

COMPLEMENTARITY, CAPABILITIES, AND THE BOUNDARIES OF THE FIRM: THE IMPACT OF WITHIN-FIRM AND INTERFIRM EXPERTISE ON CONCURRENT SOURCING OF COMPLEMENTARY COMPONENTS

ANNE PARMIGIANI^{1*} and WILL MITCHELL²

¹ Lundquist College of Business, University of Oregon, Eugene, Oregon, U.S.A.

² Fuqua School of Business, Duke University, Durham, North Carolina, U.S.A.

Theories of the firm raise conflicting arguments about how complementarities between two or more components affect firms' knowledge and production boundaries. Traditional arguments in the boundaries of the firm literature suggest that firms will tend to produce sets of complementary components internally, while more recent modularity studies argue that firms can outsource to gain flexibility. We resolve these views by examining concurrent sourcing, which arises when firms both make and buy the same components. We argue that concurrent sourcing of complementary components becomes more common in two cases: when firms have relevant knowledge about the components in conjunction with suppliers (interfirm expertise) and, perhaps more surprisingly, within the firm (within-firm shared expertise). The results suggest that firms often need to make in order to know, but can partially outsource if they possess sufficient expertise. Copyright © 2009 John Wiley & Sons, Ltd.

INTRODUCTION

Theories of the firm traditionally posit that firms determine their boundaries by choosing whether to make or buy individual components (e.g., Coase, 1937; Williamson, 1975). In practice, however, firms may make joint sourcing decisions for multiple components rather than treat them independently due to complementarities that stem from interrelated business activities, such as shared

production equipment and technological interdependence (Teece, 1982; Helfat and Raubitschek, 2000; Panzar and Willig, 1981; Santos and Eisenhardt, 2005). Strategy research dating back to scholars such as Penrose (1959), Chandler (1962), and Cyert and March (1963) has viewed the ability to manage interdependencies that involve physical goods and/or business activities as a core element of business strategy, and an important source of a firm's competitive advantage (Porter, 1996). Arguments that neglect such interdependencies by treating sourcing decisions for complementary components atomistically are likely to misinterpret firms' boundary choices and, in turn, misconstrue key aspects of business strategy by focusing on individual rather than joint decisions.

Keywords: complementarity; sourcing; firm capabilities; vertical integration; knowledge

* Correspondence to: Anne Parmigiani, Lundquist College of Business, University of Oregon, Eugene, OR 97403, U.S.A.
E-mail: annepa@uoregon.edu

A growing body of research has begun to consider how complementarity among physical goods and/or business activities influences firm boundaries. In perhaps the most formal treatment, Milgrom and Roberts (1990, 1995) define complementarity in terms of the joint returns from carrying out different activities. In their terms, activities involving physical goods and/or business processes are complementary if doing more of one activity increases the returns from doing more of another activity. Related research—which spans neoclassical economics, transaction cost economics, and the capabilities literature—has considered complementarity in terms of economies of scope that create opportunities for cost savings in production and governance activities (Panzar and Willig, 1981; Teece, 1982, 1986; Helfat and Eisenhardt, 2004), as well as technological opportunities to share design and production activities (Arrow, 1975; Armour and Teece, 1978; Helfat and Raubitschek, 2000; Kogut and Zander, 1992). The conventional conclusion concerning firm boundaries is that firms have strong incentives to integrate sets of complementary components (in which the concept of components includes both physical goods and service tasks) in order to reduce production costs, protect specialized assets, and draw on tacit inter-related skills.

The traditional conclusion that firms will prefer to integrate complementary components now faces challenges, however, because conventional arguments underestimate the benefits of outsourcing complementary components. Milgrom and Roberts (1990: 526) conclude that outsourcing complementary components creates flexibility in the face of supply and demand uncertainties. These uncertainties are common in interrelated systems of business activities, quite often dominating integration incentives. They cite the example of lean production systems, such as the Toyota Production System (TPS), in which suppliers undertake many complex interrelated tasks for end-product manufacturers. Brusoni and Prencipe (2001) and Prencipe, Davies, and Hobday (2003), meanwhile, highlight the growth of modularity in product markets, arguing that firms can act as system integrators by coordinating outsourced production activities of multiple suppliers. Boeing, for instance, gains much of its competitive advantage in aircraft production through its integration of components produced by thousands of suppliers.

Nonetheless, pure outsourcing of complementary components can be risky for firms due to loss of control, leakage of proprietary information, and lack of opportunities to gain knowledge via learning by doing (Pisano, 1994). Indeed, empirical evidence finds that many firms—such as Toyota—commonly produce a substantial degree of their complementary components internally. Boeing, meanwhile, has encountered delays in its current 787 project, in part because it has extended outsourcing of assembly tasks well beyond its traditional practice (Clark, 2007). Thus, there is a tension between traditional integration arguments and recent insights about the benefits of outsourcing complementary components.

An emerging literature discusses concurrent sourcing as an alternative to the traditional dichotomy of make versus buy boundary decisions, thereby identifying a potential solution to the tension that arises between the incentives to integrate and the benefits of outsourcing complementary components. Concurrent sourcing, which is sometimes referred to as tapered integration or dual distribution (Adelman, 1949; Harrigan, 1986), occurs when firms both make and buy some of their requirements for a component. Conceptually, Bradach and Eccles (1989), Hennart (1993), and Gulati and Puranam (2006) describe concurrent sourcing as a plural governance mode. Empirically, scholars have studied concurrent sourcing in a variety of industries and settings, including trucking, computing, restaurants, general manufacturing, and research activities (Bradach, 1997; Cassiman and Veugelers, 2006; He and Nickerson, 2006; Heide, 2003; Rothaermel, Hitt, and Jobe, 2006). Concurrent sourcing is common in sales forces, where firms use both internal agents and outside representatives (Dutta *et al.*, 1995), and also occurs with the simultaneous use of employees and contract labor (Davis-Blake and Uzzi, 1993; Lepak and Snell, 1999). Parmigiani (2007) shows that concurrent sourcing of individual components is common when a firm and its suppliers jointly possess substantial relevant expertise.

No study, however, has addressed conditions under which firms will concurrently source *sets* of complementary components. This study argues that both greater interfirm and greater within-firm shared expertise relating to a set of complementary components increase firms' incentives to concurrently source rather than integrate the components. In this view, firms' knowledge boundaries

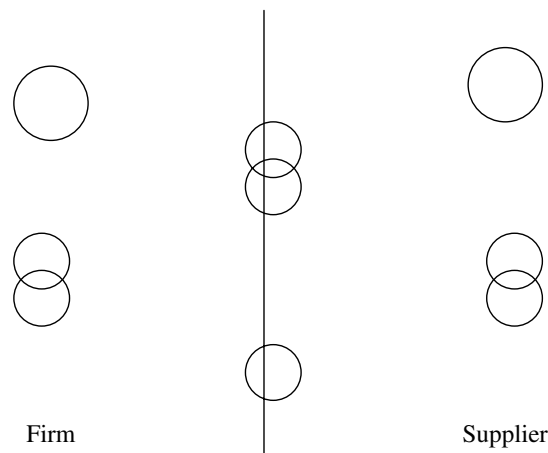
influence their production boundaries (Brusoni, Prencipe, and Pavitt, 2001; Takeishi, 2002), sometimes in nonintuitive ways. Figure 1 depicts the focus of the study. We test the predictions using a sample of joint sourcing decisions for die design, die construction, and end-part machining services of 110 North American metal stamping and powder metal firms in 2002. Die design and die construction are complements due to economies of scope, while die design and end-part machining are largely independent components.

The study makes three contributions in extending our understanding of the interplay between complementarity, capabilities, and firm boundaries. First, we demonstrate that accounting for firm capabilities, which highlights the distinction between knowledge and task boundaries, helps resolve an apparent contradiction in firms' sourcing choices for complementary components. As such, we extend capability-based theory to suggest that interfirm and within-firm expertise can be mechanisms for knowledge spillover across components. In doing so, we provide both theoretical logic and empirical exploration regarding how firms incorporate the attributes of related components into their sourcing decisions, including both similar and systemic interdependencies (Richardson, 1972). Through concurrent sourcing, firms can obtain a deeper understanding of the interdependencies among complementary components

as well as benefit from the broader knowledge of suppliers while simultaneously balancing shirking and slacking (Hennart, 1993). Moreover, concurrent sourcing opens the firm to learning arising from the spillovers from related components and different production methods of the firm and its suppliers.

Second, we demonstrate that a firm's knowledge boundaries relate more tightly to its production boundaries than the recent modularity view suggests. While firms may 'know more than they make' (Brusoni *et al.*, 2001), they often need to *make in order to know*. Nonetheless, firms do not need to make all of their components to know enough to outsource. Instead, they can solve this paradox by concurrently making some portion of their needs and buying the rest.

Third, we fill a gap between the levels of analyses of transaction cost and capability-based theories. While the transaction cost approach emphasizes decisions concerning assets underlying individual transactions and components (Williamson, 1975), the capabilities view tends to emphasize a broad approach consisting of a myriad of related activities (Penrose, 1959; Barney, 1991). Our work helps bridge this gap by analyzing how, on an intermediate level, firms source sets of complementary goods



Note: As indicated above, goods can be produced inside the firm, outsourced, or concurrently sourced (on the boundary between the firm and supplier). This study addresses the intersecting circles on the boundary, that is, concurrent sourcing of complementary goods.

Figure 1. Sourcing choices for independent and complementary components, depicted by single vs. intersecting circles

BACKGROUND

We first define complementarity, discuss the literature on sourcing choices, and outline traditional arguments concerning boundary choices for complementary components.

Complementarity

Complementarity arises when doing more of one activity increases the returns from doing more of another activity (Milgrom and Roberts, 1995: 181). Formally, complementarity can either involve smooth functions of incrementally divisible choices, or arise from indivisible choice variables. Complementarity involving smooth functions occurs when the cross-partial derivatives involving two or more activities within a pay-off function are positive: the marginal returns to one activity increase as a firm does more of the other activities (Milgrom and Roberts, 1990). However, complementarity does not require functional smoothness—indeed, in practice, complementarity commonly involves non-convexity such that changes in one activity require non-incremental changes in other activities (Penrose, 1959). Thus, as Milgrom and Roberts (1995) point out, complementarity most generally involves benefits that arise from making joint decisions about multiple goods and activities. This definition of complementarity encompasses the concept of synergy as well as the idea of system effects that arise when the whole is greater than the sum of its parts.

Complementarity stands in contrast to independence and substitution. Independence among a set of components arises when changes in one activity do not change the value of other activities; for example, vehicle audio systems are independent of power train components. Substitution arises when doing more of one activity reduces the value of another activity (Rothaermel and Hess, 2006); for example, selling economy vehicles from the same location as luxury vehicles may reduce the value of the luxury vehicles.

Complementarity may be widespread or more focal. Widespread complementarity involves extensive systems of business activities, such as key elements of the Toyota Production System or Southwest Airlines's business model, which Porter (1996) refers to as activity systems. Milgrom and Roberts (1990) use the example of the shift from mass production to lean production manufacturing

as a comparison of two complementary systems of business activities. More focally, complementarity may involve as few as two interrelated physical goods and/or business activities, such as the production of automobile engine blocks and pistons, the design of semiconductor wafers and production equipment, and the management of savings and investment accounts within financial institutions.

Whether widespread or focal, complementarity involving two or more components originates from economies of scope in the value chain of development, production, sales, and other commercial activities. We use economies of scope as a general concept that includes improving a firm's ability to create new goods and services, as well as reducing the cost of goods and services. Economies of scope that reduce the cost of current activities arise when firms gain efficiencies by jointly coordinating multiple activities (Helfat and Eisenhardt, 2004; Panzar and Willig, 1981; Teece, 1982). Such activities may include colocating fruit orchards and bee apiaries, or producing fertilizer from by-products of mineral smelting processes. Cost savings can result from more efficient utilization of a sharable resource, such as capital, labor, or managerial expertise. Such resources can include complementary assets (Teece, 1986), such as brand reputation and distribution knowledge, which firms can leverage over multiple products. For example, offering financing along with the production of durable goods allows a firm to gain from established client relationships. These sorts of efficiencies are often the basis for seemingly unrelated diversification (Campbell, Goold, and Alexander, 1995; Rumelt, 1982) because firms can share parenting skills, administrative expertise, allocation ability, and managerial talent across divisions that operate in different end-product markets.

