demonstrates that small firms' technological performance in non-equity and equity alliances are worse on average than large firms. Table 1 also indicates that small firms enter into more non-equity alliances than large firms on average, which provides preliminary support for Hypothesis H3a. Small firms also possess less cumulative production and alliance experience, are younger, and are less technologically capable vis-à-vis large firms. Somewhat surprisingly, however, small firms form alliances with partners of similar technological capability as their larger counterparts.

Table 2 indicates our two measures of technological performance vary positively with more hierarchical (e.g., equity) alliances. Given the control and coordination benefits associated with equity alliances, this finding suggests that performance penalties associated with complex economic exchanges can be mitigated in part via alliance organization selection. Table 2 also indicates that technological performance varies positively with the technical capabilities of focal firms and their partners, and negatively with technical capability distance between focal firms and partners. Our two measures of firm size—revenue and production experience—and our three measures of capabilities—firm, partner, and distance—are highly correlated, which present multicollinearity concerns and require consideration for identification purposes in the econometric analysis. Variance inflation factor (VIF) tests confirm harmful multicollinearity, so we utilize *Firm Revenue* (and eliminate *Firm Production Experience*) and *Partner Capability* and *Firm-Partner Capability Distance* (and eliminate *Firm Capability*) in the baseline analysis. We test for the effects of the eliminated variables in the robustness analysis.

Tables 3-6 present the results of our empirical analysis. Table 3 presents the first stage results of the alliance selection model, incrementally adding the independent variables of theoretical interest. Non-equity alliances represent the excluded category. Model 1 establishes a baseline that includes the year and region of origin fixed effects. Model 2 adds firm-level control measures for size (semiconductor sales revenue), age, and alliance experience (combined non-equity and equity); alliance-level control measures for scope (number of partner firms and product and process technologies involved), difficulty (structure and complexity), and relationship length; and our independent measures for partner firms' technical capabilities and technical capability distance. Model 3 adds the industry-level measures of the number of available suppliers and demand uncertainty, which serve as instruments for the second stage performance estimation. As successive models improve the fit in comparison to their predecessor, we focus our attention on Model 3.

The Model 3A results of Table 3 is based on the entire sample (both small firms and large firms), and indicate that firm size and age are not predictors of alliance organization, while alliance experience is. Firms with more alliance experience are more likely to establish equity alliances ($p < 0.05$), which suggests learning economies in alliance formation. Equity alliances are more likely with broader alliance scope ($p < 0.01$), greater alliance difficulty ($p < 0.05$) and longer relationship length ($p < 0.01$), in comparison to non-equity alliances. These findings suggests that firms select equity alliances not only to control for and monitor potential opportunism brought on by greater alliance extensiveness and interdependence, but also to facilitate the solving of more difficult technical problems (Leiblein & Macher, 2005). The Model 3A results also indicate that transaction costs affect alliance selection. An increase in the number of available suppliers—measured as the number of firms offering contract manufacturing services and the antithesis of *ex-ante* small numbers bargaining—does not significantly influence alliance selection. Increase in demand uncertainty—measured as the variance surrounding a trend in the demand for similar products—increases the likelihood of equity alliances ($p < 0.01$).

In terms of hypotheses testing, equity alliances are more likely as partner firms' technical capabilities improve ($p < 0.05$), providing support for Hypothesis H1a. This result suggests firms and/or their partners seek more hierarchical alliances to establish ownership rights and/or achieve better control and coordination. The Model 3A results also indicate that as the distance in technical capabilities between firms and their partners increase, equity alliances are more likely ($p < 0.05$). This result suggests that firms and/or their partners seek equity alliances as the technical distance between them becomes exceedingly large, which provides strong support for Hypothesis H1b.

