# RELATED DIVERSIFICATION AND STRUCTURAL COMPLEXITY

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**ABSTRACT**

The diversification literature has largely focused on the degree of applicability of firm resources to a new industry: A firm should diversify into more related industries since synergistic benefits decrease with the distance between the new industry and the firm's primary industry. This paper focuses on the costs of related diversification and, specifically, the coordination costs that accompany related diversification. It argues that related diversification presents a paradox. While related diversification provides more synergistic benefits, it also creates greater coordination costs than unrelated diversification. Interdependencies in production processes contribute to both synergies and coordination costs. With increasing interdependencies, coordination costs may rise faster than potential synergies and set limits to the related diversification strategy.

The theory not only provides an alternative explanation for limits to diversification that is independent of the assumption of diminishing synergistic benefits, but also offers a unique explanation for limits to *related* diversification. In addition, it suggests an important role for organization structure in extending firm scope in related diversification. Specifically, firms can adopt structures with more coordinating units to increase their coordination capacity. However, tradeoffs in structural design, such as that between specialized information processing and comprehensive decision making, alter firms' coordination costs and consequently the scope of related diversification. The theory has important implications. It proposes that firms in the same primary industry may differ in the degree to which they expand into related markets because of different coordination costs imposed by interdependencies in their existing production processes and by their organization structure. It also sheds light on several empirical anomalies about firms' diversification strategies, primarily the lack of consistent evidence that related diversifiers outperform unrelated diversifiers and the prevalence of unrelated diversification strategy among diversified firms.

I test and find strong support for the theory using a unique dataset about the business segments and organization structures of U.S. equipment manufacturers from 1993 to 2003.

There is widespread consensus in the strategy literature that a driving force behind firm growth is the firm's resources and capabilities that can be deployed to new market opportunities. In particular, scholars have long argued that firms should diversify into more related industries to pursue synergies (Penrose, 1959; Wernerfelt & Montgomery, 1988). A logical next question is what limits the scope of the related diversification strategy. The existing literature suggests that firms face limits to diversification when they have exhausted opportunities in "close" markets where their resources are most applicable (Montgomery & Wernerfelt, 1988). However, if diversification strategies are solely decided based on the calculation of synergistic benefits, then after controlling for conditions such as market growth and industry competitiveness we should observe firms exhaust potential opportunities in all related markets before diversifying into unrelated ones where there is less synergy.[1] In addition, we should not observe firms in the same primary industry differ systematically in their scope of related diversification with respect to unrelated diversification: Regardless of their endowment of excess resources, firms should always diversify more into related than into unrelated markets. But in reality, why do firms within the same primary industry diversify into different number of related as opposed to unrelated industries?[2]

To address this question I examine both the synergistic benefits and costs of related diversification. To achieve synergies firms need to share activities across different products, which increases interdependencies: Performing one activity affects the marginal returns to other activities (Milgrom & Roberts, 1995). While interdependencies provide synergies, they also increase coordination costs.

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[1]This paper takes the view that there should be no totally unrelated business that exists within the boundary of a firm. Hence, unrelated in this paper means less related. The words "related" and "unrelated" are used in relation to each other.

[2]Three dominant theories for unrelated diversification are agency theory, portfolio theory, and internal capital markets theory. Agency theory proposes that managers use excess cash from the core business to cross-subsidize activities in other segments that provide them private benefits (Jensen, 1986; Scharfstein & Stein, 2000; Shleifer & Vishny, 1989); they will invest in unrelated industries if they provide more private benefits. Portfolio theory suggests that firms may choose unrelated diversification to lower firm risk for investors (Mansi & Reeb, 2002) or managers (Amihud & Lev, 1981). Recently, these non-efficiency-based explanations have been criticized for failing to explain theoretically why an ex ante inefficient strategy exists in equilibrium (Gomes & Livdan, 2004). Nevertheless, I control for agency and business risk factors in my empirical tests.

Above a certain level of interdependence, coordination costs will rise faster than synergistic benefits; firms stop related diversification when the net benefit from doing so reduces to zero. Therefore, while diminishing synergistic benefits set limits to unrelated diversification, increasing coordination costs set limits to related diversification. In addition, interdependencies among business segments in different firms' business portfolios generate different demands for coordination, thereby imposing different constraints on firms' ability to diversify into related industries. Therefore, my theory not only provides an alternative explanation for limits to diversification that is independent of the assumption of diminishing synergistic benefits, but also offers a unique explanation for limits to *related* diversification.

In addition, my theory sheds light on several empirical anomalies about firms' diversification strategies despite strong theoretical support for related diversification. First, related diversifiers do not always outperform unrelated diversifiers (see reviews in Grant, Jammine, & Thomas, 1988: Table 1; Stimpert & Duhaime, 1997: 565).[3] Second, unrelated diversification is as prevalent as related diversification: About 30% of diversified firms and 60% of all manufacturing firms are unrelated diversifiers (Berger and Ofek, 1995: 43 and Table 6; Schoar, 2002: Table I).[4] According to my calculation based on the Compustat segment dataset, diversifiers derive only 8% of sales revenues from related industries but 22% from unrelated industries, and on average they have less than 0.1% market share in related industries. Thus, it is unlikely that firms exhaust opportunities in related markets before entering unrelated markets. Finally, firms within the same primary industry systematically vary in their scope of related diversification. For example, Honda makes cars, trucks,

[3] Despite the lack of conclusive evidence that unrelated diversifiers underperform related diversifiers, several studies show that unrelated segments are more likely to be divested during corporate restructuring than related segments (Bergh, 1995), and divesting unrelated segments generates higher returns than divesting related segments (Markides, 1995). It will be interesting to see, however, whether this is because it is less costly to separate an unrelated segment from the core business.

[4] Berger and Ofek's (1995) sample includes all publicly traded and non-financial firms with more than $20 million of sales revenue; diversification is measured based on the Compustat segment dataset. Schoar's (2002) sample includes all publicly traded manufacturing firms; diversification is measured based on datasets provided by the U.S. Bureau of the Census which, according to several authors, provide more comprehensive information of diversification. Relatedness is defined at the two-digit SIC level.

motorcycles, watercraft and even small aircraft (with its recent launch of HondaJet) whereas GM and Ford only make cars and trucks. If the difference is because GM and Ford have less excess resources than Honda that can be deployed to related markets, it is hard to justify the fact that GM and Ford have a much broader scope of unrelated diversification (e.g., in financial services) than Honda.[5]

Furthermore, the theory has an important implication for organization structure, which is designed to delimit coordination complexity (Thompson, 1967). Specifically, firms can adopt structures with more coordinating units to increase their coordination capacity and extend the scope of related diversification. However, firms face tradeoffs in designing their structure to reduce different elements of coordination costs: communication cost, information processing cost, and decision errors (Marschak & Radner, 1972). On the one hand, a structure with many coordinating units reduces communication cost by organizing communication channels from a horizontal web into vertical conduits, and lowers information processing cost by allowing parallel aggregation. On the other hand, such a structure increases decision errors due to information obsolescence when the environment is volatile or due to information incompleteness when the interactions among decision variables are not decomposable. These tradeoffs in structural design alter firms' coordination costs and consequently the scope of related diversification.

I test and find strong support for these arguments based on a unique dataset about the business segments and organization structures of U.S. equipment manufacturers from 1993 to 2003. I chose this empirical setting mainly because equipment manufacturing entails multiple stages and requires large quantities of intermediate inputs, which provides the potential for large variation in firm scope. The diverse portfolios of equipment manufacturers allow me to construct measures of relatedness and interdependencies that vary significantly across firms in the same primary industry, thereby providing

[5] Following the majority of the diversification literature, relatedness in this paper is defined as relatedness in the product market and measured as sharing the same two-digit SIC code. In robustness checks, I redefine relatedness based on the degree to which the primary and secondary industries require similar inputs; results are similar. Detailed discussion of the relatedness measure is provided in the "Empirical Design" Section.

strong explanatory power to my empirical models. In addition, over the last two decades, many of the industries in the equipment manufacturing sector have been evolving toward "vertical disintegration," whereby a previously integrated production process is divided between two sets of more specialized firms in the same industry (Baldwin & Clark, 2005; Fine & Whitney, 1999; Macher, Mowery, & Hodges, 1998). It is therefore useful to take a closer look at firms in these industries and examine their growth options in the face of technological and competitive changes.

The study makes several contributions to the diversification and organization structure literature. First, it accounts for within-industry variation in the scope of related diversification across firms. Diseconomies of scope in the form of coordination costs set limits to the net benefits from related diversification. Firms in the same primary industry may have diversified or vertically integrated into different secondary industries. Interdependencies among business segments in different firms' business portfolios generate different demands for coordination, thereby imposing different constraints on firms' ability to diversify into related industries. In addition, the study points to organization structure as a design element that affects coordination costs and consequently the scope of related diversification. It extends the strategy literature that, starting from Chandler (1967), investigates the means through which organization design accommodates or constrains strategic choices. By highlighting the tradeoffs that firms face in choosing organization structures, it also contributes to emerging discussions in the organization economics and management literature about the tradeoffs that give rise to Williamson's problem of "the impossibility of selective intervention" (1985).

## PRIOR LITERATURE

### Benefits of related diversification

Prior research provides ample justifications for related diversification. The primary argument is that related diversification achieves greater synergies or economies of scope (Panzar & Willig, 1981; Teece, 1982). According to Bailey and Friedlander (1982), economies of scope arise from reuse or sharing of inputs, joint utilization of fixed or intangible assets among multiple products, or joint production of networked products. Economies of scope achieved from joint production result in lower unit cost for each product. Resources that can be shared across multiple product lines include intermediate products (Lemelin, 1982), marketing and distribution channel (Montgomery & Hariharan 1991), R&D and technology (MacDonald, 1985; Silverman, 1999), and human capital (Farjoun, 1994).

Given that firm resources are in limited supply (Penrose, 1959), there is an opportunity cost to diversify (Levinthal & Wu, 2006). Therefore a diversifying firm will rank potential target industries according to the degree to which its resources are applicable to each industry; greater applicability increases the probability of entry. As firms move from their core industry into less and less related industries, it becomes more and more difficult to transfer managerial knowledge, capabilities, routines and repertoires (Nelson & Winter, 1982; Penrose, 1959; Prahalad & Bettis, 1986), to apply firm-specific resources in physical plants, human capital and technologies (Farjoun, 1994; Montgomery *et al.*, 1988; Silverman, 1999), or to govern internal capital markets (Hoskisson & Turk, 1990; Williamson, 1967). This synergistic view provides a natural explanation for limits to diversification: Firms stop diversification when potential synergistic benefits diminish to zero. However, this perspective is insufficient to explain limits to related diversification, since it does not account for the possibility that firms may enter unrelated industries – where there is less synergy – before they have exhausted potential opportunities in all related markets.

**Costs of related diversification**

Compared to the large literature advocating the benefits of related diversification, only a few authors have examined the difficulties in implementing such a strategy. Among them, the conceptual paper written by Jones and Hill (1988) is the closest in spirit to the current study. Jones and Hill argue that related diversification implies all three types of task interdependencies – reciprocal, sequential and pooled, whereas unrelated diversification implies only pooled interdependencies. Because it is more difficult to monitor highly interdependent tasks when employees can act opportunistically, coordination costs are the highest for related diversifiers and lowest for unrelated diversifiers. Hill, Hitt and Hoskisson (1992) propose that to benefit from economies of scope, firms need to establish cooperative relationships among business units, rather than resort to standard financial controls or market-based disciplines. Nayyar (1992) argues that such relationships are costly and difficult to sustain. Gary (2005) constructs a simulation model to show that growth in a related market can strain the original excess capacity that is to be shared between the primary and related markets; overstretching the resources increases costs exponentially; firms therefore need to maintain organization slack (financial capital, human resources and technology) to avoid overstretching.