Scope economies that improve a firm's ability to create new goods and services arise when a firm's innovative activities require knowledge of multiple aspects of design, production, distribution, and/or other elements of the value chain across two or more components. Such technologically based scope economies occur when changes in the design of one component require changes in another component (Dosi, 1988). For example, advances in metallurgy for automobile engine blocks in turn require changes in piston design. Scope economies resulting from technological complementarities can reflect pooled knowledge bases, sequential operations, and/or reciprocal production processes

(Thompson, 1967). Similarly, technologically based scope economies can result from the need for integrative knowledge about complex business activities (Armour and Teece, 1978; Brusoni and Prencipe, 2001; Helfat and Raubitschek, 2000), such as the ability to produce new generations of semiconductors that combine knowledge of multifaceted technical advances, production skills, and changes in customer demands.

Although it is possible to identify conceptual differences in the antecedents of scope economies, these differences can be difficult to untangle empirically because they often occur jointly. Distinguishing between scope economies that produce current savings versus scope economies that facilitate innovation can be difficult when assessing firm behavior and decisions. For example, Lear Corporation produces automotive seats and dashboards. Lear has a considerable history in the automotive industry, and has a strong reputation and extensive distribution resources that it can leverage across the two products. This results in scope economies that reduce the costs of current activities. In addition, Lear has expertise in ergonomics, electronics, and materials that it can use in development activities and innovation for both goods, yielding technologically based scope economies. Fortunately, complementarity has a common implication for boundary choices, whether the complementarity arises from current efficiencies or from contributions to innovation. In either case, firms benefit by coordinating activities needed to produce complementary components within a business system.

The empirical boundaries of complementarity within a business system can also be difficult to identify. There are few opportunities to formally estimate the change in value that arises across a system when one element of the system changes, whether calculations involve differentials of a smooth function or order statistics for step functions. Instead, identifying the boundaries of complementarity typically requires judgment by managers and/or scholars. Some examples of complementarity that the literature has used are quite sweeping, such as overall production systems that clearly consist of multiple complementary subsystems rather than single, fully integrated, complementary systems (e.g., Milgrom and Roberts, 1995; Porter, 1996; Siggelkow 2001; Porter and Siggelkow 2008). Even subsystems or subassemblies, such as vehicle braking systems

or dashboards, typically consist of multiple, inter-related, complementary components (Novak and Stern, 2009; Sako, 2003). The empirical managerial and research challenge arises in identifying logical combinations of two or more components that share economies of scope, while being at least partially separable from other sets of activities. We will return to this issue in the analysis.

Boundary choices: make, buy, and concurrent sourcing

Traditionally, the boundaries of the firm literature focused on the distinction between make and buy decisions. The core conclusion about incentives in this literature, which includes both transaction cost economics and capabilities arguments, is that firms tend to purchase goods and services through external sourcing when the exchanges depend on general investments (Coase, 1937; Williamson, 1975), or when external suppliers have substantial capability advantages (Argyres, 1996; Barney, 1986). By contrast, these studies suggest that firms tend to integrate activities when they require specialized investments and/or when the firm's capabilities provide substantial production, sales, or development advantages.

Transaction cost and capabilities arguments arise from different premises and different units of analysis, but reach similar conclusions about internal and external boundary choices for components involving idiosyncratic assets (Conner, 1991; Santos and Eisenhardt, 2005). Transaction cost economics stresses the use of vertical integration to protect the firm from transaction hazards such as holdup based on specialized investments, slacking due to an inability to accurately measure input performance prior to use, and knowledge appropriation by suppliers.¹ Transaction cost logic takes

¹ Transaction cost arguments do not address concurrent sourcing. The idea of concurrent sourcing may appear to arise when Williamson (1985) suggests that '... where firms are observed both to make and to buy an identical good or service, the internal technology will be characterized by greater asset specificity than will the external technology, *ceteris paribus*' (Williamson, 1985: 96), but technologies with different asset specificity are not identical. Williamson also discusses cases of intermediate levels of asset specificity, which he expects to result in '... mixed governance, in which some firms will be observed to buy, others to make, and all express "dissatisfaction" with their current procurement solution' (Williamson, 1985: 94), but this prediction addresses differences across firms rather than firm-level concurrent sourcing (i.e., the argument does not suggest that firms may be able to split their requirements to limit this dissatisfaction).

production costs as given, in which learning influences production costs, and focuses on the governance costs and benefits of different boundary choices, emphasizing the protection elements of governance. By contrast, capabilities arguments suggest that firm boundaries influence production costs because boundary placement influences learning opportunities. This literature emphasizes gains from engaging in activities internally based on common knowledge, resulting in reduced costs and greater development ability.

Beyond the discrete make and buy distinction, the buyer-supplier literature sometimes raises concurrent sourcing as a third sourcing option, highlighting benefits stemming from short-term efficiencies and longer-term capability development. The earliest arguments suggested that concurrent make and buy strategies help firms hedge against demand uncertainty (Adelman, 1949; Harrigan, 1986), as well as gain an understanding of production process to better monitor suppliers (Cannon, 1968; Harris and Wiens, 1980; Porter, 1980). More recent studies show that opportunities for cost sharing and learning among buyers and suppliers create incentives for concurrent sourcing (Bradach, 1997; Cassiman and Veugelers, 2006; He and Nickerson, 2006; Heide, 2003). In turn, franchising studies (Bradach, 1997; Combs, Michael, and Castrogiovanni, 2004; Lafontaine and Shaw, 1999) and work by Parmigiani (2007) suggest that concurrent sourcing is often a stable choice rather than a transitory state.²

Although most discussion of boundaries has focused on individual components, the boundaries literatures do offer several arguments concerning sourcing options for complementary components. As we discussed earlier, most arguments emphasize incentives to internalize the components. Initial arguments focused on technological complementarities (Arrow, 1975; Armour and Teece, 1978), with the premise that firms can share information across technologically interdependent components (see also Kogut and Zander, 1992). Panzar and Willig (1981) then suggested that firms will internalize assets underlying transactions for which economies of scope offer efficiencies, although

Teece (1982) argued that the internalization incentives occur only when the economies of scope arise from co-specialized assets. By contrast, Milgrom and Roberts's (1990) formal model suggested that firms gain flexibility by outsourcing complementary components in the face of technology and market uncertainties.

Nonetheless, as we will discuss below, firms also have incentives to concurrently source sets of complementary components. To date, the literature has not explored this argument. We will use the term 'concurrently source complementary components' to refer to cases in which a firm both makes and buys two or more complementary components.

PREDICTIONS

We will now explore how firm and supplier expertise shape firms' incentives to concurrently source sets of complementary components. We will restrict our comparison to concurrent sourcing versus vertical integration of the set of complementary components, because vertical integration is the traditional expectation based upon cost sharing and technological interdependencies (the empirical analysis reports other comparisons). We focus the discussion on complementary rather than independent components because complementary components will be affected by expertise that spans components; the empirical analysis will test this assumption.

We define expertise as the firm's understanding of the skills associated with a particular component, including design, production, and marketing knowledge, as well as other skills related to a good or service (Grant, 1996; Wernerfelt, 1984). Firms with expertise related to a particular component typically are able to produce the component more efficiently and effectively than firms without such expertise because they possess appropriate personnel, equipment, and knowledge (Penrose, 1959; Conner, 1991; Grant, 1996; Rubin, 1973). Components that fit closely into the firm's constellation of knowledge tend to be produced internally, while those that do not match well with the firm's expertise tend to be outsourced (Argyres, 1996; Conner and Prahalad, 1996; Grant, 1996).

We are considering the joint sourcing decision for a set of complementary components, and therefore focus on expertise relevant to the set of components. We refer to *within-firm shared expertise*

² Concurrent sourcing will be most common when scale economies are limited. With strong increasing returns to scale, firms are more likely either to fully integrate or outsource. Many physical goods and business processes exhaust scale economies within relevant production ranges (Scherer and Ross, 1990), however, so that concurrent sourcing is often viable.

as knowledge within a firm that spans two or more components, such as possessing a deep understanding of the scientific technology related to a family of goods (Danneels, 2007; Dosi, 1988; Helfat and Raubitschek, 2000; Penrose, 1959). In parallel, we use the term *interfirm expertise* to refer to the degree to which a firm and its potential suppliers each have skills relevant to a particular component and/or set of components (Dyer and Singh, 1998; Lavie, 2006). In the following predictions, we discuss how within-firm shared expertise and interfirm expertise create incentives that affect the joint sourcing decision of complementary components.

In considering interfirm expertise, we expect that concurrent sourcing will be particularly common when firms and potential suppliers have substantial interfirm expertise relevant to a set of complementary components. In such cases, firms have incentives to both leverage their own skills and gain access to suppliers' skills. Interfirm expertise typically involves both specialized skills (skills held by only one party) and redundant skills (equivalent skills possessed by two or more parties). Even in the face of redundancy, firms can gain flexibility in achieving economies of scope for a set of complementary components by making some of their requirements and outsourcing the balance from strong suppliers. For example, most fast-food franchisors have company-owned stores as well as franchised stores; they also conduct national advertising while relying on their franchisees for local advertising (Blair and Lafontaine, 2005). Thus, franchisors concurrently source the complementary activities of advertising and food production, leveraging the scope economy provided by their brand strength and reputation. They prefer knowledgeable franchisees who best understand their local market and can adapt product and advertising offerings accordingly, while also maintaining internal competencies that assist in systemwide learning (Bradach, 1997).

Substantial levels of interfirm expertise typically involve some degree of skill specialization in which the buyer and supplier each understand different aspects of the components. As a result, two or more strong firms bring differentiated value to a product, which creates an incentive to both make and buy. When interfirm expertise for a set of complementary components is sufficiently strong, a firm may elect to use concurrent sourcing, rather

than vertically integrate, in order to gain flexibility and access to the specialized skills of a partner. For example, Cassiman and Veugelers (2006) find that firms often concurrently source research and development (R&D) activities when they rely on universities for basic research.

Parmigiani (2007) found that greater combined firm and supplier expertise for a single component led to concurrent sourcing of that component. This component-level interfirm expertise was grounded in superior skills, progression up the learning curve, and the associated reduced production costs for the focal component. The current study expands the view of the potential influence of interfirm expertise by considering how such expertise may affect the sourcing decision for a set of complementary components rather than a single component. The earlier study (Parmigiani, 2007) did not address this possibility (moreover, support for the prediction in the earlier study concerning individual components does not guarantee support for the prediction concerning complementary components in this study). Here we focus on the spillover effect of interfirm expertise of one component as it affects the sourcing choice for the set of complementary components.

The presence of skill specialization and the potential for spillover across knowledgeable firms create a learning incentive for concurrent sourcing of complementary components. A firm will often gain knowledge from buying components from a highly skilled supplier. Such learning opportunities will be most productive when the firm also has strong relevant expertise, because its internal skills create an absorptive capacity that enables knowledge transfer (Cohen and Levinthal, 1990). For example, with the increased importance of electronics in automotive systems and the interdependence between these systems, Toyota chose to source related electrical components both internally and from Denso in order to better understand the technology and learn indirectly about competitors (Lincoln, Ahmadjian, and Mason, 1998). The logic leads to the first hypothesis.

Hypothesis 1: The greater the interfirm expertise of a firm and its potential suppliers for complementary components, the more likely the firm will concurrently source the set of components rather than vertically integrate.

We next consider how within-firm shared expertise, which is the focal firm's skill relevant to a set of complementary components, will influence sourcing choices for complementary components. The discussion produces a prediction that may at least initially appear counterintuitive.