Models 3B and 3C examine alliance decisions disaggregated by small and large firms, respectively. Older small firms are more likely to form equity alliances ($p < 0.01$). Large firms with more alliance experience and longer relationships are more likely to form equity alliances ($p < 0.05$ and $p < 0.01$, respectively), which appear to be driving the identical findings in Model 3A. Both small firms and large firms seek more hierarchical alliances with greater alliance scope ($p < 0.05$ and $p < 0.01$, respectively). Small numbers bargaining conditions increase the likelihood that small firms form equity alliances ($p < 0.01$), but have no effect on large firms' alliance decisions. These results suggest that exchange hazards have a greater effect on the alliance decisions of small firms than large firms. A t-test comparison between the coefficients and their standard errors achieves statistical significance, indicating *ex-ante* transaction costs have a differential impact on alliance decisions between small and large firms. Small and large firms are both more likely to form equity alliances under greater demand uncertainty ($p < 0.05$ and $p < 0.01$, respectively), with the coefficient magnitude slightly larger for large firms. A t-test comparison between the coefficients and their standard errors does not achieve statistical significance, indicating *ex-post* transaction costs do not have any differential impact on alliance decisions between small and large firms.

In terms of hypotheses testing, partner technical capabilities strongly influence large firms' alliance decisions toward greater ownership ($p < 0.01$) but have no statistically significant effect on small firms' alliance decisions, a finding that supports Hypothesis H3a. A t-test comparison between these coefficients and their standard errors, however, does not achieve statistical significance and therefore does not indicate any differential impact between these firm types. Technical capability distance has a nonlinear and statistically significant influence on alliance organization, but only for small firms. Small firms are more likely to establish equity alliance as the technical distance in capabilities increases ($p < 0.10$) but less likely as this distance becomes large ($p < 0.05$, respectively)—findings that support Hypothesis H4a. Differences in these coefficients are not statistically significant and therefore do not indicate any differential impact from firm size.

Table 4 presents the performance results using our first dependent variable, focal alliance technology compared against average technology in product market *i* at time *t*. We adjust standard errors via the Huber-White sandwich estimator technique and within-firm clustering (by focal firm). Each model in Table 4 includes the self-selection correction term for unobserved characteristics that underlie a given alliance decision; year and region of origin fixed effects; firm-level control measures for size, age and alliance experience; alliance-level measures for scope, difficulty and relationship length; and the independent measures for partner firm technical capabilities and technical capability distance. Model 1A examines alliance performance for the entire sample (both small and large firms), while Models 1B and 1C examine alliance performance disaggregated by small and large firms, respectively. We compare coefficients (in terms of their signs and magnitudes) across models to test our hypotheses. The significant coefficient estimates for the Mill's Ratio, the self-selection correction term, in some models indicates that unobserved characteristics underlying a given collaborative alliance decision influence technological performance relative to equivalent decisions where alternative alliance arrangements are chosen. There are thus comparative performance advantages to selecting particular alliance arrangements.

Firm size has a significant effect on technological performance, but this effect varies according to the particular alliance arrangement. Model 1 indicates size improves performance in non-equity alliances ($p < 0.01$) but reduces performance in equity alliances ($p < 0.10$). Model 2 indicates that firm size (e.g., "larger" small firms) improves performance in non-equity alliances ($p < 0.01$), while Model 3 indicates that firm size (e.g., "larger" large firms) decrease performance in both non-equity and equity alliances ($p<0.01$). We therefore argue that firm size moderates alliance performance, but in a non-linear fashion. Some "threshold" size appears necessary to achieve better performance, but beyond a certain point, bureaucratic features and the liability of size become acute. Older firms have worse performance in comparison to their peers in non-equity alliances ($p < 0.01$)—a result found in both small and large firm samples. More difficult alliances have significant performance effects for both small and large firms in both non-equity and equity alliances. Greater alliance scope reduces technological performance for the combined firms in non-equity ($p < 0.01$) and equity ($p < 0.05$) alliances. Small firms in particular realize performance penalties in non-equity alliances from broad scope ($p < 0.01$), while large firms realize performance penalties in equity alliances from broad scope ($p < 0.05$).