These studies provide invaluable insights into the tradeoff between the synergistic benefits from related diversification and the difficulty in maintaining the interrelationships among various business activities. However, there are several shortcomings. First, the detailed mechanisms through which the difficulty or costs cancel out the benefits are neither adequately developed nor tested. The non-linear increase in the costs of coordinating or overstretching resources among related businesses is assumed rather than theoretically derived (Gary, 2005; Jones *et al.*, 1988). Second, most studies point to opportunism as the root of the coordination problem (Hill *et al.*, 1992; Jones *et al.*, 1988). According to these authors, task interdependencies result in spillover in employees' efforts, which increases the cost of monitoring. However, coordination problems exist even in the absence of opportunistic behavior. Task interdependencies necessitate joint decision making and information sharing, which increase coordination costs even with congruent incentives (Simon, 1991). It is therefore worthwhile to analyze the coordination problem without the additional assumption of opportunism. Finally and most importantly, none of these studies explains within-industry variation in limits to related diversification.

Given that explaining differences in firm strategies is an important mandate for strategy research (Lippman & Rumelt, 1982), the omission is unsatisfactory.

## THEORY AND HYPOTHESES

### Related diversification and coordination costs

Table 1 shows all the segments[6] that are operated by all U.S. automakers. In addition to motor vehicles and passenger car bodies (SIC 3711), each automaker also operates in some related industries in the transportation equipment sector, such as truck and bus bodies (SIC 3713), motor vehicle parts and accessories (SIC 3714), truck trailers (SIC 3715) and motor homes (SIC 3716). None of them, however, operates in other related industries in this sector such as motorcycles, watercraft or aircraft. Instead, U.S. automakers are engaged in activities in a large set of segments outside the transportation equipment sector. Could operating in these other segments have an impact on the automakers' scope in the final product markets? For example, why does Honda make cars, trucks, motorcycles, watercraft and even aircraft, but GM and Ford only make cars and trucks? Is this just because there are many synergies between cars and motorcycles for Honda but not so many for GM and Ford?

Synergies or economies of scope exist between two outputs when their joint production creates more value than if they are produced separately (Panzar *et al.*, 1981; Teece, 1982). An immediate implication of this definition is interdependence: Performing one activity affects the marginal return to the other activity (Milgrom *et al.*, 1995). It then follows that to achieve potential synergies firms need to establish interrelationships among business activities (Hill *et al.*, 1992; Nayyar, 1992). Synergies do not come for free; they demand coordination.

On the one hand, internalizing potentially interdependent activities lead to synergies through various means. First, internalizing potentially interdependent activities provides economies of scope

[6] Throughout this study, both segments and industries are defined at the four-digit SIC level, whereas sectors are defined at the two-digit SIC level. A segment is the same as an industry, except that a segment of a firm is an industry that the firm operates in.

and leverages firms' capabilities (Argyres & Zenger, 2007; Hoetker, 2005; Jacobides & Hitt, 2005; Jacobides & Winter, 2005; Langlois & Robertson, 1995; Leiblein & Miller, 2003; Teece, 1980; Teece, 1982). Second, internalizing co-specialized assets facilitates investments and brings extra value for both assets (Williamson, 1975). Third, internalizing complementary development and commercial assets enables firms to appropriate their innovations (Teece, 1986). Finally, internalizing adjacent activities along the value chain improves quality control and coordination (Chandler, 1962; Monteverde & Teece, 1982; Scherer, 1980).

On the other hand, internalizing potentially interdependent activities increases coordination costs. Internalizing horizontally interdependent activities raises the tension between needs for standardization and differentiation among different product lines (Ghemawat & Levinthal, 2000; Krishnan & Gupta, 2001; Robertson & Ulrich, 1998). Internalizing vertically interdependent activities increases the demand for synchronization along multiple stages of the value chain to avoid either excess or underutilized capacity, and strategic inflexibility (Harrigan, 1984; Mahoney, 1992; White, 1971). Coordinating interdependent activities imposes significant information overload on managers (Hoskisson & Hitt, 1988).

Some of the segments listed in Table 1 supply key components for motor vehicles (Figure 1). These components include flat glass, fabricated metal products, internal combustion engines, motors and generators, mechanical power transmission equipment, among others. Take fabricated metal products as an example. Many of these metal products are made in house. In addition, automakers also manufacture in house special machine tools to fabricate these metal products. Many of these machine tools also use fabricated metal products as components. So the fabricated metal products segment and the machine tools segment are "reciprocally interdependent" (Thompson, 1967). Some automakers (e.g., Ford's Casting Division) integrate even further back, into iron and steel forging, steel foundries and iron foundries (Iron and steel forging is also involved in the making of machine tools.) In these production processes, steel foundries and iron and steel forging become “sequentially interdependent.” The machine tools and forging segments also share “pooled interdependencies” since they both directly contribute to the making of fabricated metal products. In sum, for one component of a car, i.e., fabricated metal products, some automakers already operate a complex production system that involves activities with interdependencies at all levels.

Now assume the car maker diversifies into some related final product market such as trucks, motorcycles, or aircraft. To achieve synergies, the car maker may choose to share some components such as certain fabricated metal products. However, if the production system specially designed for fabricated metal products is tightly intertwined with each step dependent on many other steps, modifying the metal products to fit not only cars but also trucks, motorcycles, and aircraft requires adaptation to the entire system (the machine tools, the forging process, the foundry operations, etc.). In order to achieve greater synergies among related final products with respect to these intermediate metal products, the automaker needs to actively engage in managing the interdependent activities to accommodate these different yet related product lines. The same is true if the automaker decides to achieve synergies with respect to internal combustion engines, motors, and generators, or other components that involve complex production processes. Therefore related diversification presents a paradox. On the one hand, relatedness provides opportunities for synergies. On the other hand, if a firm’s business activities are already complex, adding a related product line can increase the demand for coordination.

To analyze the specific challenges of interdependencies for coordination, I follow the team theory literature and decompose coordination into three key components: *communication, information processing/aggregation, and decision making* (Marschak *et al.*, 1972). Interdependencies increase coordination costs by increasing the demand for communication and information processing, and the probability of error in decision making. First, interdependencies require joint decision making, which raises the demand for information sharing and gives rise to higher communication costs (Becker and Murphy, 1992). The number of communication channels among parties engaging in interdependent activities will rise more than proportionally with the number of interdependent activities;[7] so will communication costs. Second, interdependencies increase the burden of information processing and computation for decision making. Problems with multiple interdependent components are difficult to solve, mainly because of the proliferation of the interaction terms as the number of decision variables increases (Simon, 1962). At high levels of interdependencies, the computation demand may exceed the cognitive capacity of any individual decision maker, and the task needs to be divided among multiple agents.

Third, humans are more prone to decision errors when decision variables are interdependent. Decision errors are likely to occur when the set of strategic choices exceeds "the resolution power of available mathematical, statistical or logical algorithms, either in terms of the number of state variables that must be accommodated, or in terms of the degree of stochasticity of relationships or dynamic sequences" (Sutherland, 1980: 964). As a result, firms are often constrained to local search, unable to find a globally optimal strategy or to decipher and imitate their competitors' strategies (Levinthal, 1997; Rivkin, 2000). At high levels of interdependencies, as new activities are added, the set of strategic variables as well as the number of interface conditions increases exponentially, resulting in: (1) escalation of computation load that prohibits global optimization, and (2) reduction in analytical precision (Sutherland, 1980).

A firm typically produces in its existing market(s) up to the point where marginal revenue equals marginal production cost before entering a new market. In addition, the firm diversifies into related markets before unrelated markets where synergies are lower. The picture changes when coordination cost is included in the analysis. First, with more complex production systems, coordination cost may be

[7] This is because the number of communication channels among K divisions whose activities are interdependent can be as high as K*(K-1)/2.

higher for related segments than for unrelated segments. In addition, the more related segments are added to the portfolio, the more adaptations need to be made to the production processes for them to be shared across related products, and the steeper the coordination cost curve will rise. At a certain point, the net benefit for a related market becomes smaller than that for an unrelated market. In response, the firm foregoes opportunities in the related market and diversifies into unrelated markets. In sum, the increase in coordination cost due to sharing of interdependent activities shifts the relative attractiveness of diversification strategies from related to unrelated (Jones *et al.*, 1988; Nayyar, 1992).

*Hypothesis 1: Scope of related diversification has an inverted-U relationship with the level of interdependencies among existing business segments.*

Since organizations are designed to delimit coordination complexity (Thompson, 1967), I now investigate how organization structures can be designed to reduce the average cost of coordination conditioned on the total amount of coordination required. I first examine the advantages and disadvantages of different structures in their capacity for lowering individual elements of coordination costs. I then explore the possibility (or impossibility) of designing an organization structure that jointly reduces all elements of coordination costs. In the process, I highlight the tradeoffs that firms face in designing their structures.

**Role of organization structure in reducing coordination costs**

Organization structures specify information structure and decision rules (Galbraith, 1973; Marschak *et al.*, 1972; Simon, 1947; Tushman & Nadler, 1978): Different organization structures enable decentralization in information acquisition, communication, information processing, and decision making to different degrees; their efficiency in facilitating decision making is measured by the costs of information acquisition, processing and communication, and by the probability of errors in decision making. For example, specialization in learning lowers the cost of information acquisition but increases communication costs when decisions need to be made based on shared information (Bolton & Dewatripont, 1994). One way to solve this problem is to create vertical communication channels, which economize on communication by eliminating what would otherwise be an unmanageable spaghetti tangle of interconnections (Arrow, 1974; Langlois, 2002; Zannetos, 1965).

In addition to saving communication costs, a vertical hierarchy also arises to handle complexities in large organizations' information processing requirements (Galbraith, 1977). A structure where intermediate coordinators compute independently and in parallel reduces the workload for each coordinator (Radner, 1993) and brings more information to bear for the firm as a whole (Galbraith, 1973). For example, a hierarchical structure with intermediate coordinators facilitates more efficient decision making since the CEO only needs to attend to opportunities of joint cost saving that lower-level managers may have missed (Geanakoplos & Milgrom, 1991). It also saves the CEO's energy for coordinating low-frequency, between-division interactions that yield firm-wide benefit, after high-frequency interactions have been dealt with by division managers within their respective divisions (Harris & Raviv, 2002).[8]

An illustration is given in Figure 2. When activities are interdependent, a fully decentralized structure where employees talk among themselves and make decisions will result in high communication costs (Figure 2 (a)). In this setting, a centralized structure saves communication effort by asking all employees to report to a central coordinator who aggregates the information and makes a joint decision (Figure 2 (b)). However, since the coordinator is constrained in her information processing capacity, the number employees she can coordinate is limited. One way to solve this problem is to add intermediate coordinators (Figure 2 (c)). Such a structure lowers communication costs through vertical communication channels and overcomes limits to the central coordinator's

[8] The higher the frequency of interactions, the less likely that a formal hierarchical structure can be substituted with cross-functional project teams and committees, since these transitory structures will offer less adequate coordination and more confusion in authority (Galbraith & Lawler, 1993).

information processing capacity by reducing her span of control. As a result, firms' overall coordination capacity is enhanced.