The seemingly intuitive expectation concerning within-firm shared expertise might be that greater within-firm shared expertise will lead firms to vertically integrate complementary components in order to capture and benefit from knowledge spillovers. Firms tend to accumulate tangible and intangible resources that can be used throughout a family of related products (Helfat and Raubitschek, 2000; Nelson and Winter, 1982). Thus, one might expect that a firm will make sets of complementary components when it has an opportunity to leverage a particularly strong set of internal skills, rather than outsourcing part of its requirements. These skills can include organizational capabilities that enable the firm to exploit scope economies and/or technical skills that assist the firm in managing technological interdependencies.

An intriguing counterpoint to the seemingly obvious expectation emerges from the modularity literature, which suggests complementary components can be successfully outsourced, as long as clearly described interfaces exist between components (Baldwin and Clark, 2000; Sanchez and Mahoney, 1996). One example is the possibility of separating product design from production such that a firm may internally produce designs and outsource subsequent manufacture of the products. While these two activities are clearly complementary, the forces motivating the firm to integrate the activities may differ from those that motivate internalization of either activity (Dutta *et al.*, 1995; Ulrich and Ellison, 2005). A considerable body of work has also explored system integrators, typically large firms that outsource much of their activities while retaining expertise in the underlying technologies (Brusoni and Prencipe, 2001; Prencipe *et al.*, 2003). The benefits of outsourcing include flexibility in the face of uncertainty (Milgrom and Roberts, 1990), as well as opportunities to learn from external partners (von Hippel, 1988).

An implication of the modularity research is that a firm's knowledge boundaries may be considerably broader than its production boundaries

(Brusoni *et al.*, 2001). Firms must preserve internal knowledge, however, in order to best understand the interrelationships between components based upon technologies that may be changing at different rates. Quoting Pavitt (2003), 'Firms specializing in product development and systems integration will need to maintain competencies in related manufacture, components, and subsystems' (Pavitt, 2003: 86).

The location of a firm's boundaries affects the firm's ability to monitor and learn from suppliers, however, suggesting limits to the benefits of outsourcing. From a capabilities standpoint, some degree of tacit knowledge and understanding will be gained and applied only through internal production. Hoetker's (2006) study of the computer industry shows that product modularity does not map cleanly onto organizational modularity; instead, firms prefer internal suppliers for both systemic and modular goods. Takeishi (2002) argues that, particularly for new technologies, architectural knowledge is insufficient to manage interrelated components and unravel engineering problems. Firms require component-level knowledge that they ostensibly can only obtain through production. As Dosi *et al.* (2003) suggest, 'Clearly, the balance between what these types of firms "know" and what they directly "make" will continue to depend upon product- and technology-specific patterns of knowledge accumulation and their interfaces' (Dosi *et al.*, 2003: 109). From a governance perspective, some hazards and risks are only contained through internalization, chosen only as a last resort (Williamson, 1985). Mayer and Salomon (2006) show that technical expertise reduces holdup risks by improving a firm's ability to craft contracts that govern external transactions involving specialized assets, and also find that technical expertise does not enable the firm to avoid evaluation problems or knowledge leakage in outsourced exchanges.

Evaluation and knowledge issues will tend to become even more important when goods are complementary, further limiting the incentives for pure outsourcing. In turn, this opens up the possibility for concurrent sourcing, because firms need not completely vertically integrate to gain production knowledge, but rather can produce a small portion of their requirements. For example, a firm may operate a pilot plant in order to better understand and monitor its suppliers' processes (Oster, 1994).

Concurrent sourcing helps resolve the problem of attempting to achieve the seemingly conflicting goals of deep component knowledge, flexibility, and protection. Firms need not produce their full requirements of complementary components in order to obtain deep component knowledge and maintain sufficient absorptive capacity to source effectively (Adelman, 1949; Cohen and Levinthal, 1990; Oster, 1994; Parmigiani, 2007). This suggests a greater overlap in production and knowledge boundaries than the modularity or systems integration views might suggest.

The benefits of overlap and the need to produce internally arise from the tacit nature of production and the interrelatedness of the goods. When components are complementary, the sourcing decisions for the two components become intermingled, such that concurrent sourcing of one commonly leads to concurrent sourcing for the other. This combined decision making involves both technological and organizational complexity. In turn, this complexity requires that the firm possess a significant degree of within-firm shared expertise across the components to utilize the concurrent sourcing strategy. The payoff of this difficult-to-manage mode is a richer understanding of the set of components and the underlying body of technical knowledge. This logic leads to the second hypothesis.

Hypothesis 2: The greater the within-firm shared expertise for complementary components, the more likely the firm will concurrently source the components rather than vertically integrate.

In sum, we expect both greater interfirm expertise and greater within-firm shared expertise to increase the use of concurrent sourcing over vertical integration. The analysis will also assess how firm and supplier expertise for individual components affects sourcing choices.

CONTEXT, DATA, AND METHODS

We studied sourcing decisions of North American metal stamping and powder metal firms for production tooling and services. These two sectors of the metal forming industry consist of many independent small firms, most of which are privately held. This setting allowed us to focus on straightforward buyer-supplier relationships, since these

firms rarely use sophisticated alliances or joint ventures for sourcing. Both sectors share relatively homogeneous production processes and a common end-product market of the automotive industry, which stresses the importance of production efficiency and technological progress from upstream suppliers (Womack, Jones, and Roos, 1990).

We first conducted exploratory interviews with managers of 11 metal forming firms. The interviews helped us understand their production processes and identified three components that all firms sourced: die design (progressive stamping dies in the metal stamping industry and powder compaction dies in the powder metal industry), die construction, and end-part machining services. These three components were common to all firms and are strategically significant.³ These firms use dies to create their products and must source both the design and construction of the dies. Die design is a complex process in which designers must select the proper type of steel, consider press features, and optimize the layout of the die to maximize its productivity (Poli *et al.*, 1993). Dies involve numerous interrelated components, including top and bottom shoes, punches, bearings, springs, and guide pins. Die construction typically requires tool-grade steel and employs computer numerical controlled (CNC) mills and electric-discharge machining (EDM) centers. Substantial technical expertise is required for die design and construction, as Walsh (1994) discusses in his machining handbook: ‘... die design and die making are complex arts as well as technologies that require considerable skill, knowledge, and practical experience’ (Walsh, 1994: 792). End-part machining is a downstream operation that these firms undertake in order to meet customer specifications by adding features that cannot be stamped or molded into the part, such as slots or holes.

Although we do not have a direct measure of complementarity, we identified a complementary dyad and an independent dyad among the three components. Die design and die construction are complementary components because they enjoy scope economies arising from both cost savings and technological interdependence (primarily sequential interdependence, in Thompson’s [1967]

³ We also collected data about die maintenance and end-part coating, but did not include them in this analysis because of infrequent outsourcing for die maintenance and infrequent internal production for end-part coating.

terms, with die design preceding die construction). The efficiencies arise due to firm reputation, common personnel, and administrative skills needed to manage the overall process. Technological interdependence of die design and construction arises because both draw upon a common body of knowledge, including mechanical engineering, metal working, and press operations (Walsh, 1994). Many managers we interviewed were keen to discuss the intricacies and interdependencies of sourcing tooling designs and dies. As one stated, 'Just looking at the (end) part doesn't tell you how to make it—just that it can be done ... [it's the] 'magic of the tool,' who designs it, and how it runs.' The managers also acknowledged the importance of expertise in the sourcing decision, asserting they desired suppliers that are up to date on technology, bring 'intellectual ability to the table,' and can 'grow with us and form creative solutions.' At the same time, the executives were concerned about supplier opportunism, particularly for die construction. They noted that 'when tool shops are busy, prices go up two times and delivery increases from 2–3 weeks to 10–12 weeks,' and were wary of the 'kitchen remodeler trick' in which suppliers would agree to a job but later negotiate for higher prices and/or later deliveries due to unforeseen circumstances.

The relationship between production and design, such as in tooling dies, is a classic example of complementarity, in which it is possible that firms can have strong expertise in one activity and not the other. Some firms may excel at such design capabilities as engineering, creating specifications, and environmental scanning. Other firms may be superior manufacturers, with a keener focus on process efficiency and meeting specifications. Depending upon how the activities are divided, it is sometimes possible to create a 'black box' specification for suppliers, such that they follow predetermined rules of coordination between the different subsystem components, so that firms can make separate sourcing decisions for the design and production stages (Brusoni *et al.*, 2001; Petersen, Handfield, and Ragatz, 2005). However, a firm's technical knowledge, its past experience, and its reputation create strong incentives to make joint sourcing decisions for complementary components.

In contrast with die design and construction, die design and end-part machining are largely independent of each other. The activities involve different

kinds of expertise, have little or no work flow interdependencies, and create few economies of scope. Die design requires skills in CAD software to produce the specifications for an individual design, for example, while end-part machining requires skills in managing high quantity production, often with close tolerances using metal processing equipment such as mills or lathes.

We also assessed die construction and end-part machining as a possible pair of components, but could not cleanly categorize them as complementary or independent. The two activities use some similar equipment, but the materials and product volumes differ and the workflow interdependence is minimal. Hence, we focused on the two more clearly categorical pairings of design-construction (complementary) and design-machining (independent).

Survey administration and response

Based upon our understanding of the firms and the three inputs, we designed a survey booklet with sections for data on each input, plus a section for overall firm information. We chose scales based on reviews of the literature, refined by discussions during the preliminary interviews. Most items used seven-point scales (Fowler, 1995). The 24-page survey contained over 300 items covering several aspects of the sourcing decision. We pretested the survey by soliciting feedback from academic colleagues, conducting interviews with managers, obtaining reviews from industry association executives, and performing a pilot test with managers that replicated final survey conditions. We solicited the help of industry associations for metal stamping (the Precision Metalforming Association) and powder metal (the Metal Powder Industry Federation). From these groups, we were able to obtain membership lists that we used as the basis for our sample. We called each of the 509 member firms in order to identify the correct contact person to whom we should send the survey. In the fall of 2002, we sent the survey to the 453 firms that provided us with contact information. After the initial call and survey mailing, we conducted up to four follow-up contacts by fax, phone, and mail. Through these efforts, we obtained a 43 percent usable response rate, substantially higher than the 20 percent rate that is common for firm-level surveys (Paxson, Dillman, and Tarnai, 1995).

Our dataset included 809 distinct sourcing decisions from 193 firms. Because we are investigating the sourcing choice for pairs of components, we ruled out firms that did not source all three components of interest. Our final data include 110 firms that sourced both the complementary pair of components (die design and construction) and the independent pair of components (die design and end-part machining).

We used a key informant approach for the survey. While in some cases it is preferable to have multiple survey respondents, we believed it was better to request information from one knowledgeable respondent in this study, due to the small size of these firms (mean of 75 employees, with 95% having fewer than 500 employees) and the technical and specialized nature of the survey. The key informant approach is appropriate when one can identify respondents who, by virtue of their positions in an organization's hierarchy, are able to provide opinions and perceptions that are valid reflections of other key decision makers in the firm (Li and Atuahene-Gima, 2002; Phillips, 1981). For many questions, the most qualified rater is a senior manager of the firm, who is likely to have the broadest interactions as well as the best overview of the firm's strategy and performance (Glick *et al.*, 1990; Parkhe, 1993).

In our study, the most common respondent was the president or general manager. Senior managers of metal forming firms typically have considerable experience in buying production components, particularly because metal forming is a mature industry, based upon established technology, with well established buying and supplying firms. One of the authors worked as a purchasing manager in this industry for several years and can attest to the fact that a single senior executive typically has oversight of sourcing decisions and managing suppliers. Our first-hand knowledge of this context and the fact that we asked about their sourcing experience over the past year also gave us confidence in using a single, well-qualified respondent.