In terms of hypothesis testing, we first argue that technological performance is positively related to partner firms' technical capabilities (Hypothesis H2a). We find strong support for this hypothesis in all models. Model 1A indicates a positive and statistically significant relationship for the combined firms in both equity and non-equity alliances ($p < 0.01$, respectively). Model 1B indicates that small firms whose partners have more advanced technical capabilities achieve better performance in non-equity ($p < 0.01$) and equity ($p < 0.05$) alliances, while Model 1C similarly finds large firms achieve better performance for both equity and non-equity alliances ($p < 0.01$, respectively). A comparison of the coefficients between small firms and large firms for *Partner Capability* does not indicate any differential impact from partner firms' capabilities between small and large firms, however, and suggests that the performance impact to small and large firms is similar from allying with more technical capable partners. Both small and large firms are able to absorb the technical capabilities of their partner firms and improve performance.

We also argue that technological performance is negatively related to the distance in technical capabilities between firms and their partners (Hypothesis H2b) and that firm size moderates this relationship (Hypothesis H4d). We find support for both of these hypotheses. Model 1A indicates that greater technical capability distance between firms and their partners reduces performance for both non-equity and equity alliances ($p < 0.01$, respectively), which supports Hypothesis H2b. Models 1B indicate that the technical performance of small firms decreases as the distance in technical capabilities with partner firms increases for both non-equity and equity alliance ($p < 0.01$, respectively). Model 1C similarly indicates technical performance decreases for large firms as technical capability distance with partner firms increases for non-equity ($p < 0.10$) and equity ($p < 0.01$) alliances. A comparison of the sign and magnitude of the coefficients between small firms and large firms indicates that the impact from technical capability distance is less for large firms than for small firms. Large firms are better able to "close" the technical capability gap with their more advanced partner firms than small firms for both non-equity and equity alliances.

An examination of economic significance helps to demonstrate the comparative effects of partner technical capabilities and technical capability distance for small and large firms on technological performance and provides further tests of our hypotheses. Table 6 shows how different levels of partner technical capability and technical capability differences between firms and their partners impact technological performance for non-equity and equity alliances and by small and large firms. This table holds all variables in the second-stage performance analyses at their means and then varies a particular variable of interest from low (mean less standard deviation) to high (mean plus standard deviation) levels. Alliances with "low" partner technical capabilities perform below the mean level of technological performance but improve as partner capabilities increase, for both small and large firms. Large firms in particular achieve above average technological performance in their equity alliances when their partner firms possess "high" technical capabilities. Large firms also outperform small firms in both non-equity and equity alliances, respectively, at all levels of partner technical capabilities, which provides strong support for Hypothesis H4b. As the distance in technical capabilities between firms and their partners increases, the technological performance of both small and large firms decreases, regardless of the alliance arrangement. Large firms are better able to reduce the performance degradation—evidenced by the flatter slope for both non-equity and equity alliances—in comparison to small firms. This result provides strong support for Hypothesis H4d.

Robustness Results

Table 5 provides two robustness tests. Models 1-3 replace *Firm Size* with *Firm Production Experience*, respectively. The results are strongly similar to the results of Models 1A-1C, respectively, in Table 4. Models 2A-2C replace the first dependent variable with the second dependent variable—focal alliance technological sophistication compared against average technological sophistication across all product markets at a particular time. The results are again strongly similar to the results of Models 1A-1C, respectively, in Table 4. One finding worthy of additional discussion is general loss of statistical significance in *Technical Capability* Δ for large firms using this dependent variable.

We finally examined whether *Technical Capability* Δ had a non-linear effect on the performance results by adding the square of this measure to the econometric model. This approach can determine whether and how technical distance "closer-in" and "further-away" affects technological performance. We confirm that the squared term is insignificant and fails to improve explanatory in almost all models.