Recent changes in organization structure at Nissan-Renault provide a real-world example. After signing an alliance contract with Nissan, Renault appointed CEO Carlos Ghosn to turn around Nissan. Despite his widely acclaimed experience, capability, dedication, and early success in turning around Nissan, Ghosn eventually ran into limits to his coordination capacity. When he was appointed the dual CEO for both Nissan and Renault, with the task of achieving greater synergies (e.g., by pooling component purchases and sharing auto platforms), the performance of Nissan plummeted. Facing criticisms that he had stretched himself too thin, Ghosn gave up responsibilities for North America markets to another executive and set up multiple regional offices to handle the Japanese market. Nissan also reduced the scope of responsibilities for several other executives so that they could concentrate on a narrower range of activities and manage them more effectively (The Wall Street Journal, 2/3/2007).

In sum, a structure with intermediate coordinating units lowers communication costs through vertical communication channels, and overcomes limits to individual coordinators' information processing capacity through reduced direct span of control. This enhances firms' overall coordination capacity.

*Hypothesis 2: Scope of related diversification increases with the number of coordinating units.*

## Tradeoffs in structural design

H2 suggests that firms can enhance their coordination capacity by adding intermediate coordinating units. But what limits the infinite growth of firms with increasing coordinating units? To address this question, I examine one of the tradeoffs in structural design – that between lower costs of communication and information processing and higher probability of decision errors.

Error in decision making arises from two sources. First, accurate decisions rely on timely information, any delay in communication or information processing results in obsolescence of information for the decision maker (Van Zandt, 2003). When the external environment is volatile, decisions made based on obsolete information lead to a mismatch between environmental requirements and firm responses. Second, accurate decisions rely on complete information. When the interactions among decision variables are not decomposable, specialization in information processing results in loss of information about significant number of interactions between variables across groups. Decisions made based on incomplete information about these between-group interactions are not likely to be globally optimal (Marengo & Dosi, 2005; Siggelkow & Rivkin, 2006).

Environmental volatility

A structure with many coordinating units is likely to cause delay in decision making: Both communication and information processing become sequential along the vertical chains (Keren & Levhari, 1979). The delay reduces the efficacy of the decisions since they are likely to be made based on old information (Van Zandt, 2003): By the time a decision is made at the top of the hierarchy, local conditions at the bottom would have changed. The faster the change in the environment, the greater demand for speed and the fewer middle managers can be afforded. Firms in these environments are more likely to substitute timeliness for comprehensiveness and adopt structures with fewer coordinating units.

Span of control and vertical layers in a hierarchy are substitutes – they both increase the ability of the organization to process information concurrently by expanding its size (Patacconi, 2005). With limited freedom to increase middle managers, top management has to oversee a larger number of units. Broader span, however, prevents sufficient specialization and gets us back to the problem of limited information processing capacity for individual processors. Firms in volatile environments, therefore, are limited in their freedom to adjust organization structure and in their coordination capacity. "[O]rganizations tend to be smaller and more internally decentralized the more quickly the environment is changing" (Van Zandt, 2003: 3).

*Hypothesis 3: Number of coordinating units decreases with environmental volatility.*

Task indecomposability

A structure with many coordinating units is also likely to cause over-segmentation of the decision variables and their interaction terms. When decision variables are decomposable, they can be prioritized and hierarchically decomposed into groups which can be further divided into subgroups (Simon, 1962). In this case, a firm can subject the most interdependent activities to a common coordinator and delegate less interrelated activities to other coordinators, thereby increasing its total coordination capacity.[9]

However, if these activities are not decomposable or modular, a hierarchical structure with intermediate coordinators will not reduce coordination costs. Quite the opposite, it will hinder coordination, because a modular structure has both benefits and drawbacks. For example, while a modular organization structure facilitates local exploration of knowledge, it reduces overall system-wide exploration and innovation (Marengo *et al.*, 2005; Siggelkow *et al.*, 2006). A major design goal is therefore to partition organization structure at an appropriate level according to the decomposability of underlying tasks. While a precise match may not always be possible (Nickerson & Zenger, 2002), over- or under-modularizing the organization structure relative to the task structure leads to poor performance, not only for the particular modules but also for the entire system (Ethiraj & Levinthal, 2004). More specifically, when decision variables are densely interconnected, an overly fragmented

[9] This is similar to Thompson's (1967) idea that hierarchical structure reflects decisions about task clustering: Tasks of reciprocal interdependencies should be clustered first, followed by tasks of sequential interdependencies before grouping tasks of pooled interdependencies. However, Thompson did not specifically discuss the tradeoffs between the horizontal and vertical dimensions of the hierarchical structure.

structure leads to local search and prohibits broad-scope information processing (Ethiraj *et al.*, 2004; Rivkin & Siggelkow, 2003), which may cause decision errors. Modularization in organization structure, therefore, necessitates modularization in activities (Hoetker, 2006; Sanchez & Mahoney, 1996; Schilling & Steensma, 2001).

The point is illustrated in Figure 3, where the nodes represent business activities, the edges represent the presence of interdependencies between them, and the colors represent optimal grouping of the activities that allow the most within-group but least between-group interdependencies. Firm A has a business portfolio that is fairly modular; the activities can be grouped into three distinctive departments. In contrast, Firm B has a much less modular portfolio; the best segmentation of the activities still leaves out significant interrelationships between the groups. For firm B, departmentalization will not help coordination. Rather, it will sacrifice significant amount of synergies between groups. To realize the synergies, Firm B has to adopt structures with broader horizontal span and fewer intermediate coordinators. Because of the greater demand imposed by indecomposable coordination tasks, Firm B will be less likely to diversify into related industries.

*Hypothesis 4: Number of coordinating units decreases with task indecomposability.*

## Performance implications

Figure 4 summarizes Hypotheses 2 to 4, which predict a positive relationship between the scope of related diversification and the number of coordinating units, subject to the two contingencies of environment volatility and task indecomposability. What about firms operating off the diagonal in that matrix?

At a given level of interdependencies, firms in the top-right cell have many related segments but only a few coordinating units. Such firms will perform poorly since communication and information processing costs outweigh synergies. Firms in the bottom-left cell have only a few related segments but many coordinating units; these firms will also perform poorly since loss from decision errors outweighs savings in communication and information procession costs.

*Hypothesis 5: Firms that have a mismatch between the scope of related diversification and the number of coordinating units perform worse than other firms.*

## EMPIRICAL DESIGN

### Empirical context

I tested my hypotheses on a sample of U.S. equipment manufacturers from 1993 to 2003. Together these firms produce fabricated metal products, industrial machinery and equipment, electrical and electronic equipment, transportation equipment, and instruments and related products. According to data provided by the Bureau of Economic Analysis (BEA), equipment manufacturers produce about $1.6 trillion of output in terms of shipment value, or 30% of the output produced by all manufacturing sectors. When adjusted for inflation, their shipment value grew by 85% from 1993 to 2002, whereas the average growth rate for the entire manufacturing sector was only 32%.

I chose this empirical setting mainly because equipment manufacturing entails multiple stages and requires large quantities of intermediate inputs, which provides the potential for large variation in firm scope across firms. The diverse portfolios of equipment manufacturers allow me to construct measures of relatedness and interdependencies that vary significantly across firms in the same primary industry, thereby providing strong explanatory power to my empirical models.

In addition, this empirical setting is of great relevance for firm strategy. For managers, the multi-stage production processes and the requirement of large quantities of intermediate inputs not only offer opportunities for diversification at multiple points along the value chain, but also pose significant challenges for coordination. The working of a simple personal computer (PC) requires an operating system, a PC case, a floppy disk drive, a hard drive, a CD-ROM drive, a processor, a processor cooling fan, a motherboard, memory modules, a power supply, a video card, a keyboard, and user application software, each of which requires subcomponents of their own. Whether to engage in the integrative production of the entire computer system, or to outsource some components of the system and diversify into related products such as portable digital devices, is a real and active decision made by the firms in the industry. Apple learned the hard lesson of trying to make an overly integrated computer system. Now through the drastic strategic decision to break the interdependencies between chip design and operating system design,[10] managers at Apple are able to reorient their focus toward understanding consumer needs and expand its market share, not only in personal computers but also in other consumer electronics such as iPod and iPhone.

Furthermore, equipment manufacturers are facing fierce global competition and intense pressure for outsourcing, which makes their strategies about firm scope critical to their growth. For example, in the automotive industry, Toyota just beat GM in 2007 first-quarter global car sales, ending the 77-year era in which GM dominated global car sales (The Wall Street Journal, 4/25/2007). Sliding market share and profits have put U.S. automakers under tremendous pressure to restructure their overly cumbersome production system and outsource more components and processes. One of the key restructuring initiatives of Ford's new CEO, Alan Mulally, was to sell 17 component plants and six component facilities, which manufacture a wide range of components such as glass, fuel tanks, climate control systems, powertrains, chassis, and steering components (Ford, 1/25/2007).

Over the last two decades, many of the industries in equipment manufacturing sectors have been evolving toward "vertical disintegration," whereby a previously integrated production process is divided up between two sets of specialized firms in the same industry. For example, Baldwin and Clark (2005) mentioned that the computer industry that used to be dominated by a few vertically integrated giants such as IBM and DEC has transformed into one where "a large number of firms [are] spread out among a set of horizontal layers, e.g., the chip layer, the computer layer, the operating system,

[10] According to CEO Steve Jobs, Apple has recently made it a rule that its designs for "OS X must be processor-independent and that every project must be built for both the PowerPC and Intel processors" (1996).

application software" (Page 3). The same trend also is reported in the telecommunication (Baldwin *et al.*, 2005), automotive (Fine *et al.*, 1999), and semiconductor (Macher *et al.*, 1998) industries. In the semiconductor industry, an increasing number of U.S. firms are becoming "fabless." They design components but rely on other firms (specialized commercial "foundries" or integrated device manufacturers) for production (Macher *et al.*, 1998). It is therefore useful to take a closer look at firms in these industries and examine their growth options in the face of technological and competitive changes.

## Data and sample

The main dataset used in this study is the Directory of Corporate Affiliations (DCA) offered by LexisNexis. DCA provides corporate reporting linkage information on parent companies and their divisions, subsidiaries, and affiliates, down to the seventh level of corporate linkage. In addition to the name, location, level and type (division, department, unit, subsidiaries, affiliates, joint ventures, etc.) of each unit, the dataset describes up to 30 segments (four-digit SIC level) for each unit.[11] An example of the data, about the business segments and organization structure of Ford Motor Company, is provided in Figure 5.

Several factors contribute to the reliability of the DCA data. According to LexisNexis, the dataset is compiled based on information gathered from the companies, as well as from annual reports and business publications in the LexisNexis database. In addition, each company is contacted directly for information verification (LexisNexis, 2004). To check the accuracy of the data, I randomly selected a

[11]Prior research on diversification relies mainly on the Compustat segment dataset. However, as pointed out by various authors the dataset has its limitation when used to measure diversification (Davis & Duhaime, 1992; Denis, Denis, & Sarin, 1997; Villalonga, 2004). Mainly the dataset tends to under-report firms' level of diversification (Lichtenberg, 1991) due to its ten percent materiality rule. In addition, it does not capture vertical integration (Financial Accounting Standards Board, 1976; Villalonga, 2004). These shortcomings are particularly problematic for my study of intra-organizational activities. A major advantage of the DCA dataset is that it provides unique and more comprehensive information about firms' business segments and organization structure. For example, Villalonga (2004) finds, based on establishment-level datasets provided by the U.S. Bureau of the Census, that the most diversified firm operates in 133 segments (at the four-digit SIC level); but the number of segments reported by the same firm in the Compustat dataset is ten. More consistent with the Census datasets than the Compustat dataset, the DCA dataset shows the most diversified firm has 166 segments.

few companies and gathered their organization charts from company Web sites or through discussions with company executives. For example, Figure 6 shows Ford's organization structure based on my conversations with Ford executives. The comparisons turned out satisfactory.