We recognize that consistency artifacts and a common method variance bias can result from collecting dependent and independent variables from the same respondent. While this is a drawback of this type of survey design, we sought to avoid consistency artifacts by placing more subjective items, such as supplier expertise, before objective ones, such as firm size (Salancik and Pfeffer, 1977). We

investigated common method variance by conducting the Harman one-factor test, which involves entering all the independent and dependent variable items into a factor analysis (Podsakoff and Organ, 1986). A principal component factor analysis of all measurement items yielded seven factors with an eigenvalue exceeding one. These factors accounted for 57 percent of the variance. The factor with the greatest eigenvalue accounted for 15 percent of the variance. Because no single factor emerged as a dominant factor accounting for most of the variance, common method variance is unlikely to be a serious problem in the data.

Variables

Dependent variable

The sourcing choice variable reflects the sourcing firm's procurement choice for the pair of components over the prior year. Including a time period is essential for questions that seek to understand behavior (Fowler, 1995). We measured the dependent variable based on a question that asked if the firm sourced each item internally, externally, or concurrently (see Appendix A). For concurrent sourcing, we obtained the percentage of internal production. The survey provided six choices rather than relying on a respondent's ability to recall a precise percentage. This procedure improves accuracy and reduces response distortion by cueing the respondent's memory, pushing him or her to consider the different options and choose the best one (Fowler, 1995). Consistent with prior work (Harrigan, 1986; Jacobides and Hitt, 2005; Parmigiani, 2007; Sa Vinhas, 2002), we used a 10 percent cutoff, such that components that firms produced at least 90 percent internally were considered 'made,' those that firms outsourced 90 percent or more were 'bought,' and the rest concurrently sourced.

We investigated whether firms' use of concurrent sourcing tended to be stable or represented a transitory state. The data in this study appear to reflect stable boundary choices, based on survey responses to items measuring longevity ('How long has the good been sourced this way?') and likelihood of change ('Do you plan to change sourcing modes within the next two years?'); the means for concurrently sourced items did not differ significantly from those made or bought. Nearly 60 percent of the goods had always been

sourced in the mode indicated, and less than 12 percent were likely to change modes, indicating stability.

Because there are three options (make, buy, concurrent) for each component, the joint sourcing decision for a pair of components includes nine options. For clarity, we focus on four of the joint options, when firms: made both components (make/make), concurrently sourced both components (concurrent/concurrent), bought both components (buy/buy), and used some combination of choices (mixed mode). Hypotheses 1 and 2 compare the concurrent/concurrent to the make/make option.

We chose to pool the six combined options into the mixed mode classification for both conceptual and econometric reasons. Conceptually, our key explanatory variables involve expertise and our main comparison of interest is between concurrently sourcing both goods versus making both goods. We have no reason to predict that interfirm or within-firm shared expertise will influence the choice of concurrent/concurrent versus make/buy any differently than that of concurrent/concurrent versus buy/make, nor does the mixed choice speak clearly to firm boundary issues addressed in this study. Given that our main interest involved complementary pairs of goods, which we believed would be more likely sourced by the same mode, no explanatory power is lost by grouping the mixed modes together. Moreover, reducing the choice options from nine to four reduced the number of comparisons from 36 to six, a much more manageable number.

Combining the categories and pooling the data also helps resolve an econometric issue, because the data were not well balanced for each pair of goods by sourcing mode. Tables 3a and 3b demonstrate this point. For example, firms made dies and concurrently sourced designs in only three of the 110 cases. A drastically uneven number of cases in each category creates a sparse cell count problem and, if left uncorrected, can bias parameter estimates in multinomial logit models (Agresti, 1996). Hence, we pooled the mixed mode observations (i.e., make/buy, make/concurrent, buy/make, buy/concurrent, concurrent/make, concurrent/buy) into one category. Our dependent variable for the complementary pair thus results in four categories: make/make (25 cases), buy/buy (18 cases), concurrent/concurrent (25 cases), and mixed mode (42 cases).

Explanatory variables

We created expertise variables with questionnaire items that used a seven-point Likert-type scale. Since the variables used multiple items, we used exploratory factor analysis (EFA) and then confirmatory factor analysis (CFA) to investigate the relationships between the items and the variables (Anderson and Gerbing, 1988). The EFA results indicated that each of the variables were unidimensional and distinct. We created CFA submodels for each individual variable and then aggregated a final, full model. All of the CFA models used full information maximum likelihood, with evaluation based on six indices (Hu and Bentler, 1998). The final model sufficiently fit the data (chi-square = 1521.642, 421 degrees of freedom, $p < 0.001$, chi-square/dof = 3.614, TLI = 0.972, CFI = 0.976, RMSEA = 0.057). All parameter estimates were significant ($p < 0.02$), supporting convergent validity, and none of the covariances were significantly close to one, supporting divergent validity (Bollen, 1989; Bagozzi, 1994). Reliability estimates for the firm expertise variables were all over 0.60, suggesting adequate consistency among the items (Nunnally, 1967). The loadings from this final CFA model provided item weighting factors to construct aggregate scores for each variable (Pedazhur and Schmelkin, 1991); the subsequent analysis used these scores. Appendix A lists items for the explanatory and control variables.

Firm component expertise

We constructed measures of firm expertise for all three components, to assess the extent to which a firm had substantial skills and capabilities for producing the good and an understanding of the underlying technology. Four items measured firm component expertise and five measured supplier component expertise. Some of these items were drawn from prior work (Noordewier, John, and Nevin, 1990; Walker and Weber, 1984) and others were original. This approach assumes that firms have knowledge of supplier expertise, which is reasonable in a clearly defined, mature industry. These items are perceptual and, while they could potentially be influenced by the strength of the supplier relationship, prior work has indicated that these effects are independent (Parmigiani and Mitchell, 2005).

Within-firm shared expertise

This variable represents a firm’s internal expertise across pairs of components. The measure was constructed by multiplying the mean-differenced firm component expertise scores for the two components. This interaction assumes the expertise of one component can enhance the expertise of another due to shared skills and other resources, making the aggregate expertise greater than the sum of its parts.

Interfirm expertise

This variable reflects the aggregate expertise of a firm and its potential suppliers related to a component. The measure was constructed by multiplying the mean-differenced firm and supplier expertise variables for each component. Using this type of measure captures interfirm expertise based on dissimilar factors (e.g., a firm’s skilled labor versus a supplier’s unique equipment) and related factors (e.g., a firm’s experienced engineers and the supplier’s use of advanced design software).

Control variables

Several items addressed alternate explanations. In addition to supplier component expertise and within-supplier shared expertise for the pair of components, item-level control variables included asset specificity, performance uncertainty, volume requirements, and component homogeneity. Firm control variables included scope economies for the pair of components and firm size (the number of employees). Table 1 provides details on the operationalization of the explanatory and control variables, as well as descriptive statistics. Table 2 provides descriptive statistics and correlations for the expertise variables.

Methods

To test the hypotheses, we created multinomial logit models for the pair of complementary components using the four categories (make/make: MM; buy/buy: BB; concurrent/concurrent: CC; and mixed mode: Mix). Our equation for these models is as follows:

$$SMODE_{ij} = FEX_i + FEX_j + SUPEX_i + SUPEX_j + (FEX_i)*(FEX_j) +$$

$$(SUPEX_i)*(SUPEX_j) + (FEX_i)*(SUPEX_i) + (FEX_j)*(SUPEX_j) + FSCOPE_{ij} + AS_i + AS_j + PU_i + PU_j + VOL_i + VOL_j + ALLSAME_i + ALLSAME_j + EMPEES$$

In this model, $SMODE_{ij}$ indicates the sourcing mode choice for the pair of components, while FEX_k and $SUPEX_k$ reflect firm and supplier component expertise. Within-firm shared expertise is represented by the mean-differenced interaction of the firm expertise variables for both components, while interfirm expertise is represented by the mean-differenced interaction of the firm and supplier expertise variables for each component. Control variables include asset specificity, performance uncertainty, volume requirements, and homogeneity for each component, as well as firm size and firm scope economies for the pair of components.

Multinomial logit is appropriate because we have independent choice categories (Maddala, 1983). Altogether, the models provide six comparisons involving the four modes (CC v. MM, CC v. BB, CC v. Mix, MM v. BB, MM v. Mix, BB v. Mix). Consistent with our conceptual intent, our discussion compares concurrently sourcing both components with making both components (CC v. MM); Appendices B and C report all six comparisons.

RESULTS

Tables 3a and 3b provide descriptive information concerning the firms’ boundary choices for complementary (die design and die construction) and independent (die design and end-part machining) components. Higher figures along the diagonals of the tables indicate the use of common sourcing modes for the pairs of components. Table 3a shows particularly high figures on the diagonal (62% of the cases), indicating that firms often source complementary components in the same manner. By contrast, Table 3b shows that common sourcing modes for independent components are less prevalent (45% of the cases fall along the diagonal). The difference is statistically significant ($p < 0.005$). Thus, firms are more likely to use common sourcing modes for complementary components than for independent components.

In turn, Tables 3a and 3b show that firms concurrently sourced complementary components

Table 1. Operationalization and descriptive statistics for explanatory and control variables (110 cases)

	Variable name	Operationalization	Mean	Standard deviation
1	Firm expertise—die design	4 item, Likert scale	5.59	1.21
2	Firm expertise - die construction	4 item, Likert scale	4.99	1.53
3	Firm expertise - machining	4 item, Likert scale	5.41	1.14
4	Supplier expertise—die design	5 item, Likert scale	3.48	1.06
5	Supplier expertise—die construction	5 item, Likert scale	3.78	0.96
6	Supplier expertise—machining	5 item, Likert scale	3.43	0.94
7	Interfirm expertise—die design	#1 * #4	-0.59	1.49
8	Interfirm expertise - die construction	#2 * #5	-0.44	1.60
9	Interfirm expertise - machining	#3 * #6	-0.45	1.17
10	Within-firm shared expertise - die design and die construction	#1 * #2	0.48	2.13
11	Within-firm shared expertise - die design and machining	#1* #3	0.13	1.26
12	Within-supplier shared expertise - die design and die construction	#4* #5	0.60	1.53
13	Within-supplier shared expertise - die design and machining	#4* #6	0.25	0.94
14	Firm scope economies die design and die construction	Summed scores from two 2-item Likert scales	8.46	2.52
15	Firm scope economies - die design and machining	Summed scores from two 2-item Likert scales	8.85	2.42
16	Asset specificity—die design	3 item, Likert scale	4.06	1.28
17	Asset specificity—die construction	3 item, Likert scale	3.98	1.26
18	Asset specificity—machining	3 item, Likert scale	3.81	1.18
19	Performance uncertainty—die design	5 item, Likert scale	2.96	0.93
20	Performance uncertainty—die construction	5 item, Likert scale	2.89	0.97
21	Performance uncertainty—machining	5 item, Likert scale	2.85	0.87
22	Volume requirements—die design	Number of designs, 5 point scale from 1 to 200+	2.70	1.52
23	Volume requirements—die construction	Number of dies, 5 point scale from 1 to 200+	2.79	1.53
24	Volume requirements—machining	Number of part numbers, 5 point scale from 1 to 100+	2.70	1.53
25	Item homogeneity, die design	1 item, Likert scale	3.62	1.87
27	Item homogeneity, die construction	1 item, Likert scale	3.65	1.75
28	Item homogeneity, machining	1 item, Likert scale	3.48	1.85
29	Firm size	Number of employees (5 point scale)	2.56	1.11

Notes (1) To construct aggregate scores for variables using items with Likert scales, we used loadings from a CFA model to determine item weights; scores can range from 1 to 7.

(2) Die design = Design of progressive stamping (conventional molding) dies; die construction = construction of progressive stamping (conventional molding) dies; machining = machining of end parts.

(3) To create the interfirm expertise and within-firm shared expertise variables, the firm (supplier) expertise variables were mean-differenced and then multiplied together.

(25/110 cases = 23%) more often than independent components (16/110 = 15%). The difference is moderately significant ($p = 0.06$), and likely arises because greater economies of scope based on cost savings and technological interdependence create stronger incentives for common sourcing.