DISCUSSION

The econometric results indicate that small and large firms' alliance decisions are determined by factors that are both similar and different from each other. Both small and large firms are less likely to use equity alliances as technical capability distance between them and their partner firms increases. Small firms differ from large firms in their use of equity alliances depending on the level of alliance difficulty, while large firms differ from small firms according to alliance experience and relationship length. These results suggest that small firms face constraints different from large firms in their selection of particular alliance arrangements.

Our results suggest at least two reasons to believe that exchange hazards exacerbate the organization and performance difficulties that small firms face in their alliance arrangements in comparison to large firms. First, firms' abilities to mitigate potential contracting hazards are in part a function of their prior alliance experience (Anand & Khanna, 2000), which facilitates learning that develops 'relational capabilities' important to alliance success (Dyer & Singh, 1998). The development of an alliance capability not only helps firms to identify trustworthy partners, but also effectively negotiate, monitor, and enforce the terms of exchange (Zollo & Singh, 2004). Large firms typically have greater alliance experience than small firms, and thus have advantages not only in searching for and selecting capable partners, but also in monitoring partner firms' alliance efforts. Large firms are also more likely to have dedicated alliance functions in place, whose sole purpose is to coordinate alliance activities (Kale *et al.*, 2002). Large firms are thus more effective in handling unforeseen circumstances in comparison to small firms, as they have the resources and skills already in place. Second, small firms are more likely forced to collaborate in comparison to large firms, insofar as they are limited in upstream or downstream activities or necessary complementary assets. To the extent that these resource and/or financial constraints alter the decision-making calculus related to desired levels of incentives, control and coordination, small firms may choose or be forced into more "inappropriate" alliances in comparison to their larger counterparts. Because no alliance limits or effectively precludes participation, small firms are more likely to accept less desirable alliance arrangements. Large firms have other organizational alternatives at their disposal (e.g., vertical integration), and are thus more likely to reach better alliance terms with their partner firms. It therefore follows that if small firms are systematically prone to enter into "inappropriate" alliances, then they should also achieve worse performance than large firms.

The performance results also indicate similar and different performance effects from alliance-, firm- and partner-level factors for small and large firms. In particular, technological performance improves when partner firms bring more advanced technical capabilities to the alliance but degrades as the distance in technical capabilities between firms and their partner(s) increases—results found for both types of firms and both kinds of alliances. The results thus suggest that small and large firms both benefit from alliance activity, but somewhat unequally. Large firms achieve superior technological performance to small firms at all levels of partner technical capabilities and all levels of technical capability distance, on average, in both non-equity and equity alliances. While small firms are able to establish alliances with partner firms as technically capable as those of their larger counterparts, large firms are superior in reducing the performance penalty gap associated with technical capability differences than small firms. Large firms thus appear to systematically benefit more from their alliance arrangements than small firms

This paper is not without limitations. The empirical setting of this paper is somewhat unusual, characterized by rapid technological advancement and a complex manufacturing environment. While detailed data are critical for examining organization and performance in firms' technological development activities, the analysis takes place in a single industry. Given the uniqueness of the semiconductor industry, the generalizability of empirical results to other industries—particularly outside of high technology—may be limited. The evidence presented is also restricted to the technological development performance of firms involved in production sourcing alliance arrangements. Although alliance arrangements have become increasingly important aspects of semiconductor firms' strategies in technological development, we ignore the internal development efforts related to production of semiconductor firms.

CONCLUSION

This paper combines the comparative insights of transaction cost economics (TCE) with the strategic orientation of the resource based view (RBV) of the firm to examine not only alliance organization, but also alliance performance. It contributes to the literature by examining the antecedent conditions and consequences of alliances between small and large firms. Two propositions are developed and tested to examine whether and why small firms achieve lower alliance performance than large firms. Technological development and production sourcing alliances in semiconductor industry serve as the empirical setting.