I started with the DCA dataset for publicly traded firms from 1993 to 2003, which covers firms with revenues of more than $10 million and more than 300 employees (LexisNexis, 2004). The dataset contains 9,850 parent companies and 120,113 units. 2,075 parent companies list their primary industries as in the equipment manufacturing sectors.

In order to obtain financial data for the parent companies, I augmented the dataset with Compustat Industrial Annual financial and Compustat segment datasets. I matched the two datasets by parent company names first through a software program[12] and then through manual checks. Ambiguous matches were further verified via company Web sites. So far I have matched 1,621 (78%) parent companies in the equipment manufacturing sectors. Since the focus of my study is coordination across business segments and units, I dropped 376 firms that report only one segment and 346 firms that report only the general office of the parent company. Since I was interested in studying within-industry firm-level variation, I excluded firms that have no competitor in their primary industries in my dataset. My final sample contained about 999 firms and 4,768 firm-year observations.

## Variable definitions and operationalization

### Dependent variables

There are three dependent variables for this study, $D^R$ for scope of related diversification (H1 and H2), M for number of coordinating units (H3 and H4), and P for performance (H5).

RELATED DIVERSIFICATION ($D^R$). Related diversification was measured using the number of segments (according to DCA data) in a firm's business portfolio that are in the same two-digit SIC code as the firms' primary industry.

[12] I thank Minyuan Zhao for her help with the matching.

Relatedness has been defined in various ways in prior studies. There are two broad classes of measures. One class is based on SIC codes, which reflects horizontal relatedness in product markets. For example, a majority of the studies use a dummy variable showing whether the segments are in the same sector (i.e., the same two-digit SIC code). Segments in the same sector are treated as related and otherwise unrelated (e.g., Lang & Stulz, 1994). While the distance between SIC codes does not necessarily reflect relatedness (Montgomery, 1982), this measure has an advantage in that it can be objectively defined. Also based on SIC codes, the entropy measure (Jacquemin & Berry, 1979; Palepu, 1985) calculates a "concentration index" for total, related, and unrelated diversification, respectively, based on business-level information. It is a weighted average measure based on revenues from different industries (four-digit SIC codes), in the same or different sectors (two-digit SIC codes). The entropy measure has the advantage of having continuous value, but it also relies on the numeral distance between SIC codes. In addition, under certain conditions, e.g., when firms increase both the size of the dominant segment and the number of secondary segments, the prediction of the measure becomes rather uncertain. The problem can be so severe that early results on related diversification and performance may be subject to different interpretation (Robins & Wiersema, 2003).

A second class of measures follow Rumelt's (1974) definition that businesses are related when "… a common skill, resource, market, or purpose applies to each" (p. 29). Such measures (e.g., Markides & Williamson, 1994) have not been widely adopted since they are based on more subjective judgment. But a few authors manage to find innovative ways to measure relatedness in the underlying resources, such as similarities in the employment of human capital (Chang, 1996; Farjoun, 1994) or technologies (Robins & Wiersema, 1995; Silverman, 1999). Among them, Farjoun (1994) evaluates structural-equivalence similarity in human capital between pairs of industries based on industry employment data; Robins and Wiersema (1995) use patent cites to estimate structural-equivalence similarity in inter-industry technology flows; Silverman (1999) also uses patent cites to measure applicability of technology across industries. Two industries are considered related if they employ certain types of employees (managers, engineers, etc.) in similar proportions or if they require technology inflows from and provide technology outflows to similar sets of industries. MacDonald (1985) predicts entry into related industries based on a measure of similarity between the originating industry and the (potential) target industry using the negative absolute differences in their R&D to shipment ratios, final consumer demand shares of original industry input, and employment growth rates.[13]

I adopted the SIC code-based approach for three reasons. First, this is more consistent with the approach used in the majority of the studies on related diversification. Second, several studies of the construct validity of diversification measures have found strong correspondence between the SIC-based measures and Rumelt's measure (Chatterjee & Blocher, 1992; Lubatkin, Merchant, & Srinivasan, 1993; Montgomery, 1982). In addition, Lubatkin, Merchant, and Srinivasan (1993), using alternative data sources including DCA, conclude that a simple count of the number of SIC codes a firm operates in not only captures diversification as well as the weighted measures (e.g., entropy), but also is more suited for large-sample, strategy research when business-level data are not reliable. Last but most important, this approach allows me to distinguish between horizontal relatedness between final products and production interdependencies, which are two different constructs for my dependent variable and key independent variable, respectively. In robustness checks, I redefined relatedness based on the degree to which the primary and secondary industries require similar inputs; results were similar.

NUMBER OF COORDINATING UNITS (M): Number of coordinating units was measured using the number of units in the corporate hierarchy per thousand employees. This was different from the few empirical studies on corporate hierarchy, which measured centralization or decentralization using

[13] Teece *et al.* (1994) proposed yet another approach to measure *ex post* relatedness between pairs of industries, based on the frequency of firms operating simultaneously in each pair of industries. This measure, however, is less relevant to the underlying dimension of relatedness that I am concerned about.

internal reporting data based on small-scale surveys. This also was different from studies on supportive components of organizations in the organization theory literature. As reviewed by Child (1973), these studies often employed different classifications of personnel and hence failed to operationalize the central concept. Recently, Rajan and Wulf (2006) use a dataset of managerial job descriptions in more than 300 large U.S. firms and count the number of levels between division heads and the CEO. Closest to my approach, Argyres and Silverman (2004) use organization charts to study the relationship between centralization and R&D output. I used number of coordinating units rather than individual coordinators because supporting staff in each unit helps to share the most direct administrative workload within that unit. Prior research suggests that this approach is both more reasonable and realistic.[14]

PERFORMANCE (P): Performance was measured using both accounting profitability (EBIT/total assets) and market valuation (Tobin's Q).

**Independent variables**

INTERDEPENDENCIES (K): Interdependencies in the production process were constructed from BEA Input-Output (IO) tables. It is the number of segment pairs that are interdependent (based on IO coefficients) with each other, normalized by the total number of segment pairs in the firm's portfolio.

This is a measure based on flow of inputs between a firm's primary and secondary industries (for vertical – sequential or reciprocal interdependencies) or flow of inputs between the primary or

[14] According to Robinson (1934: 235), "[A] scalar chain [of authority] … must in almost every case be supplemented by a staff organisation, whether the staff be formally recognised as such or not. The task of the staff is threefold: first to acquire the knowledge necessary to co-ordination and the creation of a central plan of administration, second to interpret the plan of action to those in the scalar chain of authority whose task is to carry the plan into effect, third to discover at the earliest moment defects in the plan, or divergences from the plan and to secure modification of the plan itself or of its method of interpretation." Van Zandt (2003: 17) also believes this is a more realistic view of organizations: "An organizational chart does not show the links between every manager, professional, secretary, clerk, and computer in an administrative apparatus. Instead, it shows offices within which many people and machines may work. Furthermore, the chart depicts the structure of decision-making procedures that persist over time, even when there are changes in personnel…. Hence, whereas the literature on organizations that process information with an endogenous number of agents has focused on the micro structure of communication between individual agents, we should be at least as interested in the macro structure of communication between offices and division nodes."

secondary industry and other industries (for horizontal – pooled interdependencies). This idea is not entirely new. Burton and Obel (1980) use a computer-simulated IO table to measure decomposability of technology and its impact on performance under an M-form structure. Based on the IO tables, Lemelin (1982) measures vertical relatedness between two industries using the share of each industry's intermediate input purchases that come from the other industry directly or indirectly through other industries. In addition, Lemlin measures "industry complementarity" in markets and distribution channels using simple correlation coefficient between the amounts of intermediate inputs two industries require per dollar of their respective output. Similarly, MacDonald (1985) assesses vertical relatedness between pairs of industries using a dummy variable that signals if either industry contributes more than one percent of the inputs to the other.

The measure has several limitations. First, it only captures interdependencies with respect to the flow of intermediate products, or interdependencies in production. Two segments can be interdependent in their distribution channels, human capital usage or R&D, even if they do not provide goods to each other or rely on common inputs. Excluding measures of interdependencies along other dimensions leads to an omitted-variable problem. If the omitted variable is correlated with the production interdependencies variable, my estimates will be biased. According to Wooldridge (2002: 62), the direction of the bias depends on the relationship between the omitted variable and the dependent variable, as well as the relationship between the omitted variable and the independent variable of interest – interdependencies in my case. If the two relationships are of the same direction, the estimated coefficient will be larger than the true coefficient. Since I expect a negative coefficient, this leads to an attenuation bias.

Both synergistic benefits and coordination costs arguments suggest that interdependencies along multiple dimensions can be correlated. The synergy argument proposes that interdependencies along multiple dimensions are positively correlated with each other. Interdependencies in production give rise to opportunities for knowledge sharing and joint problem solving. Broader scope of synergies also leads to broader scope of related diversification. In contrast, my coordination argument proposes that above a certain point, interdependencies along multiple dimensions are negatively correlated. Interdependencies in production consumes so much of managers' attention that they deter coordination in other functional areas, such as marketing or R&D. Coordination costs arising from interdependencies along multiple dimensions also limit firm scope in related diversification. In either case, the omitted variable (interdependencies along other dimensions) has the same direction (positive or negative) of correlation with both the dependent variable (scope of related diversification) and the independent variable of interest (interdependencies in production). The omission therefore leads to more conservative estimates.

A second limitation of the measure is that it captures interdependencies at the industry rather than firm level. Segments within a firm can choose to supply inputs to each other more or less than the average flow of inputs between two industries. This results in a measurement error which, if correlated with the true value of the interdependencies variable, causes an attenuation bias toward zero and makes my results more conservative.

Despite these shortcomings, the measure has a major advantage of being exogenous to any individual firm's decision and is therefore less likely to be correlated with unobserved firm heterogeneity. For this reason, measures of inter-industry relationships in production inputs (Lemelin, 1982), human capital (Chang, 1996; Farjoun, 1998), or technology (Robins *et al.*, 1995; Silverman, 1999) have been used by various scholars to proxy inter-segment relationships within firms. In particular, the use of IO-table coefficients as proxies for inter-segment relationships within diversified firms has been adopted by recent studies in both finance (Fan & Lang, 2000; Matsusaka, 1993; Schoar, 2002; Villalonga, 2004) and economics (Alfaro & Charlton, 2007).

I used the inter-segment IO coefficients calculated by Fan and Lang (2000). The calculation is based on the IO "Use Table," which contains the value of pair-wise commodity flows among roughly 500 private-sector, intermediate industries. The table is updated every five years. Since the IO industry code system was changed by BEA in 1997, to ensure comparability I used coefficients for 1992. Luckily, several authors (including Fan and Lang) have observed that the coefficients have been fairly stable over the years.