Table 4 tests the predictions. Models 1a to 1d examine concurrent sourcing of complementary components (die design and die construction).

Model 1a reports the control variables. Models 1b and 1c add interfirm expertise then within-firm and within-supplier shared expertise separately. Model 1d then includes the full set of interfirm, within-firm, and within-supplier shared expertise variables. We will focus the discussion on Model 1d, because the results are consistent with the simpler preceding models. Model 1d fits the data quite well, with a McFadden's pseudo r-squared value

Table 2. Descriptive statistics and correlations for expertise variables (110 cases)

	Mean	s.d.	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Firm expertise—die design	5.59	1.21	1												
2 Firm expertise - die construction	4.99	1.53	0.26*	1											
3 Firm expertise—machining	5.41	1.14	0.09	0.16	1										
4 Supplier expertise—die design	3.48	1.06	-0.46*	-0.04	0.00	1									
5 Supplier expertise—die construction	3.78	0.96	-0.34*	-0.30*	0.09	0.59*	1								
6 Supplier expertise—machining	3.43	0.94	-0.07	-0.13	-0.43*	0.26*	0.31*	1							
7 Interfirm expertise—die design	-0.59	1.49	0.40*	0.19*	-0.05	-0.38*	-0.32*	-0.07	1						
8 Interfirm expertise - die construction	-0.44	1.60	0.05	0.28*	0.03	0.17	0.02	-0.02	0.14	1					
9 Interfirm expertise—machining	-0.45	1.17	-0.05	-0.13	0.24*	-0.01	0.06	-0.13	-0.06	0.00	1				
10 Within-firm shared expertise - die design and die construction	0.48	2.13	-0.33*	0.06	-0.11	0.19*	0.05	-0.02	-0.34*	-0.30*	0.09	1			
11 Within-firm shared expertise - die design and machining	0.13	1.26	-0.09	-0.14	0.14	-0.07	-0.02	-0.06	-0.11	-0.02	0.21*	0.42*	1		
12 Within-supplier shared expertise - die design and die construction	0.60	1.53	-0.25*	0.13	0.19*	0.33*	0.20*	-0.07	-0.45*	0.29*	0.04	0.09	-0.05	1	
13 Within-supplier shared expertise - die design and machining	0.25	0.94	-0.09	0.13	-0.01	-0.03	-0.11	-0.06	-0.07	0.02	-0.23*	0.03	0.11	0.35*	1

* p < 0.05

Table 3a. Sourcing choices for die design and die construction (complementary components)

	Make dies	Buy dies	Concurrently source dies	
Make designs	25	17	9	51
Buy designs	1	18	3	22
Concurrently source designs	3	9	25	37
	29	44	37	110

Table 3b. Sourcing choices for die design and end part machining (independent components)

	Make machining	Buy machining	Concurrently source machining	
Make designs	28	9	14	51
Buy designs	6	5	11	22
Concurrently source designs	18	3	16	37
	52	17	41	110

Comparisons from Tables 3a and 3b

(1) Firms were more likely to commonly source complementary components than independent components (68/110 = 62% in Table 3a v. 49/110 = 45% in Table 3b, $p < 0.005$).

(2) Firms were moderately more likely to concurrently source complementary components than independent components (25/110 in Table 3a=23% v. 16/110 in Table 3b=15%; $p = 0.06$).

of 0.48. This model also satisfies the Wald test that indicates none of the categories can be combined (Long and Freese, 2001).

The results in Model 1d of Table 4 partly support Hypothesis 1. Greater interfirm expertise for die design contributes to concurrent sourcing ($p < .005$). That is, when both a firm and its potential suppliers have substantial expertise relevant to die design in the set of complementary components, the firm is more likely to concurrently source rather than make both components in the complementary set. By contrast, although interfirm expertise for die construction also has a positive coefficient, the effect is not statistically significant. The difference in the two types of components may suggest that the more complex technical knowledge that underlies die design has a greater effect on sourcing choices than the more procedural knowledge that underlies die construction.

In turn, the results in Model 1d strongly support Hypothesis 2. As expected, greater within-firm shared expertise leads to more use of concurrent sourcing of the pair of complementary components, rather than producing the components internally ($p < 0.05$). That is, the firm's own skill base appears to provide absorptive capacity that allows it to manage the outsourcing relationships that are part of a concurrent sourcing strategy.

For completeness, Appendix B provides the full set of results for Model 1d, showing comparisons between concurrent sourcing, making both goods, buying both goods, and mixed sourcing. These comparisons provide further support for concurrent sourcing over mixed sourcing modes in the case of within-firm shared expertise, and also suggest that firms will be less likely to make both goods if they have extensive interfirm die design expertise.

Model 2 of Table 4 reports the results for the pair of independent components, as a comparison with the complementary components in Model 1d (simpler nested models for the independent components produced equivalent results). Model 2 shows that neither interfirm expertise nor within-firm shared expertise influence concurrent sourcing of the independent components. The null effects are consistent with the logic of Hypotheses 1 and 2, given that the independent components have few shared scope economies.

Several control variables from Model 1d in Table 4 provide useful results concerning incentives to undertake concurrent sourcing of complementary components. First, firm component expertise for die design in the complementary pair promotes vertical integration of the system of complementary components. However, firm component expertise for die construction has no significant

Complementarity, Capabilities, and the Boundaries of the Firm

Table 4. Multinomial logit models of joint sourcing decisions for complementary components (die design and die construction) and independent components (die design and end part machining): concurrently source both components (CC) versus make both components (MM)(positive coefficient indicates that concurrent sourcing is more likely than making both components)

	1. Complementary components: CC v. MM				2. Independent components: CC v. MM
	1a	1b	1c	1d	
Interfirm expertise—die design (H1: +)		0.87** (0.39)		0.92** (0.49)	0.62 (0.40)
Interfirm expertise—die construction (H1: +)		0.08 (0.43)		0.54 (0.66)	-0.43 (0.57)
Within-firm shared expertise (H2: + for complementary)			1.17** (0.67)	1.26** (0.64)	-0.07 (0.48)
Within-supplier shared expertise			-0.17 (0.37)	0.12 (0.41)	0.05 (0.47)
Firm expertise- die design	-0.59 (0.55)	-0.78 (0.59)	-1.28** (0.70)	-1.54** (0.73)	-1.02** (0.57)
Firm expertise - die construction	0.97** (0.48)	1.23** (0.54)	0.56 (0.66)	0.96 (0.70)	-0.01 (0.52)
Supplier expertise- die design	-0.20 (0.53)	-0.51 (0.59)	-0.06 (0.56)	-0.31 (0.64)	-0.32 (0.52)
Supplier expertise- die construction	0.01 (0.53)	0.20 (0.77)	-0.04 (0.56)	-0.46 (1.02)	-0.36 (0.58)
Firm scope economies	-0.36** (0.19)	-0.40** (0.20)	-0.40** (0.20)	-0.43** (0.21)	#
Asset specificity- die design	-0.17 (0.33)	-0.16 (0.34)	-0.09 (0.33)	-0.06 (0.36)	-0.37 (0.34)
Asset specificity- die construction	-0.49 (0.32)	-0.45 (0.33)	-0.49 (0.34)	-0.50 (0.35)	-0.21 (0.38)
Performance uncertainty- die design	-0.08 (0.37)	-0.11 (0.39)	-0.10 (0.38)	-0.12 (0.39)	0.37 (0.40)
Performance uncertainty - die construction	-0.82** (0.40)	-0.90** (0.43)	-1.02*** (0.43)	-1.07*** (0.45)	-0.09 (0.46)
Volume requirements- die design	-0.08 (0.25)	0.10 (0.28)	-0.10 (0.26)	0.11 (0.29)	0.22 (0.29)
Volume requirements - die construction	-0.20 (0.28)	-0.12 (0.30)	-0.18 (0.28)	-0.08 (0.30)	-1.01*** (0.38)
Item homogeneity - die design	-0.09 (0.21)	-0.10 (0.21)	-0.08 (0.21)	-0.08 (0.23)	0.83** (0.39)
Item homogeneity - die construction	-0.37 (0.24)	-0.46** (0.26)	-0.30 (0.25)	-0.40 (0.27)	#
Firm size	0.91*** (0.37)	0.96*** (0.40)	0.81** (0.40)	0.87** (0.44)	#
Log likelihood (d.f.)	-83.8(42)	-79.85(48)	-80.4(48)	-75.79(54)	-81.5(45)
Pseudo r-squared	0.43	0.46	0.45	0.48	0.32
Cases	110	110	110	110	110

*** p < 0.01; ** p < 0.05 (one-tailed tests); reported results omit estimates for constants.

Model 2 omits the firm scope economies and item homogeneity control variables in order to obtain convergence.

Note: The table reports the focal comparison (CC v. MM); Appendices B and C report the full set of sourcing comparisons (CC v. Buy/Buy (BB), CC v. Mixed mode (Mix), MM v. BB, MM v. Mix, BB v. Mix).

impact once within-firm shared expertise across the pair of components is added to the analysis. Thus, when a firm is strong in die design expertise but not in die construction expertise, it prefers to make both components, rather than attempt to manage

the more complicated process of concurrent sourcing.⁴ This conclusion reinforces the logic that

⁴ This conclusion emerges if one sets the value of the component-level die construction expertise variable to zero in Model 1d,

underlies Hypothesis 1, and again may arise for die design rather than die construction because of greater technological complexity of design.

Second, firms tend to vertically integrate when they enjoy substantial internal economies of scope (the negative effect of 'firm scope economies' on concurrent sourcing), which will allow them to capture the cost savings. Third, performance uncertainty increases the incentive for vertical integration (with a statistically significant impact for the die construction variable), most likely because the uncertainty creates measurement problems. Fourth, larger firms are more likely to concurrently source complementary components, because they have managerial resources needed to manage this more complex sourcing mode. Finally, neither supplier component expertise nor within-supplier shared expertise affects the decision to use concurrent sourcing rather than internal production. These null results may suggest that firms are more concerned about their internal skills than suppliers' skills when considering concurrent sourcing. Moreover, they may not want to depend upon strong and potentially opportunistic suppliers.

We undertook several sensitivity analyses. We added the square of the asset specificity terms to check whether concurrent sourcing arose from intermediate levels of specificity; the squared terms were not significant and our predicted results continued to be significant. Our predicted results held when we included measures of technological uncertainty for die design and die construction. We combined the two component-level measures of interfirm expertise into a single interfirm expertise measure (essentially a four-way interaction) and added this variable to Model 1d in Table 4. The combined measure had a significantly positive impact on CC v. MM, reflecting the impact of interfirm die design expertise, but did not significantly improve the explanatory power of the model. Finally, we pooled the complementary and independent sets within a single model. Our predicted results continued to hold but the model's explanatory power was not as great as the two separate models, most likely because the sourcing decisions for the two groups manifested different functional forms.

which means that the within-firm shared expertise variable also will be zero, leaving only the negative effect of the non-zero component-level die design expertise variable.

Overall, the results show that expertise relevant to complementary components, both within firms and between firms, strongly influences firms' boundary decisions. Strong interfirm expertise of a company and its potential suppliers enables concurrent sourcing of complementary components, at least with respect to die design expertise. Perhaps most strikingly, strong within-firm shared expertise provides the absorptive capacity that firms require to manage concurrent sourcing relationships, rather than having to rely solely on internal production.

DISCUSSION AND CONCLUSION

This study investigates how firms source complementary components, adding to economic and capability theories of the firm that typically consider only sourcing decisions of individual items. Our finding that firms often concurrently source complementary sets of components resolves a tension between the traditional view that firms will vertically integrate to coordinate technical interfaces and gain scope economies (Arrow, 1975; Panzar and Willig, 1981), with the emerging view that firms will outsource these components to obtain flexibility (Milgrom and Roberts, 1990; Sanchez and Mahoney, 1996; Brusoni *et al.*, 2001). Concurrent sourcing helps solve the coordination versus flexibility quandary because it permits both activities, but requires knowledgeable suppliers and a substantial degree of internal expertise about the components.