Evidence is provided that alliance organization and performance is determined by alliance-, firm- and partner-level factors. In particular, the empirical results indicate that partner technical capabilities and the relative distance in capabilities between firms and their partners are important factors in both alliance selection and performance. These findings suggest firms must not only determine who the "right" partner firms are in their alliances, but also determine how best to ally with those partners. While firms' own technological capabilities are not surprisingly important in determining technological performance, so too are partner firms' technical capabilities and the relative distance in technical capabilities between these firms.

The empirical results also indicate that small firms systematically benefit less from collaborative activity in comparison to their larger counterparts. Large firms appear better at managing the control and coordination requirements of alliances and benefit more from their partners' technical knowledge. For the former, size might facilitate the creation of superior control mechanisms or coordinative routines that are necessary when operating across organizational boundaries. For the latter, size appears to proffer benefits related to absorptive capacity of new knowledge. While our findings also suggest that all firms face managerial, organizational and technical challenges on how to ally for technological development and production sourcing, the empirical results suggest that these constraints are particularly acute for small firms.

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Table 1: Summary Statistics

	Alliance Type	Tech. Performance 1	Tech. Performance 2	Firm Size	Firm Age	Firm Production Experience	Firm Alliance Experience	Alliance Scope	Alliance Difficulty	Relationship Length	Firm Capability	Partner Capability	Technical Capability Δ	Supplier Availability	Demand Uncertainty
ENTIRE SAMPLE (N = 665)															
Mean	0.424	0.000	0.000	6.618	33.970	9.426	0.969	3.439	0.371	5.817	0.346	0.384	0.810	4.863	1.694
Standard Deviation	0.494	0.996	0.994	2.025	13.676	2.214	4.771	2.046	0.483	2.991	0.187	0.198	0.324	2.613	0.424
Minimum	0.000	-1.627	-2.586	0.095	5.000	4.255	0.000	2.000	0.000	0.000	0.100	0.100	0.189	0.000	0.841
Maximum	1.000	2.474	2.962	9.975	57.000	12.406	39.000	15.000	1.000	13.000	1.000	1.000	2.398	12.000	3.143
SMALL FIRMS (N = 197)															
Mean	0.289	-0.476	-0.531	4.027	25.437	6.807	0.162	2.812	0.244	5.284	0.239	0.359	0.973	5.259	1.546
Standard Deviation	0.455	0.838	0.979	1.066	9.416	1.369	0.944	1.030	0.430	3.188	0.122	0.177	0.352	2.231	0.450
Minimum	0.000	-1.627	-2.586	0.095	12.000	4.255	0.000	2.000	0.000	0.000	0.100	0.100	0.300	0.000	0.841
Maximum	1.000	1.987	1.741	5.303	57.000	9.866	8.000	9.000	1.000	11.000	0.714	1.000	2.234	9.000	2.050
LARGE FIRMS (N=468)															
Mean	0.474	0.180	0.200	7.690	37.241	10.413	1.274	3.675	0.419	6.017	0.386	0.393	0.749	4.713	1.750
Standard Deviation	0.500	0.992	0.924	1.183	13.649	1.576	5.540	2.272	0.494	2.891	0.192	0.205	0.290	2.730	0.400
Minimum	0.000	-1.627	-1.995	5.318	5.000	4.615	0.000	2.000	0.000	0.000	0.100	0.100	0.189	0.000	0.841
Maximum	1.000	2.474	2.962	9.975	57.000	12.406	39.000	15.000	1.000	13.000	1.000	1.000	2.398	12.000	3.143