Based on these coefficients, I defined two segments as interdependent if their coefficients were more than the mean coefficients between all pairs of industries in the "Use Table." The coefficients for vertical and horizontal interdependencies had a mean (standard deviation) of 0.01 (0.03) and 0.28 (0.29), respectively. The benchmark for vertical interdependencies was somewhat consistent with the literature. On the one hand, several authors treat industry pairs as vertically interdependent if they receive more than five percent of input from or supply more than five percent of output to one other (Matsusaka, 1993; Schoar, 2002; Villalonga, 2004). On the other hand, MacDonald (1985) defines two industries to be vertically interdependent if either industry contributes more than one percent of the inputs to the other. I tested different thresholds for vertical interdependencies on selected firms in my sample. For example, at the one percent level, Ford's secondary segments that are vertically interdependent with its primary segment include plastics products (pipe fittings, plastics sausage casings, etc., SIC 3089), air-conditioning and warm air heating equipment, and commercial and industrial refrigeration equipment (including motor vehicle air conditioning, SIC 3585), semiconductors and related devices (SIC 3674), electrical equipment for internal combustion engines (SIC 3694), wholesale trade of automobiles and other motor vehicles (SIC 5012), motor vehicle supplies and new parts (SIC 5013), tires and tubes (SIC 5014), used motor vehicle parts (SIC 5015), construction and mining machinery and equipment (SIC 5082), farm and garden machinery and equipment (SIC 5083), industrial machinery and equipment (SIC 5084), and industrial supplies (SIC

5085). At the five percent level, only non-manufacturing segments such as SIC 5012, SIC 5013, SIC 5015, and SIC 5082 – SIC 5085 will count as vertically interdependent. I used one percent in my main analyses and plan to use five percent in robustness checks.

There is no benchmark value for horizontal interdependencies in the literature. I therefore used the sample mean as the threshold. I checked the robustness of my results by measuring only vertical interdependencies and ignoring horizontal interdependencies; results were similar. I also excluded interdependencies among non-manufacturing segments; results were again similar.

ENVIRONMENTAL VOLATILITY (VOL): Following prior studies (Amit & Wernerfelt, 1990), volatility was measured through both systematic and total volatility based on stock returns. To minimize potential endogeneity, I constructed the measures at the industry rather than firm level. For systematic volatility, I used the absolute value of average beta of all firms in the same primary industry for the past 36 months, weighted by the firms' market capital. For total volatility I used the weighted average variance of stock returns.

INDECOMPOSABILITY(INDECOMP): The indecomposability measure was the inverse of a modularity index. The modularity index was computed for each firm's business portfolio based on the pattern of interdependencies among the segments. I used a program designed by Guimerà *et al.* (2005a; 2005b; 2004). Following an algorithm of simulated annealing, the program first identifies modules – densely connected groups of nodes – in the actual network. It then randomly rewires – redistributes the linkages in the network retaining the number of nodes, number of linkages, and number of degrees for each node. Finally, it compares the modularity of the original network with the average modularity of the randomized networks and calculates the standard deviation of the modularity of the randomized networks. The difference between the modularity of the original network and the average modularity of the randomized networks, normalized by the standard deviation of the modularity of the randomized networks, is the modularity index.

MISMATCH BETWEEN DIVERSIFICATION STRATEGY AND STRUCTURE (MISMATCH): The mismatch between diversification strategy and organization structure is measured as the highest degree of misfit between the two. I sorted the firms into three categories according to their number of related segments: few, medium and many. I then sorted the firms into three categories based on their number of coordinating units. A mismatch is defined as having many related segments but only a few coordinating units or having only a few related segments but many coordinating units.

**Control variables**

To control for other factors that may affect a firm's diversification decision, I included characteristics of the firm and its primary and related industries, such as industry growth and competitiveness, as well as capital and knowledge intensity, and profitability at both the firm and the industry levels. Table 2 summarizes the measures and sources of data for these control variables. In addition, at the industry level, I controlled for the number of industries in each sector. The more industries that exist in a firm's primary sector, the larger is the firm's opportunity set for related diversification. Therefore, number of industries in the sector should be positively associated with the number of related segments. At the firm level, I controlled for firm size (employees), age, number of segments, geographic dispersion, among others. I controlled for year fixed effects. In addition, I included industry fixed effects and firm random or fixed effects, respectively, in robustness checks. In robustness checks I also included a corporate governance index (Gompers, Joy, & Metrick, 2003) and leverage ratio (Mansi *et al.*, 2002) to control for alternative motivations behind unrelated diversification based on agency and portfolio theories.

## Model specification

**Scope of related diversification**

For H1 and H2 I adopted the following Poisson model as the main specification:

$$E[D_{it}^{R}] = \lambda_{it} = \exp(\beta_0 + \beta_1 K_{it} + \beta_2 K_{it}^{2} + \beta_3 M_{it} + \Lambda_{it}) \qquad (1)$$

where,

$D_{it}^{R}$ is the number of segments operated by firm i in year t, that are related to (share the same two-digit SIC code with) the primary segment;

$K_{it}$ is the number of segment pairs that are interdependent (based on IO coefficients) with each other, normalized by the total number of segment pairs in firm i's portfolio in year t;

$M_{it}$ is the number of coordinating units per thousand employees for firm i in year t;

$\Lambda_{it}$ is a vector of control variables for firm i in year t.

H1 predicts $\beta_1 > 0$ and $\beta_2 < 0$. H2 predicts $\beta_3 > 0$.

I used the Poisson model because the dependent variable is a count of the number of segments. Estimating count outcomes using linear regression models can result in inefficient, inconsistent and biased results (Long & Freese, 2003). There are some complications in estimating Equation (1). First, many firms in my sample (about 35%) only diversify into unrelated industries, which leads to mass point at zero for the dependent variable. I adopted three different models to deal with the issue. To account for the possibility that the zeros and non-zeros follow two different data generating processes, I adopted a zero-inflated Poisson (ZIP) model. To account for over-dispersion of the distribution caused by unobserved firm heterogeneity, I adopted a negative binomial (NB) model. To account for both over-dispersion and heterogeneous data generating processes for zeros and non-zeros, I adopted a zero-inflated negative binomial model (ZINB) (Cameron & Trivedi, 1998). Second, the majority of the firms in my sample operate in either zero (35%) or only one (30%) related segment.[15] I therefore estimated a probit model where the dependent variable is a dummy that shows whether a firm operates in at least two related segment in any given year.

[15] Since my sample includes only diversified firms, having zero related segment implies that the firm operates in at least one unrelated segment.

A third issue with Equation (1) is that while it directly estimates firm scope in terms of the number of industries a firm operates in, it controls for industry-specific characteristics only at an aggregate level – it collapses characteristics of all related industries into an average measure. For example, it uses average growth or average level of competition for all the related industries. In order to measure industry characteristics more accurately, I used an alternative specification that predicts the probability a firm operates in a related industry, given the characteristics of its primary industry and the related industry, and the complexity of the firm's entire portfolio.[16] Since the number of four-digit SIC codes (or related industries) depends on the specific sector, I ran this specification separately for each sector.

$$P(D_{ijkt}^{R}=1)=\Phi(\beta_0+\beta_1 K_{it}+\beta_2 K_{it}^2+\beta_3 * M_{it}+\beta_4 * S^{'}(I_{it},I_{kt})+I_{jt}+I_{kt}+\Lambda_{it}+\varepsilon_{ijkt}) \qquad (2)$$

where,

$D_{ijkt}^{R}$ is a dummy variable for whether firm i whose primary industry is j also operates in related industry k in year t;

$K_{it}$ is the number of segment pairs that are interdependent with each other, normalized by the total number of segment pairs in firm i's portfolio in year t;

$M_{it}$ is the number of coordinating units per number of employees for firm i in year t;

$I_{jt}$ and $I_{kt}$ are characteristics of industry j and k, respectively, in year t;

$S(I_{jt},I_{kt})$ is the relationship between industry j and k, for example, their similarity to each other;

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[16] Similar specifications have been used by a number of authors in predicting the direction of diversification. But the independent variable of interest in these studies is the similarity between pairs of industries. Therefore, the interdependencies variable is not included in the regressions. For example, Lemelin (1982) uses a dataset very similar to DCA, albeit for Canadian firms, and estimates the probability that a firm operates in any particular combination of two industries. Silverman (1999) randomly selects 412 firms that collectively operate in 433 SICs and predicts their entry into a different SIC during a three-year window (1982-1985) 'as a function of firm, industry, and resource characteristics in 1981" (page 1112). Breschi, Lissoni, and Malerba (2003) predict the probability a firm with a core technology is also present in a different technological field as a function of the technological relatedness between the two fields. Chang (1996) gathers segment establishment data for 772 firms and estimates entry based on human capital similarity: "Entry is defined by a number of establishments corresponding to each SIC industry from zero to a positive number" (page 594).

$\Lambda_{it}$ is a vector of characteristics for firm i in year t.

I assumed $\Phi(\bullet)$ to be a standard normal Cumulative Distribution Function that gives the probit model. Logit models gave similar results. H1 predicts $\beta_1 > 0$ and $\beta_2 < 0$. H2 predicts $\beta_3 > 0$.

**Determinants of organization structure**

For H3 and H4a I ran the following specification:

$$M_{it} = \beta_0 + \beta_1 VOL_{it} + \beta_2 INDECOMP_{it} + \Lambda_{it} + \eta_{it} \quad (3)$$

where,

$M_{it}$ is the number of coordinating units for firm i in year t;

$VOL_{it}$ is a measure of environmental volatility based on stock returns of all firms in the primary industry;

$INDECOMP_{it}$ is a measure of indecomposability based on the inverse of the modularity index;

$\Lambda_{it}$ is a vector of control variables for firm i in year t.

H3 predicts $\beta_1 < 0$. H4 predicts $\beta_2 < 0$.

**Performance implication**

For H5 I estimated the following Poisson specification:

$$P_{it} = \beta_0 + \beta_1 D_{it}^R + \beta_2 M_{it} + \beta_3 Mismatch_{it} + \Lambda_{it} + \upsilon_{it} \quad (4)$$

where,

$P_{it}$ is performance;

$D_{it}^R$ is the number of segments operated by firm i in year t, that are related to (share the same two-digit SIC code with) the primary segment;

$M_{it}$ is the number of coordinating units per number of employees for firm i in year t;

$MISMATCH_{it}$ is the measure of misfit between the scope of related diversification and organization structure;

$\Lambda_{it}$ is a vector of control variables for firm i in year t.

H5 predicts $\beta_3 < 0$.

In addition to standard firm performance measures such as profitability and market value, I also used "excess" profitability and market value that adjust for average performance of all industries a firm operates in, following the "chop-shop" approach widely used in the finance literature (Berger & Ofek, 1995; Lang *et al.*, 1994; LeBaron & Speidell, 1987; Villalonga, 2004). The approach approximates the standalone value of divisions of a conglomerate by the average value of specialized firms in the divisions' industries, and calculates the difference between the conglomerate's value and the total standalone value of its divisions.

**Endogeneity**

There potentially exists the issue of endogeneity of my main independent variables in Equation (1): interdependencies and number of coordinating units. As discussed earlier, the issue of endogeneity between related diversification and interdependencies is of less concern: Potential endogeneity due to measurement error or omitted variables makes my estimation more conservative. In addition, the feedback between these two variables is most likely to be positive: Firms in more related segments are more likely to have more interdependent production systems. Since H1 predicts a negative correlation between related diversification and interdependencies, my estimates are likely to be biased against H1.

The endogeneity of the number of coordinating units is of bigger concern. The number of coordinating units can be endogenous due to measurement error or omitted variables. My first strategy was to instrument for the structural variable using a number of instrumental variables (IVs). The number of coordinating units can also be endogenous because of simultaneity or reverse causality:

Whether strategy drives structure or structure drives strategy has been debated among scholars since Chandler (1967). Even though H2 does not predict a causal relationship between strategy and structure, simultaneity can lead to bias in estimates of the coefficients. To deal with simultaneity, I adopted a simultaneous-equations model that treats both related diversification and number of coordinating units as endogenous.