Implications

The results provide insight into the distinction between a firm's production and knowledge boundaries, as well as the need for overlap between these boundaries. Because firms learn through internal production, they cannot fully outsource key activities and hope to preserve their skills. However, they need not produce the entirety of their requirements. The study offers a better understanding of the activity systems of firms such as Toyota Motors and Southwest Airlines, which utilize concurrent sourcing for electronic components and aircraft maintenance.

Knowledge is a key driver toward concurrent sourcing of complementary components. In particular, interfirm expertise leads firms toward this sourcing mode because they can benefit from

the combination of their own and their suppliers' understanding of the components. Whether suppliers have highly specialized or somewhat redundant skills, firms benefit from the broad and diverse types of knowledge they acquire through supply relationships, because this learning augments knowledge that the firm obtains through internal production and provides the firm with a greater degree of absorptive capacity. Supply relationships also open the firm to serendipitous learning arising from the spillovers from related components and different production methods of the firm and its suppliers. Thus, firms that enjoy a high degree of interfirm expertise related to a set of complementary components often will concurrently source rather than produce these goods only internally.

Perhaps the most intriguing result is that firms with substantial expertise that spans the complementary components often concurrently source rather than integrate. This contrasts with traditional boundaries arguments, which argue that skilled firms should internalize production of related components to gain scope economies and better coordinate technical change. Instead, our results align better with the more recent modularity and systems integration literatures, which posit that firms can outsource effectively if they retain understanding of the technology (Brusoni *et al.*, 2001). In parallel, we suggest that firms can outsource some of their requirements if they have an underlying expertise in the base technology.

Hence, there may be a virtuous cycle in which knowledge of how to produce enhances the firm's ability to partially outsource, thereby augmenting their knowledge base as they learn from their suppliers, which, in turn, enables them to produce more effectively. In this way, concurrent sourcing of complementary components can be a stable, reinforcing sourcing strategy. This approach bridges the gap between the traditional and modularity arguments by suggesting that firms often do not need to unilaterally make or buy a set of components, but can sometimes do both.

Our study also bridges the gap between the levels of analysis of the transaction cost and capabilities perspectives. Consider four levels of analysis: the transaction level (e.g., buying one die), the good level (annual die purchases), the activity level (designing and constructing dies which together constitute die creation), and the system level (die creation, pressing, heat treating, and inspection activities that together comprise a work

cell). The theoretical standpoint of transaction cost logic emphasizes the lowest level, although empirical studies of transaction costs tend to be at the level of the good due to data limitations (e.g., the inability to obtain sourcing decisions about one particular item at one given time, such as individual shipment or purchase order line data). Looking specifically at concurrent sourcing, Parmigiani (2007) and He and Nickerson (2006) conduct their work at the level of the good. Studies that take a capabilities approach have tended to be at the more general system level, such as Bradach's (1997) study on franchisors, Harrigan's (1984) work on strategic business units, and Rothaermel *et al.*'s (2006) study of computer firms. Our work connects the transaction/good levels of analysis with the system level by exploring complementary goods that make up a related set of activities.

Two managerial implications emerge from this study. First, when considering sourcing options for complementary components, firms neither need to solely vertically integrate nor completely outsource. Instead, they can consider doing both in order to take advantage of the increased learning and flexibility from concurrent sourcing. While typically not relevant for sets of independent components, concurrent sourcing may be especially valuable for complementary components, because it enables the firm to better understand the scope economies and technological interrelationships between the components, and withstand different levels of change and uncertainty. Second, managers, however, should keep in mind that firms need to have a thorough understanding of the base technologies for the complementary components in order to undertake concurrent sourcing. If they lack this breadth of experience (perhaps knowing a lot about one component but little about the other), they may be better off producing both internally, until the firm gains more experience.

Is concurrent sourcing relevant in practice?

During the course of the study, one question that arose was whether concurrent sourcing is sufficiently common in practice to merit extensive study. We have cited multiple academic studies of concurrent sourcing dating back to the 1940s, which have included both mature and developing technologies in manufacturing and service industries. Nonetheless, it is possible that such academic attention simply focuses on uncommon

events. Therefore, we took advantage of a classroom opportunity to determine whether experienced managers recognized the concept of concurrent sourcing and whether it was relevant for their firms.

We asked a class of senior executive MBA students—that one of the authors was teaching—whether their firms engaged in concurrent sourcing. We received 25 examples of concurrent sourcing (from about half of the students participating in the discussion), including cases of IT and software development, R&D, production (consumer goods, metal production, chemicals, electronic components, and computers), engineering shops, financial services, insurance, and hospital lab testing. The most common reason that the students cited for use of concurrent sourcing was dealing with demand uncertainty (14/25 cases), followed by gaining access to suppliers' skills (10 cases). Other reasons included taking advantage of supplier cost advantages, responding to customer requirements, and transitioning to fully internal or external sourcing. We believe that the responses demonstrate that practicing managers readily recognize the concept of concurrent sourcing and that concurrent sourcing is common in their experience.

Given its prevalence in practice, why has academic research on firm boundaries research paid relatively little attention to concurrent sourcing? We believe that a core reason for the lack of study is that theoretical concepts often create empirical blinders. Such blinders have been particularly common in the dominant recent paradigm for firm boundaries studies, transaction cost economics, with its emphasis on the dichotomous choice between markets and hierarchies, leavened by use of alliances as an intermediate governance mode. Hence, studies sometimes neglect to ask if firms use modes other than make or buy, code data into just two categories, or exclude data that do not fit the categories.

Thus, theory is a powerful two-edged sword. One edge pares away detail in order to allow scholars to focus on key phenomena. At the same time, however, the other edge of the sword risks chopping up important phenomena, thereby distorting the realities of what firms actually do. Hence, one of our jobs as scholars is to create new types of swords that allow us to do battle with understudied concepts and facts.

Limitations and further research

This study has limitations in context and method that suggest further research. These findings might be most common for small manufacturing firms and fairly low levels of technological change; it would be informative to investigate joint sourcing decisions among larger firms in more volatile environments. We did not include buyer/supplier alliances or other more complicated forms of organizing. It would be interesting to understand how sourcing of complementary components fits into these relationships. This study used a cross-sectional survey method and, as such, does not consider the dynamics of joint sourcing decisions; further study could investigate how sourcing modes influence the development of firm expertise.

Other extensions would be valuable. Additional work could explore possible differential effects of cost-based and technologically based elements of scope economies. In addition, due to our emphasis on firm production boundary decisions, we focus on complementarities in production, rather than complementarities that might arise in the use of components.⁵

Both types of complementarities involve reducing costs through the grouping of related products, but reduce costs for different parties. Combinations of products that are complementary for users may not result in production economies for manufacturers, and may actually raise production costs. Further research could explore implications for firm boundaries that might arise from these different complementarities. For example, complementarities to users that do not offer scope economies to producers might lead toward more alliances, while production complementarities might lead to more mergers.

Understanding more specifically how firms concurrently source, such as whether they use single or multiple suppliers and what proportion of their requirements they choose to outsource, will also advance work in this area. It would be informative to consider more complicated systems

⁵ Some product features may have both user and producer complementarities, while others may favor one or the other. For example, the initial push to add electronic systems into automotive dashboards had greater benefits for users than for producers. Once these are incorporated, however, adding another electronic feature (e.g., an MP3 connector) is relatively easy and has benefits to both users and producers. We are grateful to a reviewer for suggesting the implications of this distinction.

of components, with a greater number of components and more complex interactions between them. Scholars could also investigate performance implications of the sourcing strategy chosen for these components, perhaps contrasting individual component performance versus that of the system using multistage modeling techniques. Longitudinal studies would also be useful in determining whether firms continue to source subsequent generations or particular families of products in the same manner over time, and how the associated inter-firm relationships evolve. It also would be useful to better understand the supplier's perspective in participating with the firm in sourcing these types of components. We look forward to studies that explore how firms source the myriad of products they require, how they manage the associated relationships, and how the knowledge and production boundaries of the firms evolve.

ACKNOWLEDGEMENTS

We appreciate financial support from the Institute for Supply Management, the American Production and Inventory Control Society, the University of Michigan Business School, and the Lundquist College of Business. Thanks to the seminar participants at the West Coast Research Symposium and attendees at our Academy of Management session. We also appreciate the efforts of the editor and reviewers in helping us develop this work. Any remaining errors are our own.

REFERENCES

- Adelman MA. 1949. The large firm and its suppliers. *Review of Economics and Statistics* **31**: 113–118.
- Agresti A. 1996. *An Introduction to Categorical Data Analysis*. Wiley: New York.
- Anderson E. 1985. The salesperson as outside agent or employee: a transaction cost analysis. *Marketing Science* **4**: 235–254.
- Anderson E, Schmittlein DC. 1984. Integration of the sales force: an empirical examination. *RAND Journal of Economics* **15**: 385–395.
- Anderson JC, Gerbing DW. 1988. Structural equation modeling in practice: a review and recommended two-step approach. *Psychological Bulletin* **103**: 411–423.
- Anderson SW, Glenn D, Sedatole KL. 2000. Sourcing of complex products: evidence on transaction costs, high powered incentives, and ex-post opportunism. *Accounting, Organizations, and Society* **25**: 723–749.
- Argyres N. 1996. Evidence on the role of firm capabilities in vertical integration decisions. *Strategic Management Journal* **17**(2): 129–150.
- Armour HO, Teece DJ. 1978. Vertical integration and technological innovation. *Review of Economics and Statistics* 470–474.
- Arrow KJ. 1975. Vertical integration and communication. *Bell Journal of Economics* **6**: 173–183.
- Bagozzi RP. 1994. *Principles of Marketing Research*. Blackwell Publishers: Oxford, UK.
- Baldwin CY, Clark KB. 2000. *Design Rules: The Power of Modularity*. MIT Press: Cambridge, MA.
- Barney JB. 1986. Strategic factor markets: expectations, luck, and business strategy. *Management Science* **32**: 1231–1241.
- Barney JB. 1991. Firm resources and sustained competitive advantage. *Journal of Management* **17**(1): 99–120.
- Blair RD, Lafontaine F. 2005. *The Economics of Franchising*. Cambridge University Press: New York.
- Bollen KA. 1989. *Structural Equations with Latent Variables*. Wiley: New York.
- Bottom P. 1992. Technology management through the selection of alternative sourcing strategies. PhD diss, University of Minnesota: Minneapolis, MN.
- Bradach JL. 1997. Using the plural form in the management of restaurant chains. *Administrative Science Quarterly* **42**: 276–303.
- Bradach JL, Eccles RG. 1989. Price, authority, and trust: from ideal types to plural forms. *Annual Review of Sociology* **15**: 97–118.
- Brunson S, Prencipe A. 2001. Unpacking the black box of modularity: technologies, products, and organizations. *Industrial and Corporate Change* **10**: 179–205.
- Brunson S, Prencipe A, Pavitt K. 2001. Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make? *Administrative Science Quarterly* **46**: 597–621.
- Campbell A, Goold M, Alexander M. 1995. Corporate strategy: the quest for parenting advantage. *Harvard Business Review* **73**: 120–132.
- Cannon JT. 1968. *Business Strategy and Policy*. Harcourt, Brace, & World: New York.
- Cassiman B, Veugelers R. 2006. In search of complementarity in innovation strategy: internal R&D and external knowledge acquisition. *Management Science* **52**: 68–82.
- Chandler A. 1962. *Strategy and Structure: Chapters in the History of the Industrial Enterprise*. MIT Press: Cambridge, MA.
- Clark N. 2007. Boeing delays deliveries of 787. *New York Times* 10 October. Available at: <http://www.nytimes.com/2007/10/10/business/10cnd-boeing.html>.
- Coase RH. 1937. The nature of the firm. In *Organizational Economics: Toward a New Paradigm for Understanding and Studying Organizations*, Barney JB, Ouchi WG (eds). Jossey-Bass: San Francisco, CA.
- Cohen WM, Levinthal DA. 1990. Absorptive capacity: a new perspective on learning and innovation. *Administrative Science Quarterly* **35**: 128–152.