Table 2: Correlation Statistics

	Alliance Type	Tech. Performance 1	Tech. Performance 2	Firm Size	Firm Age	Firm Production Experience	Firm Alliance Experience	Alliance Scope	Alliance Difficulty	Relationship Length	Firm Capability	Partner Capability	Technical Capability Δ	Supplier Availability	Demand Uncertainty
Alliance Type	1.00														
Tech. Performance 1	**0.25**	1.00													
Tech. Performance 2	**0.20**	**0.87**	1.00												
Firm Size	**0.24**	**0.28**	**0.31**	1.00											
Firm Age	**0.15**	0.07	0.06	**0.48**	1.00										
Firm Production Experience	**0.23**	**0.18**	**0.22**	**0.86**	**0.46**	1.00									
Firm Alliance Experience	0.04	**-0.21**	-0.02	0.04	0.02	0.07	1.00								
Alliance Scope	**0.27**	**0.22**	**0.13**	**0.23**	**0.23**	**0.19**	-0.05	1.00							
Alliance Difficulty	**0.31**	**0.52**	**0.46**	**0.27**	**0.12**	**0.27**	**-0.09**	**0.33**	1.00						
Relationship Length	**0.29**	**0.17**	**0.25**	**0.17**	0.03	**0.14**	**0.11**	**0.18**	**0.30**	1.00					
Firm Capability	**0.18**	**0.54**	**0.29**	**0.39**	**0.12**	**0.27**	**-0.17**	**0.24**	**0.13**	**-0.08**	1.00				
Partner Capability	**0.11**	**0.31**	0.01	-0.01	0.03	**-0.08**	**-0.21**	**0.14**	0.05	-0.06	**0.41**	1.00			
Technical Capability Δ	**-0.10**	**-0.21**	**-0.30**	**-0.39**	**-0.12**	**-0.36**	**-0.08**	**-0.10**	**-0.16**	**0.08**	**-0.38**	**0.49**	1.00		
Supplier Availability	0.03	-0.04	**-0.32**	-0.05	-0.04	-0.04	**-0.25**	**0.13**	-0.04	**-0.13**	**0.24**	**0.31**	**0.09**	1.00	
Demand Uncertainty	**0.29**	0.00	**0.11**	**0.33**	**0.11**	**0.45**	0.07	**0.19**	**0.32**	**0.30**	**-0.20**	**-0.28**	**-0.12**	-0.03	1.00

Bold represents pair-wise significance at 0.05 level.

Table 3: Alliance Organization Results

	MODEL 1	MODEL 2	MODEL 3A	MODEL 3B	MODEL 3C
	ALL FIRMS	ALL FIRMS	ALL FIRMS	SMALL FIRMS	LARGE FIRMS
	β (se)	β (se)	β (se)	β (se)	β (se)
Firm Size		0.151** (0.073)	0.029 (0.079)	-0.287 (0.187)	0.120 (0.155)
Firm Age		0.006 (0.008)	0.007 (0.009)	0.080*** (0.023)	-0.011 (0.010)
Firm Alliance Experience		0.066** (0.030)	0.064*** (0.025)	-0.025 (0.210)	0.054** (0.028)
Alliance Scope		0.187*** (0.057)	0.200*** (0.062)	0.399** (0.179)	0.203*** (0.070)
Alliance Difficulty		0.668*** (0.212)	0.495** (0.235)	0.673 (0.431)	0.191 (0.325)
Relationship Length		0.218*** (0.034)	0.180*** (0.037)	0.032 (0.066)	0.233*** (0.054)
Partner Capability		0.572 (0.757)	2.431** (1.203)	2.008 (2.299)	3.344* (1.830)
Technical Capability Δ		0.397*** (0.161)	8.317* (4.539)	17.374* (9.300)	6.542 (5.514)
Supplier Availability			-0.072 (0.050)	-0.452*** (0.148)	-0.079 (0.058)
Demand Uncertainty			1.449*** (0.390)	1.461** (0.679)	2.110*** (0.738)
Constant	-0.6385** (0.3152)	-4.425*** (0.732)	-9.049*** (1.798)	-12.547*** (3.849)	-9.862*** (2.209)
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes
N	665	665	665	197	468
LogL	-448.27	-340.85	-329.98	-85.68	-217.25
χ^2	67.19***	192.31***	194.81***	65.66***	137.65***
Pseudo-R^2	0.09	0.25	0.27	0.25	0.33

*** p<0.01 ** p<0.05 * p<0.10

Non-equity alliances represent the comparison group.