For the instrument approach, a natural candidate is environmental volatility, which affects organization structure according to H3 but does not directly affect the scope of related diversification. Another candidate is firm age. Older firms may have more units for agency reasons: Managers prefer empire-building. Firm age, however, should not have a direct impact on the scope of related diversification. Yet another candidate is whether the firm recently changed its CEO. It is relatively easier for a new CEO to change the organization structure by combining a few units within a year of his arrival, than to enter into a new industry or exit from an existing industry. I am exploring other IVs for number of coordinating units, including the average level of salary and skills of managers in the states that firms operate in.

For the simultaneous-equations approach, I use firm age, environmental volatility and CEO change as exogenous variables in the estimation of coordinating units. In addition, I use number of industries in the same two-digit SIC code as the firm's primary industry as an exogenous variable in the estimation of related diversification. As argued before, the more industries that exist in a firm's primary sector (including those that the firm has not entered), the larger is the firm's opportunity set for related diversification. Therefore, the number of industries in the primary sector is positively associated with related diversification. The opportunity set, however, should not have a direct impact on organization structure.

# RESULTS

## Descriptive statistics

Table 3 provides some summary statistics of the sample. Firms in the sample have an average sales revenue of about $300 million (exp(5.62)=276). On average, a firm operates in about four states in America and five countries outside. To control for the possibility that some units were established mainly for tax evasion purposes, for robustness checks I excluded units that were located in tax havens, or whose supervising units were in tax heavens. Tax havens are those listed by Hines and Rice (1994) or OECD (2002).[17]

An average firm in the sample operates in eight segments, 1.6 of them are related with the primary segment. Despite the fact that there are on average 34 industries in each sector (Item 21), firms operate in very few related segments. In 34% (100%-66%=34%) of the cases, they operate in their primary segment and at least one unrelated but no related segment. In the rest of the cases where firms operate in at least one related segment, about half of them operate in only one related segment. According to the Compustat segment data (which, as discussed, underreports diversification), on average firms derive more than 86% of their sales revenue from their primary segment (Item 8). Also on average, firms derive about 26% of their sales revenue from related segments.

On average, firms have 109 pairs (86%) of segments that are horizontally or vertically interdependent with each other, 46 of them are vertically interdependent with each other. Of the manufacturing segments, 55 (47%) are horizontally or vertically interdependent with each other, 14 (19%) of them are vertically interdependent with each other. I used these different measures of

[17] The tax havens are, Andorra, Anguilla, Antigua and Barbuda, Aruba, Bahamas, Bahrain, Barbados, Belize, British Virgin Islands, Cayman Islands, Channel Islands, Cook Islands, Cyprus, Dominica, Gibraltar, Grenada, Guernsey, Hong Kong, Ireland, Isle of Man, Jordan, Lebanon, Liberia, Liechtenstein, Luxembourg, Macao, Maldives, Marshall Islands, Monaco, Montserrat, Nauru, Netherlands Antilles, Niue, Panama, Samoa, Seychelles, Singapore, St Christopher and Nevis, St Lucia, St Martine, St Vincent and the Grenadines, Switzerland, Tonga, Turks & Caicos, UK Caribbean Islands, US Virgin Islands, Vanuatu.

interdependencies in robustness checks. On average, a firm has 18.13 units, spreading over 2.43 layers in the hierarchical structure.

As for industry statistics, the average growth of the primary industry is 7%, whereas the average growth of related industries is 3%. Capital investment, labor cost, and material cost account for 15, 49, and 49 percent, respectively, of the industry's shipment value. In terms of intangible assets, R&D and advertising expenditures cost 19% and 3%, respectively, of the shipment value. On average, the industries are fairly competitive, evidenced by the low levels of the Herfindahl indices and individual firms' market shares. However, there is great variation across industries, which suggests that an entry model controlling for individual industry characteristics, such as that based on Equation (2), may be more appropriate.

Table 4 summarizes the pair-wise correlation coefficients between the key variables in this study.

Figure 7 plots some general patterns observed from the data. Figure 7 (a) shows that the number of related segments increases first with the level of interdependencies (the percentage of segment pairs that are interdependent with each other) and then decreases as firms move from median to high level of interdependencies. Figure 7 (b) demonstrates that this "inverted-U" relationship also applies to firms' likelihood of having at least one related segment. The likelihood of having at least one related segment increases with interdependencies up to a point, at which interdependencies start to reduce the probability of related diversification. Since my sample is composed of only diversified firms, firms with above-median level of interdependencies are less likely to have at least one related segment; instead they are more likely to diversify into unrelated segments. Figures 7 (c) and 7 (d) show the relationship between related diversification and number of coordinating units. Firms with more coordinating units both have more related segments and are more likely to have at least one related segment compared to firms with fewer coordinating units.

These correlations therefore suggest that above a certain point, interdependencies may constrain firms' scope of related diversification, and that coordinating units may facilitate related diversification. In the next section, I show the significance of these correlations based on statistical regressions.

**H1 and H2: Scope of related diversification**

As discussed earlier, I estimate the scope of related diversification using two classes of models. The first class of models estimate directly the scope of related diversification, i.e., the number of (any) related segments a firm operates in, as a function of the characteristics of the firm and its primary industry, and aggregate characteristics of all related industries. The second class of models estimate the probability that a firm diversifies into a particular related industry. While the second class of models do not estimate directly the total number of related segments, it nevertheless predicts the direction of diversification and allows for better control of the characteristics of individual target industries.

**<u>Count models</u>**

Table 5 estimates the number of related segments based on standard Poisson models. The first two columns start by investigating the impact of the control variables. They both include year fixed effects to control for general trendy or cyclical factors that affect firms' diversification decisions. First, as expected, the more industries that exist in a firm's primary sector, the larger is the firm's opportunity set for related diversification, and the more related segments that the firm operates in. Second, growth rate in the primary industry is negatively correlated with number of related segments. This is consistent with a number of theoretical models (e.g., Matsusaka, 2001) that suggest that firms face opportunity cost of diversification. When their home industry has greater growth potential, they are less likely to diversify into other industries – this should also be true for related diversification which requires more coordination. In contrast, average growth rate in related industries makes diversification into those industries more attractive.

Third, concentration of market power in the primary industry is negatively correlated with the number of related segments, suggesting that firms may face higher opportunity cost of diversification (in terms of managerial attention) when their home industry is difficult to compete in. However, higher concentration of market power in related industries is positively correlated with the number of related segments (except when firm random and fixed effects are added). This is counter-intuitive. When I examine the effects more closely using entry models based on Equation (2) to control for characteristics of individual target industries, I find more reasonable results that higher concentration in related industries is negatively correlated with the probability of entry (Tables 7-9).

The impact of firm characteristics is in line with expectation. Columns (1) and (2) measure firm size using sales revenue and employment, respectively. Larger firms have more related segments, suggesting that they may have more resources to share across segments. Since sales revenue and employment are highly correlated (correlation coefficient: 0.95), I choose employment to proxy firm size. However, results are similar when I instead choose sales or both.

Firms' total product diversification, in terms of number of segments (both related and unrelated), is positively correlated with number of related segments, suggesting that they may have more resources to share across segments. In contrast, geographic expansion does not have a significant impact on related diversification in the first two columns, but it becomes negatively associated with related diversification in Columns (4) to (7) where more variables are added.

Columns (3) to (7) investigate the association between related diversification and interdependencies and the number of coordinating units. Column (3) reports the impact of interdependencies, and Column (4) adds coordinating units. In addition to year fixed effects, Columns (5) and (6) control for unobserved firm heterogeneity using firm random and fixed effects, respectively. Coefficients for interdependencies and coordinating units become smaller with more controls, but they remain statistically significant.

Overall, interdependencies are positively correlated with the scope of related diversification up to a point, beyond which greater interdependencies are associated with narrower scope of related diversification. The percentage of interdependent segment pairs corresponding to the maximum number of related segments lies between 72% (=6.475/(2*4.476), Column (6)) and 79% (=7.705/(2*4.904), Column (4)). This is a little below the sample mean of interdependencies, 86% (Table 3, Item 10). H1 is supported.

Number of coordinating units is positively correlated with the scope of related diversification. The sample average number of coordinating units per thousand employees is 18.13 (Table 3, Item 18). The marginal effect (not reported) of the logarithm of the number of coordinating units per thousand employees is 0.343 for the specification in Column (4). This means that *ceteris paribus*, increasing the number of coordinating units per thousand employees from 18.13 to 19.13 increases the number of related segments by 0.02 (=0.343*(ln(19.13)-ln(18.13))). H2 is also supported.

Table 6 runs several alternative specifications. Columns (1) to (3) employ ZIP, NB, and ZINB models respectively. All the covariates are used for both the count and the inflation models except for the year dummies which are excluded from the inflation model. The Vuong statistics (Vuong, 1989) has large positive values ($z \approx 7$ and $p > 0.01$) for both ZIP and ZINB models, suggesting the choice of the zero-inflated models over the standard count models.

However, Figure 8 shows that the differences between the observed and predicted counts based on various count models are small. While the Poisson model under-predicts zeros, the ZIP and NB models under-predict ones more than the Poisson model, and the ZINB model over-predicts zeros. Fortunately, results from these alternative models are fairly consistent with predictions from the standard Poisson model in Table 5. For example, while the zero-inflated models produce smaller coefficients for the interdependencies variables, they remain statistically significant. The percentage of interdependent segment pairs corresponding to the maximum number of related segments, calculated from the coefficients in the first three columns, is between 79% and 83%, slightly higher than but consistent with results in Table 5. Since the standard Poisson model has fewer convergence problems when random or fixed effects are added, it is used in my main regressions.

Columns (4) to (7) adopt probit models to estimate the probability that a firm operates in at least two related segments. Columns (8) and (9) estimate the probability that a firm operates in at least one related segment as opposed to operating in at least one unrelated but no related segment. The results provide evidence that high level of interdependencies constrain related diversification (at least the first diversification into a related segment) more than unrelated diversification, and that coordinating units facilitate related diversification more than unrelated diversification. To control for unobserved heterogeneity, Columns (5) to (9) use year dummies, industry dummies, and firm random effects, respectively. Logistic regressions generate similar results.[18]

I run a number of robustness checks. To partly address the issue of reverse causality, I regress related diversification against lagged value of interdependencies and coordinating units. To make sure results are not driven by the fact that less diversified firms may have higher percentage of interdependent segment pairs – imagine a firm operates in only two segments that are interdependent vs. a firm operates in four segments with all but one segment pair interdependent, I rerun the regressions separately for firms with at least or more than three segments. Results from these robustness checks are qualitatively similar.

**Entry models**

Tables 7 to 9 estimate firms' probability of entering into a particular related industry. All regressions are estimated by maximum likelihood probit following Equation (2). Since the number of

[18] For the probit model there does not exist a sufficient statistic allowing the firm fixed effects to be conditioned out of the likelihood. In addition, since a large number of firms remain as related or unrelated diversifiers throughout the sample period, running the logit model with firm fixed effects results in significant reduction in sample size (more than 80%). I therefore use year and industry fixed effects and firm random effects instead; results are qualitatively similar.

related industries is different for each sector, firms in different sectors have different opportunity sets for related diversification. I therefore estimate the entry model separately for firms in each sector. Tables 7 through 9 report detailed results for the industry machinery and equipment sector (SIC=35). Table 9 compares the full models across all sectors.

Table 7 assesses the impact of industry (at the four-digit SIC level) characteristics on entry. Column (1) includes two of the most cited factors that affect entry – industry growth and competition. Consistent with Tables 5 and 6, growth in the primary industry is negatively correlated with diversification into a related industry, while growth in the target industry is positively correlated with entry. Market concentration in the primary industry has a positive impact on related diversification (but has a significant negative impact in the full model in Column (6)). Unlike Table 5 which under some specifications reports a positive association between the average concentration in related industries and related diversification, Table 7 disaggregates the concentration measure to individual industry level and finds it to be negatively associated with entry. This result is more consistent with the conventional wisdom that monopolistic or oligopolistic markets deter entry.