- Combs JG, Michael SC, Castrogiovanni GJ. 2004. Franchising: a review and avenues to greater theoretical diversity. *Journal of Management* **30**: 907–931.
- Conner KR. 1991. A historical comparison of resource-based theory and five schools of thought within industrial organizational economics: do we have a new theory of the firm? *Journal of Management* **17**: 121–154.
- Conner KR, Prahalad CK. 1996. A resource-based theory of the firm: knowledge versus opportunism. *Organization Science* **7**: 477–501.
- Cyert RM, March JG. 1963. *A Behavioral Theory of the Firm*. Prentice Hall: Englewood Cliffs, NJ.
- Danneels E. 2007. The process of technological competence leveraging. *Strategic Management Journal* **28**(5): 511–533.
- Davis-Blake A Uzzi B. 1993. Determinants of employment externalization: a study of temporary workers and independent contractors. *Administrative Science Quarterly* **38**: 195–223.
- Dosi G. 1988. Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature* **20**: 1120–1171.
- Dosi G, Hobday M, Marengo L, Prencipe A. 2003. The economics of systems integration: towards an evolutionary interpretation. In *The Business of Systems Integration*, Prencipe A, Davies A, Hobday M (eds). Oxford University Press: New York; 78–91.
- Dutta S, Bergen M, Heide JB, John G. 1995. Understanding dual distribution: the case of reps and house accounts. *Journal of Law, Economics, & Organization* **11**: 189–204.
- Dyer JH, Singh H. 1998. The relational view: cooperative strategy and sources of interorganizational competitive advantage. *Academy of Management Review* **23**: 660–679.
- Fowler FJ. 1995. *Improving Survey Questions: Design and Evaluation*. SAGE Publications: Thousand Oaks, CA.
- Glick WH, Huber GP, Miller CC, Doty DH, Sutcliffe KM. 1990. Studying changes in organizational design and effectiveness: retrospective event histories and periodic assessments. *Organization Science* **1**: 293–313.
- Grant RM. 1996. Toward a knowledge-based theory of the firm. *Strategic Management Journal*, Winter Special Issue **17**: 109–122.
- Gulati R, Puranam P. 2006. Complementarity and constraints: why firms both make and buy the same thing. Working paper. Northwestern University Graduate School of Management, Evanston, IL. Available at: C:\Users\bby327\AppData\Local\Microsoft\Windows\Temporary Internet Files\Low\Content.IE5\6DUV5JV5\Ranjay_Gulati,_Phanish_Puranam_[1].pdf.
- Harrigan KR. 1984. Formulating vertical integration strategies. *Academy of Management Review* **9**(4): 638–652.
- Harrigan KR. 1986. Matching vertical integration strategies to competitive conditions. *Strategic Management Journal* **7**(6): 535–555.
- Harris RG, Wiens EG. 1980. Government enterprise: an instrument for the internal regulation of industry. *Canadian Journal of Economics* **13**: 125–132.
- He D, Nickerson JA. 2006. Why do firms make and buy? Efficiency, appropriability, and competition in the trucking industry. *Strategic Organization* **4**: 43–69.
- Heide JB. 2003. Plural governance in industrial purchasing. *Journal of Marketing* **67**: 18–29.
- Helfat CE, Eisenhardt KM. 2004. Inter-temporal economies of scope, organizational modularity, and the dynamics of diversification. *Strategic Management Journal* **25**(13): 1217–1232.
- Helfat CE, Raubitschek RS. 2000. Product sequencing: co-evolution of knowledge, capabilities, and products. *Strategic Management Journal*, October–November Special Issue **21**: 961–979.
- Hennart J-F. 1993. Explaining the swollen middle: why most transactions are a mix of ‘market’ and ‘hierarchy.’ *Organization Science* **4**(4): 529–547.
- Hoetker G. 2006. Do modular products lead to modular organizations? *Strategic Management Journal* **27**(6): 501–518.
- Hu LT, Bentler PM. 1998. Fit indices in covariance structure modeling: sensitivity to underparameterized model misspecification. *Psychological Methods* **3**: 424–453.
- Jacobides MG, Hitt LM. 2005. Losing sight of the forest for the trees? Productive capabilities and gains from trade as drivers of vertical scope. *Strategic Management Journal* **26**(13): 1209–1227.
- Kogut B, Zander U. 1992. Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science* **3**: 383–397.
- Lafontaine F, Shaw KL. 1999. The dynamics of franchise contracting: evidence from panel data. *Journal of Political Economy* **107**: 1041–1080.
- Lavie D. 2006. The competitive advantage of interconnected firms: an extension of the resource-based view. *Academy of Management Review* **31**: 638–658.
- Lepak DP, Snell SA. 1999. The human resource architecture: toward a theory of human capital allocation and development. *Academy of Management Journal* **24**: 31–48.
- Li H, Atuahene-Gima K. 2002. The adoption of agency business activity, product innovation, and performance in Chinese technology ventures. *Strategic Management Journal* **23**(6): 469–490.
- Lincoln JR, Ahmadjian CL, Mason E. 1998. Organizational learning and purchase-supply relations in Japan. *California Management Review* **40**: 241–264.
- Long JS, Freese J. 2001. *Regression Models for Categorical Dependent Variables Using Stata*. Stata Press: College Station, TX.
- Maddala GS. 1983. *Limited-dependent and Qualitative Variables in Econometrics*. Cambridge University Press: New York.
- Mayer KJ, Salomon RM. 2006. Capabilities, contractual hazards, and governance: integrating resource-based and transaction cost perspectives. *Academy of Management Journal* **49**: 942–959.

- Milgrom P, Roberts J. 1990. The economics of modern manufacturing: technology, strategy, and organization. *American Economic Review* **80**: 511–528.
- Milgrom P, Roberts J. 1995. Complementarities and fit: strategy, structure, and organizational change in manufacturing. *Journal of Accounting and Economics* **19**: 179–208.
- Nelson RR, Winter SG. 1982. *An Evolutionary Theory of Economic Change*. Harvard University Press: Cambridge, MA.
- Noordewier TG, John G, Nevin JR. 1990. Performance outcomes of purchasing arrangements in industrial buyer-vendor relationships. *Journal of Marketing* **54**: 80–93.
- Novak S, Stern S. 2009. Complementarity among vertical integration decisions: evidence from automobile product development. *Management Science* **55**(2): 311–332.
- Nunnally JC. 1967. *Psychometric Theory*. McGraw-Hill: New York.
- Oster SM. 1994. *Modern Competitive Analysis*. Oxford University Press: New York.
- Panzar JC, Willig RD. 1981. Economies of scope. *American Economic Review* **71**: 268–272.
- Parkhe A. 1993. Strategic alliance structuring: a game theoretic and transaction cost examination of interfirm cooperation. *Academy of Management Journal* **36**: 794–829.
- Parmigiani A. 2007. Why do firms both make and buy? An investigation of concurrent sourcing. *Strategic Management Journal* **28**(3): 285–311.
- Parmigiani A, Mitchell W. 2005. How buyers shape supplier performance: can governance skills substitute for technical expertise in managing outsourcing relationships? *Academy of Management Best Paper Proceedings*.
- Pavitt K. 2003. Specialization and systems integration: where manufacture and services still meet. In *The Business of Systems Integration*, Prencipe A, Davies A, Hobday M (eds). Oxford University Press: New York; 78–91.
- Paxson MC, Dillman DA, Tarnai J. 1995. Improving response to business mail surveys. In *Business Survey Methods*, Cox BG, Binder BA, Chinnappa BN, Christianson A, Colledge MJ, Kott PS (eds). Wiley: New York: 303–316.
- Pedhazur EJ, Schmelkin LP. 1991. *Measurement, Design, and Analysis*. Lawrence Erlbaum Associates: Hillsdale, NJ.
- Penrose ET. 1959. *The Theory of the Growth of the Firm*. Wiley: New York.
- Petersen KJ, Handfield RB, Ragatz GL. 2005. Supplier integration into new product development: coordinating product, process and supply chain design. *Journal of Operations Management* **23**: 371–388.
- Phillips LW. 1981. Assessing measurement error in key informant reports: a methodological note on organizational analysis in marketing. *Journal of Marketing Research* **18**: 395–415.
- Pisano G. 1994. Knowledge, integration, and the locus of learning: an empirical analysis of process development. *Strategic Management Journal*, Winter Special Issue **15**: 85–100.
- Podsakoff PM, Organ DW. 1986. Self-reports in organizational research: problems and prospects. *Journal of Management* **12**: 531–544.
- Poli C, Dastidar P, Mahajan P, Graves RJ. 1993. Design for stamping: analysis of part attributes that impact die construction costs for metal stampings. *Journal of Mechanical Design* **115**: 735–743.
- Poppo L, Zenger T. 1998. Testing alternative theories of the firm: transaction cost, knowledge-based, and measurement explanations for make-or-buy decisions in information services. *Strategic Management Journal* **19**(9): 853–877.
- Porter ME. 1980. *Competitive Strategy*. Free Press: New York.
- Porter ME. 1996. What is strategy? *Harvard Business Review* **74**: 61–78.
- Porter ME, Siggelkow N. 2008. Contextuality within activity systems and the sustainability of competitive advantage. *Academy of Management Perspectives* **22**: 34–56.
- Prencipe A, Davies A, Hobday M. 2003. *The Business of Systems Integration*. Oxford University Press: New York.
- Richardson GB. 1972. The organisation of industry. *Economic Journal* **82**(327): 883–896.
- Rothaermel FT, Hess A. 2006. Innovating within a new technological paradigm: the role of individual, firm, and network-level effects in building capabilities. *Academy of Management Best Paper Proceedings*, C1–C6.
- Rothaermel FT, Hitt MA, Jobe LA. 2006. Balancing vertical integration and strategic outsourcing: effects on product portfolio, product success, and firm performance. *Strategic Management Journal* **27**(11): 1033–1056.
- Rubin PH. 1973. The expansion of firms. *Journal of Political Economy* **71**: 936–949.
- Rumelt RP. 1982. Diversification strategy and profitability. *Strategic Management Journal* **3**(4): 359–369.
- Sa Vinhas A. 2002. Dual distribution channels in business-to-business marketing: a transaction interdependencies view. PhD diss., INSEAD: Fontainebleu, France.
- Sako M. 2003. Modularity and outsourcing: the nature of co-evolution of product architecture and organization architecture in the global automotive industry. In *The Business of Systems Integration*, Prencipe A, Davies A, Hobday M (eds). Oxford University Press: New York; 229–253.
- Salancik GR, Pfeffer J. 1977. An examination of need-satisfaction models of job attitudes. *Administrative Science Quarterly* **22**: 427–456.
- Sanchez R, Mahoney JT. 1996. Modularity, flexibility, and knowledge management in product and organization design. *Strategic Management Journal*, Winter Special Issue **17**: 63–76.
- Santos FM, Eisenhardt KM. 2005. Organizational boundaries and theories of organization. *Organization Science* **16**: 491–508.