Table 4: Alliance Performance Results

	MODEL 1A ALL FIRMS		MODEL 1B SMALL FIRMS		MODEL 1C LARGE FIRMS	
	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY
	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)
Firm Size	0.122*** (0.030)	-0.087*** (0.025)	0.316*** (0.064)	-0.138 (0.113)	-0.153*** (0.050)	-0.239*** (0.044)
Firm Age	-0.015*** (0.005)	-0.001 (0.003)	-0.024*** (0.008)	-0.009 (0.015)	-0.021*** (0.005)	0.001 (0.003)
Firm Alliance Experience	-0.022** (0.010)	-0.034*** (0.010)	0.009 (0.039)	-0.600** (0.278)	-0.006 (0.014)	-0.032*** (0.011)
Alliance Scope	-0.118*** (0.040)	-0.074*** (0.019)	-0.275*** (0.084)	0.063 (0.100)	-0.020 (0.045)	-0.083*** (0.021)
Alliance Difficulty	0.802*** (0.110)	0.849*** (0.113)	0.751*** (0.249)	0.422 (0.287)	0.915*** (0.119)	1.084*** (0.122)
Relationship Length	0.068*** (0.019)	-0.058** (0.024)	0.037 (0.041)	0.091 (0.093)	0.068*** (0.025)	-0.071*** (0.027)
Partner Capability	2.019*** (0.310)	2.319*** (0.334)	1.513*** (0.429)	2.567** (0.978)	1.788*** (0.415)	1.614*** (0.480)
Technical Capability Δ	-1.133*** (0.198)	-1.017*** (0.234)	-1.110*** (0.414)	-1.990*** (0.530)	-1.095*** (0.257)	-0.569* (0.322)
Inverse Mill's Ratio	-0.430 (0.287)	-1.008*** (0.211)	-0.216 (0.830)	-0.292 (0.711)	-0.252 (0.307)	-0.728*** (0.272)
Constant	-0.516** (0.257)	2.176*** (0.617)	-0.418 (0.410)	2.708 (2.711)	1.058** (0.427)	2.907*** (0.813)
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
F-test	25.31***	33.27***	9.48***	5.08***	30.21***	36.83***
N	384	280	140	57	244	223
Adjusted R^2	0.48	0.65	0.59	0.74	0.57	0.70