Column (2) adds capital intensity. Capital intensity in the primary industry is positively correlated with related diversification, suggesting some scope of economies in physical assets. In contrast, capital intensity in the target industry is negatively correlated with entry, suggesting that capital intensity can be an entry barrier. Column (3) adds R&D intensity and (4) adds the intensity of advertisement expenditure and industry profitability. Results for these variables are ambiguous (R&D intensity), insignificant (advertisement intensity), or counter intuitive (industry profitability). This may be due to collinearity. For example, the correlation between industry profit and R&D intensity is -0.97. The exact impact of these industry measures is worthy of further investigation. For now, I exclude these ambiguous control variables from the main regressions; however, my results are similar with them included.[19]

Columns (5) and (6) study the impact of the relationship between the primary and target industries. Forward horizontal relatedness – the degree to which the primary and target industries provide inputs to a similar set of industries – is associated with higher probability of entry. In contrast, backward horizontal relatedness – the degree to which the primary and target industries require inputs from a similar set of industries – is associated with lower probability of entry. By comparison, forward vertical relatedness – the contribution of the primary industry's output to the target industry's input – is negatively correlated with the probability of entry (although the coefficient becomes insignificant once other industry controls are added in the last column), whereas backward vertical relatedness – the contribution of the target industry's output to the primary industry's input – is positively correlated with the probability of entry.

Table 8 incorporates firm characteristics into the specification. As in count models, firm size is positively correlated with related diversification. Product diversification is positively correlated with related diversification, and geographic expansion does not have a significant impact. In robustness checks I add more control variables at the firm level including intensities of capital investment, R&D, and advertising expenditures. Results are similar.

Finally, the first two columns in Table 9 add interdependencies and coordinating units to the entry model. Results are fairly consistent with those using the count models (Tables 5 and 6). Interdependencies at the portfolio (or system) level have a curve-linear relationship with the probability of diversifying into any related segment. The point at which interdependencies start to have a negative impact on related diversification is when about 78% (=1.899/(2*1.236) or 1.726/(2*1.087)) of the segment pairs are interdependent. H1 is supported. The marginal effects (not shown) of the

[19] Silverman (1999: 1117) also suggests industry profitability be excluded since it does not have additional impact once profitability drivers such as industry concentration, growth, R&D intensity and advertising intensity are included.

logarithm of the number of coordinating units at the sample mean are about 0.008, much smaller than the marginal effects under the count models. However, the coefficients are still statistically significant and H2 is supported. The last four columns replicate the specification in Column (3) across all sectors. Results are comparable, though weaker in some sectors such as the transportation equipment sector (SIC37).

Overall, the results in Tables 5 through 9 show that, consistent with my hypotheses and the relationships presented in Figure 7, interdependencies have an inverted-U relationship with related diversification, and more coordinating units are associated with higher level of related diversification. H1 and H2 are supported by both the count and entry models. The results are robust across most of the alternative specifications.

**H3 and H4: Number of coordinating units**

In the next two subsections I econometrically examine two important determinants of organization structure: environmental volatility (H3) and decomposability of tasks (H4). Column (1) in Table 10 presents coefficients on the control variables. Interdependencies have a curve-linear impact on number of coordinating units per thousand employees. Firm size has a negative impact on the number of coordinating units per thousand employees. Both product diversification and geographic dispersion have a positive impact on the number of coordinating units per thousand employees. Older firms are generally associated with more coordinating units.

Columns (2) and (3) investigate the associations between the number of coordinating units and the volatility of stock returns in the firm's primary industry. Both beta and variance of industry stock returns are negatively associated with number of coordinating units. H3 is supported.

Columns (4) and (5) examine the relationship between organization structure and task indecomposability, which is measured using the inverse of the modularity index. Each firm is treated as a network; each of its segments is treated as a node in the network. Since it is only meaningful to construct modules for networks with more than five nodes, I calculate the modularity indices only for networks with more than five nodes; they make up 50% of the sample. I include a dummy to represent networks with no more than five nodes. In addition, about 30% of the networks failed the simulated annealing program because they are too dense to be decomposed at all. I assign an extreme value of 200 for these networks. Column (4) includes the continuous indecomposability measure and Column (5) uses a dummy to represent the networks that are not decomposable at all. Results show that firms with less decomposable portfolios have fewer coordinating units. H4 is supported.

**Addressing endogeneity: Instrumentation and system equations**

Estimation procedures for count models using instrumental variables are complicated due to nonlinearity in the parameters and the fact that the error terms can be either additive or multiplicative (Windmeijer & Silva, 1997). For simplicity, I use an IV probit model to estimate the probability that a firm operates in at least two related segments; the same specifications, albeit without the IV approach, are estimated in Columns (4) to (7) in Table 5.

Columns (2) to (7) in Table 12 present results from the IV provit models. By comparison, in Column (1) I replicate the probit regression (Table 6, Column (4). I used three IVs for organization structure, firm age, environmental volatility and a dummy showing whether the firm changed its CEO in the past or current year. They all turn out to be significant with the correct sign for stage one. The F-statistics for the first stage are highly significant for both models (Columns (2) and (4)). Compared with coefficients in Column (1), coefficients for H1 are smaller in the IV probit models, but they remain statistically significant. Coefficients for H2 are stronger in the IV probit model than in Column (1). Again, both H1 and H2 are supported.

Columns (6) and (7) present results from a three-stage-least-square (3SLS) regression model. As before, interdependencies have an inverted-U relationship with related diversification, although the coefficients are not statistically significant. Coefficients for coordinating units are again stronger compared to Column (1).

### H5: Performance implication

Table 12 investigates the performance implication of a misfit between the related diversification strategy and organization structure. Columns (1) through (4) present results for firm profitability, and Columns (5) through (8) present results for industry adjusted firm profitability according to the "chop-shop" approach. Results show that firms perform poorly when they have many related segments but only a few coordinating units or many coordinating units but only a few related segments. Results for market value, measured using Tobin's q, are similar.

Overall, the results in Tables 5 through 12 show that, consistent with my hypotheses, (1) related diversification has an inverted-U relationship with interdependencies, (2) related diversification is increasing in the number of coordinating units, (3) firms that need to make faster decisions and firms with less decomposable portfolios have fewer coordinating units, and (4) a mismatch between related diversification and number of coordinating units leads to poor performance. These results are robust across most of the alternative specifications.

## CONCLUSION

This study examines coordination costs as limits to related diversification, and the role of organization structure in altering coordination costs and consequently the scope of related diversification. It makes several contributions to the diversification and organization structure literature. First, it accounts for within-industry variation in the scope of related diversification across firms. Diseconomies of scope in the form of coordination costs set limits to the net benefits from related diversification. Firms in the same primary industry may have diversified or vertically integrated into different secondary industries. Interdependencies among business segments in different firms' business portfolios generate different demands for coordination, thereby imposing different constraints on firms' ability to diversify into related industries.

With these arguments, the study joins the recent discussions by several authors around the process of vertical disintegration, modularization and segregation of supply chains (Arora, Fosfuri, & Gambardella, 2000; Baldwin *et al.*, 2005; Fine *et al.*, 1999; Jacobides, 2005; Langlois & Robertson, 1992; Macher *et al.*, 1998; Schilling *et al.*, 2001; Zenger & Hesterly, 1997), and suggests that an implication of the process could be broader horizontal scope in related markets. The challenges of interdependencies for firms have been studied at multiple levels. At the project level, they complicate the innovation and product design process (e.g., Ethiraj *et al.*, 2004). At the organization level, they obscure the evolutionary path firms take to search or decipher best practices (Levinthal, 1997; Rivkin, 2000), and subject firms to more decision errors (Siggelkow, 2002). At the operational level, they reduce the value of many operational practices if they are not implemented with their complementary counterparts. For example, innovative human resource practices (e.g., high-power incentive pay, teams, flexible job assignments, employment security, and training) achieve substantially higher levels of productivity only if they are implemented together (Ichniowski, Shaw, & Prennushi, 1997). At the industry level, interdependencies lead to industry structures with persistent heterogeneous profits across firms (Lenox, Rockart, & Lewin, 2006). Despite the amount of scholarly attention paid to the challenges of interdependencies to firms, few studies have looked at the impact of interdependencies on firm scope. This study fills in this gap by highlighting the impact of interdependencies on the cost of coordinating across business lines and subsequently, firm scope.

Second, the study points to organization structure as a design element that affects coordination costs and consequently the scope of related diversification. It extends the strategy literature that, starting from Chandler (1967), investigates the means through which organization design accommodates or constrains strategic choices. By highlighting the tradeoffs that firms face in choosing organization structures, it also contributes to emerging discussions in the organization economics and management literature about the tradeoffs that give rise to Williamson's problem of "the impossibility of selective intervention" (Alonso, Dessein, & Matouschek, 2006; Friebel & Raith, 2006; Inderst, Müller, & Wärneryd, 2005; Nickerson & Zenger, 2006; Williamson, 1985). The study reasons that even in the absence of incentive problems, so far the focus of many such studies, with fully cooperative agents, interdependencies can still lead to coordination problems due to the cost of communicating and processing information and making joint decisions. Organization structures can be designed to partly mitigate the problem, but constraints in structural design that are posed by the external environment and the underlying tasks limit the degree of selective intervention and ultimately firm growth.

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**Figure 1.** **Interdependencies in automotive productive systems**

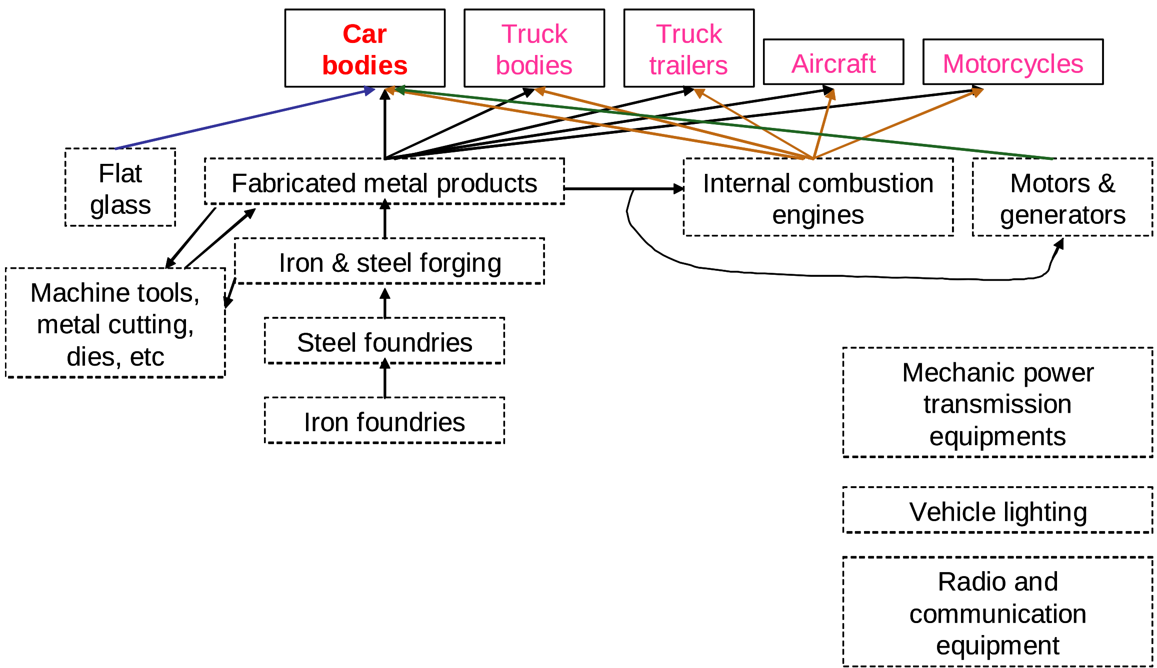
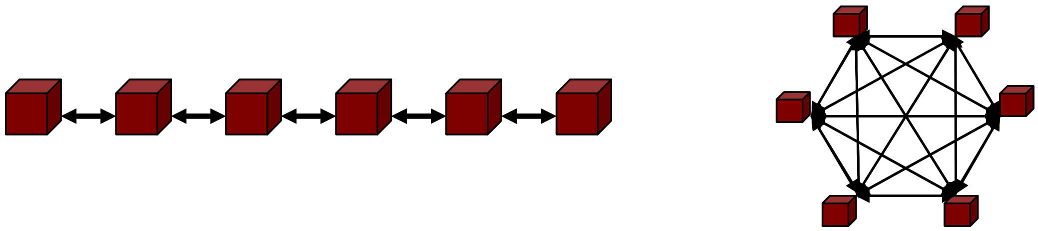
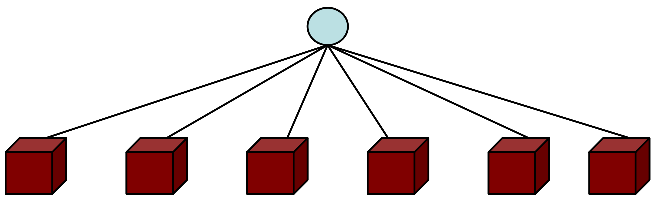