A. Parmigiani and W. Mitchell

- Scherer FM, Ross D. 1990. *Industrial Market Structure and Economic Performance*. Houghton Mifflin: Boston, MA.
- Siggelkow N. 2001. Change in the presence of fit: the rise, the fall, and the renaissance of Liz Claiborne. *Academy of Management Journal* **44**: 838–857.
- Stump RL, Heide JB. 1996. Controlling supplier opportunism in industrial relationships. *Journal of Marketing Research* **33**: 431–441.
- Takeishi A. 2002. Knowledge partitioning in the interfirm division of labor: the case of automotive product development. *Organization Science* **13**: 321–338.
- Teece DJ. 1982. Towards an economic theory of the multiproduct firm. *Journal of Economic Behavior & Organization* **39**: 39–63.
- Teece DJ. 1986. Profiting from technological innovations: implications for integration, collaboration, licensing, and public policy. *Research Policy* **15**: 283–303.
- Thompson JD. 1967. *Organizations in Action*. McGraw Hill: New York.
- Ulrich K, Ellison D. 2005. Beyond make-buy: internalization and integration of design and production. *Production and Operations Management* **14**: 315–330.
- von Hippel E. 1988. *The Sources of Innovation*. Oxford University Press: New York.
- Walker G, Weber D. 1984. A transaction cost approach to make-or-buy decisions. *Administrative Science Quarterly* **29**: 373–391.
- Walsh RA. 1994. *McGraw-Hill Machining and Metalworking Handbook*. McGraw-Hill: New York.
- Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* **5**(2): 171–180.
- Williamson OE. 1975. *Markets and Hierarchies: Analysis and Antitrust Implications*. Free Press: New York.
- Williamson OE. 1985. *The Economic Institutions of Capitalism*. Free Press: New York.
- Womack JP, Jones DT, Roos D. 1990. *The Machine that Changed the World*. Harper Perennial: New York.

APPENDIX A: SURVEY ITEMS

Dependent variable

For the past fiscal year, which best describes how you source progressive stamping dies?

- All done internally (either within your plant or from a division with which your firm shares a common corporate parent)
- All purchased from external suppliers
- Both done internally and purchased from external suppliers

(i.) If you marked this response, what % of your requirements did you produce internally (please mark one)?

- | | | |
|---------------------------------|---------------------------------|-----------------------------------|
| <input type="checkbox"/> 0–10% | <input type="checkbox"/> 26–49% | <input type="checkbox"/> 75–90% |
| <input type="checkbox"/> 11–25% | <input type="checkbox"/> 50–74% | <input type="checkbox"/> Over 90% |

- Don't use this input.

Explanatory variables

Each item included a response scale of 1 to 7, indicating totally true to totally untrue. Items were edited to reflect each different good (e.g., 'dies' was replaced with 'end part machining'). This resulted in three similar four-page sections, one section for each good. (Items adapted from prior work are designated by citations; other items are original.)

Firm expertise

1. Our manufacturing staff can/could easily produce dies.
2. Making dies requires a deep expertise that our firm understands (Walker and Weber, 1984).
3. We have internally produced dies for years.
4. The skills used to make dies are closely related to those that we use to make other similar products.

Supplier expertise

1. The leading die suppliers have proprietary knowledge that gives them an advantage over other firms (Walker and Weber, 1984).
2. We rely on our suppliers to help us keep up with die technology (Stump and Heide, 1996).

3. There is very little difference between the process we would use to make dies and that used by a supplier (reversed).
4. As compared to suppliers, our internal production of dies is/would be higher in price (Anderson, 1985; reversed).
5. As compared to our suppliers, our internal production of dies is/would be lower in quality (Anderson, 1985; reversed).

Firm scope economies

1. By making our own dies, we do/could reduce our overall production costs of other products.
2. We do/could better utilize our labor and equipment by making dies in addition to our other products.

Asset specificity

1. The skills needed to create dies are generic and widely available (reversed).
2. Numerous capable die suppliers exist in the market (Walker and Weber, 1984; reversed).
3. Switching die suppliers would be quick and easy to do (Poppo and Zenger, 1998; reversed).

Performance uncertainty

1. We can easily describe dies to our suppliers through printed/electronic descriptions and/or drawings (reversed).
2. Through a simple inspection, we can predict how well the die will function in our downstream production processes (Bottum, 1992; reversed)
3. We use several forms of inspection and several different metrics to evaluate die quality (Anderson, Glenn, and Sedatole, 2000).
4. When there is a problem with a die, we usually can determine its cause (reversed).
5. It is difficult to equitably measure one supplier's die versus another supplier's (Anderson and Schmittlein, 1984).

Volume requirements

1. Approximately how many progressive stamping dies did you require in the most recent fiscal year?

<input type="checkbox"/> 1–25	<input type="checkbox"/> 51–100	<input type="checkbox"/> Over 200
<input type="checkbox"/> 26–50	<input type="checkbox"/> 101–200	<input type="checkbox"/> I don't know.

Item homogeneity

1. The dies we require are basically all the same. 1–49 100–249 500 or more
 50–99 250–499 I don't know.

FirmsSize

1. How many employees work for your firm?

Appendix B: Multinomial logit model of joint sourcing decisions for complementary components (a positive coefficient indicates that the first choice is more likely than the second combination)

	1. CC v. MM	2. CC v. BB	3. CC v. Mix	4. MM v. BB	5. MM v. Mix	6. BB v. Mix
Interfirm expertise—die design	0.92** (0.49)	-1.01 (0.91)	-0.02 (0.48)	-1.92** (0.94)	-0.94** (0.50)	0.99 (0.89)
Interfirm expertise—die construction	0.54 (0.66)	0.47 (0.84)	0.55 (0.68)	-0.07 (0.66)	0.01 (0.43)	0.08 (0.53)
Within-firm shared expertise	1.26** (0.64)	0.38 (0.70)	0.94** (0.55)	-0.88 (0.72)	-0.32 (0.53)	0.56 (0.55)
Within-supplier shared expertise	0.12 (0.41)	-0.41 (0.59)	-0.33 (0.37)	-0.53 (0.60)	-0.45 (0.39)	0.08 (0.50)
Firm expertise - die design	-1.54** (0.73)	1.93** (1.01)	-0.98** (0.59)	3.47** (1.09)	0.56 (0.56)	-2.91** (1.01)
Firm expertise - die construction	0.96 (0.70)	3.13** (0.97)	2.42** (0.66)	2.17** (0.87)	1.46** (0.56)	-0.72 (0.69)
Supplier expertise - die design	-0.31 (0.64)	-1.33 (1.25)	-1.20** (0.65)	-1.02 (1.22)	-0.89 (0.61)	0.13 (1.12)
Supplier expertise - die construction	-0.46 (1.02)	-0.09 (1.13)	0.28 (0.94)	0.37 (0.91)	0.74 (0.63)	0.37 (0.75)
Firm scope economies	-0.43** (0.21)	-0.76** (0.35)	-0.13 (0.20)	-0.32 (0.35)	0.30 (0.19)	0.63** (0.32)
Asset specificity - die design	-0.06 (0.36)	0.27 (0.55)	-0.08 (0.36)	0.33 (0.55)	-0.02 (0.33)	-0.35 (0.49)
Asset specificity - die construction	-0.50 (0.35)	-0.66 (0.52)	-0.16 (0.36)	-0.17 (0.53)	0.33 (0.36)	0.50 (0.48)
Performance uncertainty - die design	-0.12 (0.39)	0.44 (0.74)	-0.15 (0.40)	0.55 (0.73)	-0.04 (0.36)	-0.59 (0.69)
Performance uncertainty - die construction	-1.07** (0.45)	-0.25 (0.62)	-0.62 (0.46)	0.81 (0.63)	0.45 (0.43)	-0.36 (0.56)
Volume requirements- die design	0.11 (0.29)	-0.21 (0.41)	0.43 (0.30)	-0.32 (0.41)	0.32 (0.28)	0.64** (0.36)
Volume requirements - die construction	-0.08 (0.30)	-0.59 (0.46)	-0.61** (0.31)	-0.52 (0.48)	-0.53** (0.29)	-0.01 (0.45)
Item homogeneity - die design	-0.08 (0.23)	0.15 (0.37)	-0.22 (0.22)	0.23 (0.37)	-0.14 (0.22)	-0.37 (0.33)
Item homogeneity - die construction	-0.40 (0.27)	-0.38 (0.34)	0.19 (0.26)	0.01 (0.35)	0.59** (0.24)	0.58** (0.31)
Firm size	0.87** (0.44)	1.26** (0.62)	0.25 (0.39)	0.39 (0.64)	-0.62 (0.41)	-1.01** (0.57)

*** p < 0.01; ** p < 0.05 (one-tailed tests); results omit estimates for constants

Notes

1. CC=Concurrently source both components; MM=Make both components; BB=Buy both components; Mix= different sourcing mode for each component.

2. Column 1 is Model 1d from Table 4.

Discussion: Concurrent sourcing was more likely for firms with considerable within-firm shared expertise and for larger firms. Making both components was unlikely if firms had high interfirm die design expertise or low levels of component expertise. Buying both components was unlikely if firms had component expertise.

Complementarity, Capabilities, and the Boundaries of the Firm

Appendix C: Multinomial logit model of joint sourcing decisions for independent components (a positive coefficient indicates that the first choice is more likely than the second combination)

	1. CC v. MM	2. CC v. BB	3. CC v. Mix	4. MM v. BB	5. MM v. Mix	6. BB v. Mix
Interfirm expertise—die design	0.62 (0.40)	-4.10 (3.53)	-0.12 (0.35)	-4.72 (3.53)	-0.73*** (0.30)	3.98 (3.51)
Interfirm expertise - end part machining	-0.43 (0.57)	-3.23 (3.25)	0.14 (0.48)	-2.81 (3.24)	0.57 (0.45)	3.37 (3.23)
Within-firm shared expertise	-0.07 (0.48)	1.67 (2.15)	0.06 (0.41)	1.74 (2.13)	0.13 (0.33)	-1.61 (2.11)
Within-supplier shared expertise	0.05 (0.47)	2.19 (2.55)	0.23 (0.42)	2.13 (2.53)	0.17 (0.35)	-1.96 (2.52)
Firm expertise - die design	-1.02** (0.57)	6.89 (6.61)	0.40 (0.44)	7.90 (6.61)	1.42*** (0.46)	-6.48 (6.60)
Firm expertise - end part machining	-0.01 (0.52)	6.62 (5.84)	0.48 (0.44)	6.63 (5.84)	0.49 (0.38)	-6.15 (5.84)
Supplier expertise- die design	-0.32 (0.52)	-9.08 (7.72)	-0.43 (0.48)	-8.76 (7.71)	-0.12 (0.37)	8.65 (7.70)
Supplier expertise—end part machining	-0.36 (0.58)	-5.99 (5.69)	-1.04** (0.52)	-5.63 (5.69)	-0.68 (0.46)	4.95 (5.66)
Asset specificity - die design	-0.37 (0.34)	-1.27 (2.01)	-0.21 (0.31)	-0.90 (2.00)	0.16 (0.24)	1.06 (1.99)
Asset specificity - end part machining	-0.21 (0.38)	-0.15 (1.06)	-0.28 (0.35)	0.07 (1.04)	-0.07 (0.29)	-0.14 (1.00)
Performance uncertainty - die design	0.37 (0.40)	-2.24 (2.98)	0.34 (0.37)	-2.61 (2.97)	-0.03 (0.31)	2.57 (2.96)
Performance uncertainty - end part machining	-0.09 (0.46)	-0.03 (1.29)	0.04 (0.44)	0.06 (1.26)	0.12 (0.35)	0.06 (1.22)
Volume requirements - die design	0.22 (0.29)	-0.12 (0.77)	0.20 (0.26)	-0.34 (0.76)	-0.02 (0.22)	0.32 (0.74)
Volume requirements - end part machining	-1.01*** (0.38)	-0.99 (0.75)	-1.11*** (0.38)	0.01 (0.68)	-0.11 (0.20)	-0.12 (0.66)
Firm size	0.83** (0.39)	-0.41 (1.42)	0.61** (0.36)	-1.24 (1.41)	-0.22 (0.29)	1.02 (1.39)

*** p < 0.01; ** p < 0.05 (one-tailed tests); results omit estimates for constants

Notes

1. CC=Concurrently source both components; MM=Make both components; BB=Buy both components; Mix= different sourcing mode for each component.

2. Column 1 is Model 2 from Table 4.

Discussion: Overall, and consistent with the logic of our arguments, expertise had little impact on the joint sourcing choice of independent components.