*** p<0.01 ** p<0.05 * p<0.10.
Standard errors are robust and adjusted for clustering (by focal firm)

Table 5: Robustness Results

	MODEL 1A ($DV=TechPerf_1$) ALL FIRMS		MODEL 1B ($DV=TechPerf_1$) SMALL FIRMS		MODEL 1C ($DV=TechPerf_1$) LARGE FIRMS		MODEL 2A ($DV=TechPerf_2$) ALL FIRMS		MODEL 2B ($DV=TechPerf_2$) SMALL FIRMS		MODEL 2C ($DV=TechPerf_2$) LARGE FIRMS	
	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY	NON-EQUITY	EQUITY
	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)	β (se)
Production Experience	0.040	-0.094***	-0.070	-0.205	-0.088*	-0.116***						
	(0.025)	(0.022)	(0.077)	(0.144)	(0.050)	(0.032)						
Firm Size							0.177***	-0.053*	0.341***	-0.018	-0.159**	-0.198***
							(0.034)	(0.032)	(0.068)	(0.121)	(0.062)	(0.051)
Firm Age	-0.005	0.002	-0.003	-0.004	-0.013**	0.004	-0.022***	-0.003	-0.030***	-0.023	-0.030***	-0.001
	(0.005)	(0.003)	(0.007)	(0.015)	(0.006)	(0.003)	(0.005)	(0.003)	(0.008)	(0.016)	(0.006)	(0.003)
Firm Alliance Experience	-0.009	-0.021**	0.128**	-0.319	0.003	-0.006	-0.039***	-0.033***	0.036	-1.066***	-0.025	-0.022
	(0.009)	(0.010)	(0.050)	(0.421)	(0.011)	(0.011)	(0.013)	(0.013)	(0.044)	(0.346)	(0.019)	(0.015)
Alliance Scope	-0.105***	-0.048***	-0.250***	0.027	0.001	-0.035**	-0.163***	-0.067***	-0.331***	0.016	-0.051	-0.062***
	(0.041)	(0.015)	(0.088)	(0.059)	(0.043)	(0.017)	(0.045)	(0.020)	(0.075)	(0.089)	(0.052)	(0.023)
Alliance Difficulty	0.762***	0.962***	0.768***	0.457**	0.814***	1.272***	0.588***	0.837***	0.423**	0.149	0.693***	1.204***
	(0.104)	(0.116)	(0.173)	(0.223)	(0.121)	(0.127)	(0.126)	(0.146)	(0.194)	(0.245)	(0.154)	(0.167)
Relationship Length	0.104***	-0.037*	0.101***	0.083	0.100***	-0.034	0.049**	-0.060**	0.021	0.052	0.031	-0.045
	(0.018)	(0.022)	(0.031)	(0.065)	(0.025)	(0.023)	(0.021)	(0.026)	(0.031)	(0.068)	(0.036)	(0.029)
Partner Capability	1.937***	2.499***	1.934***	1.576*	1.449***	2.496***	0.728**	1.651***	1.124**	1.303	-0.005	1.189**
	(0.284)	(0.268)	(0.498)	(0.898)	(0.379)	(0.381)	(0.331)	(0.369)	(0.451)	(1.039)	(0.461)	(0.533)
Firm-Partner Capability Δ	-0.427***	-0.488***	-0.408***	-0.490***	-0.311***	-0.474***	-0.132**	-0.289***	-0.244***	-0.412*	-0.036	-0.192
	(0.069)	(0.062)	(0.077)	(0.180)	(0.102)	(0.074)	(0.063)	(0.099)	(0.081)	(0.210)	(0.077)	(0.156)
Inverse Mill's Ratio	-0.693***	-0.609**	-0.944**	-0.524	-0.542*	0.124	0.200	-1.251***	0.516	-1.176	0.654	-0.494
	(0.240)	(0.282)	(0.467)	(0.599)	(0.284)	(0.356)	(0.272)	(0.352)	(0.453)	(0.786)	(0.427)	(0.464)
Constant	-1.062***	1.254*	-0.261	0.387	-0.033	0.490	-0.106	2.773***	-0.035	0.915***	1.895***	2.792**
	(0.276)	(0.679)	(0.453)	(1.581)	(0.579)	(0.854)	(0.263)	(0.801)	(0.399)	(1.752)	(0.517)	(1.107)
Time Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Region Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-test	25.48***	39.47***	8.96***	4.87***	26.81***	48.80***	14.05***	16.75***	14.66***	4.94***	12.19***	17.50***
N	384	280	140	57	244	224	384	280	140	57	244	224
Adjusted R^2	0.45	0.66	0.55	0.73	0.52	0.71	0.36	0.55	0.60	0.73	0.36	0.57

*** p<0.01 ** p<0.05 * p<0.10.
Standard errors are robust and adjusted for clustering (by focal firm)

Table 6: Economic Significance of Results

	PARTNER CAPABILITY				FIRM-PARTNER CAPABILITY Δ			
	NON-EQUITY		EQUITY		NON-EQUITY		EQUITY	
	SMALL FIRMS	LARGE FIRMS	SMALL FIRMS	LARGE FIRMS	SMALL FIRMS	LARGE FIRMS	SMALL FIRMS	LARGE FIRMS
Low	-1.285	-0.851	-0.780	-0.230	-0.710	-0.477	0.087	0.353
Mean	-1.098	-0.619	-0.484	0.146	-1.098	-0.619	-0.484	0.146
High	-0.910	-0.387	-0.188	0.522	-1.485	-0.760	-1.055	-0.062

Low = (μ-σ); Mean = (μ); High = (μ+σ)