**Figure 2.** **Hierarchical structures for interdependent activities**

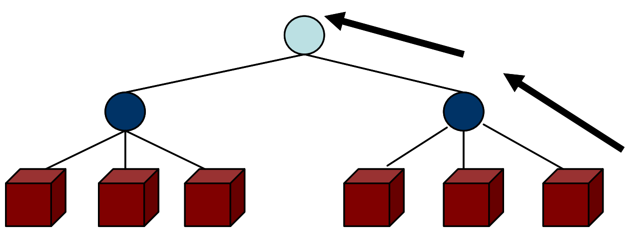
**(a) A decentralized structure**



**(b) A centralized structure**



**(c) A hierarchical structure**



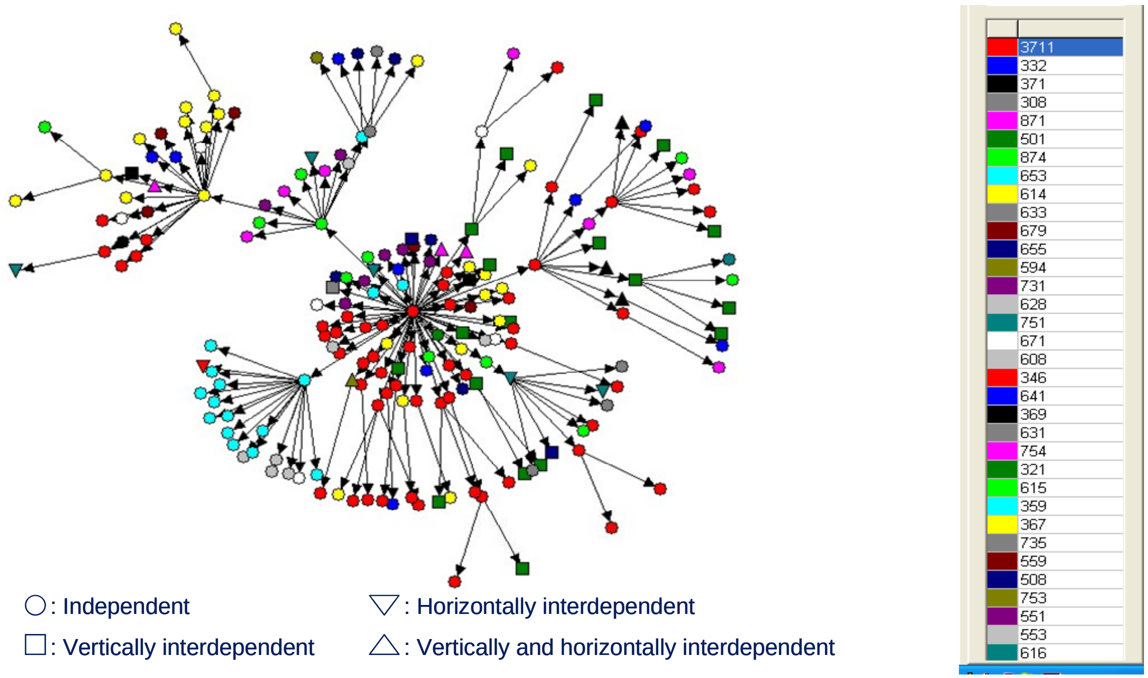
## Figure 3. More vs. Less modular portfolios


## Figure 4. Related Diversification, structure and performance

Scope of related diversification

| Number of coordinating units | | Narrow | Wide |
|---|---|---|---|
| | Few | Volatile environment or indecomposable tasks: H3, H4 | X |
| | Many | X | Decomposable tasks & stable environment: H2 |

**Figure 5. Business segments and organization structure of Ford Motor Company based on DCA data, 2003**




Note: Each node represents a business unit. Its color represents the primary segment of the unit. The shape of the node represents the type of interdependencies with (or independency from) the company's primary segment. The calculation of interdependencies is explained in the "Independent variables" Section.

**Figure 6. Organization structure of Ford Motor Company, based on conversations with company executives**

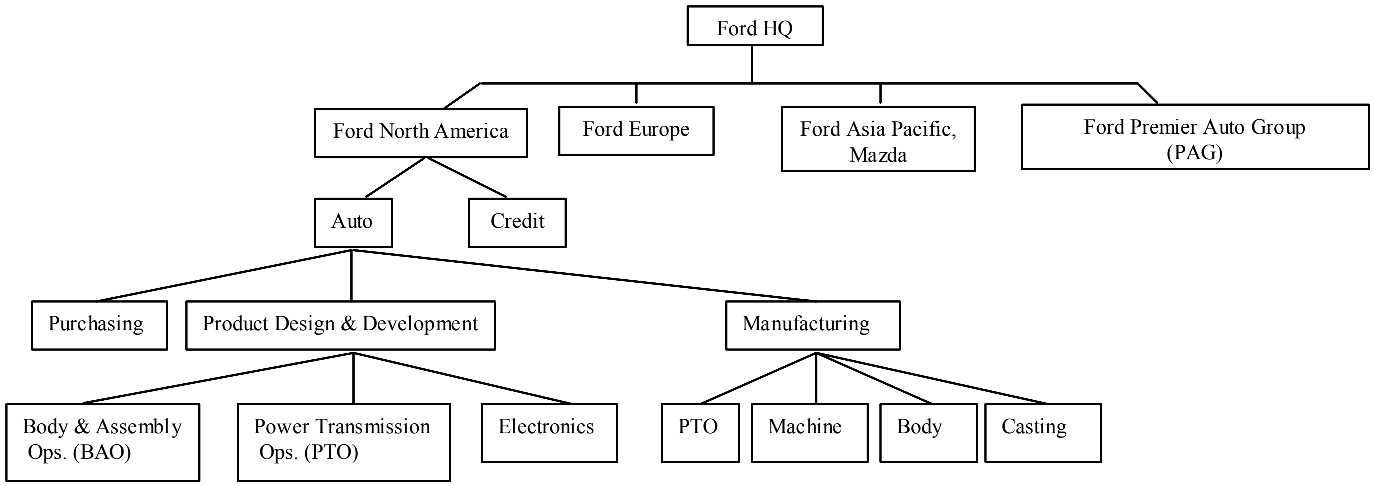
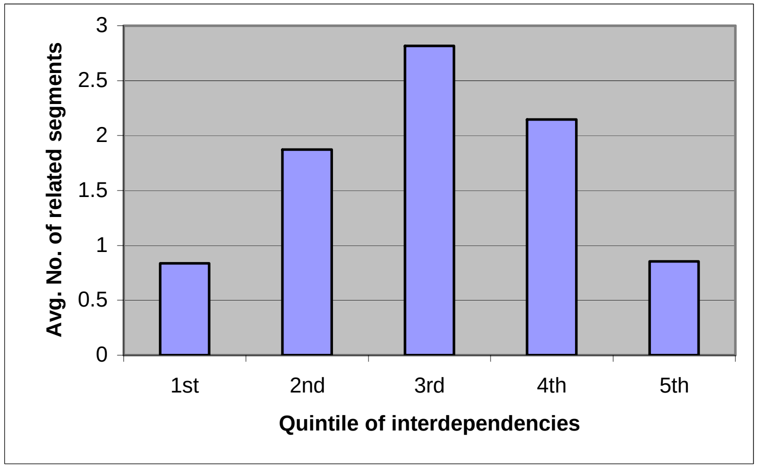
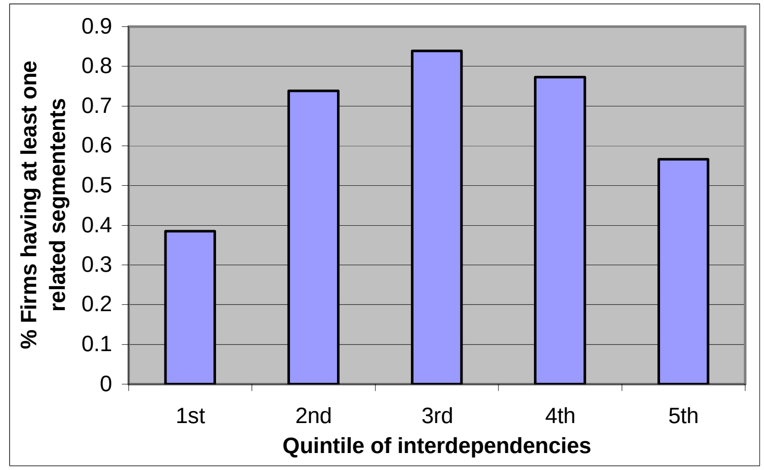


**Figure 7. Interdependencies and related diversification**

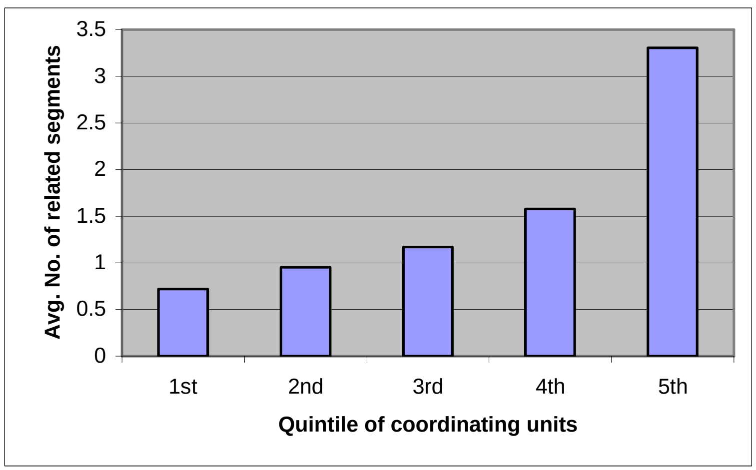
(a) Interdependencies and the number of related segments




(b) Interdependencies and the likelihood of having at least one related segment




(c) Coordinating units and the number of related segments




(d) Coordinating units and the likelihood of having at least one related segment

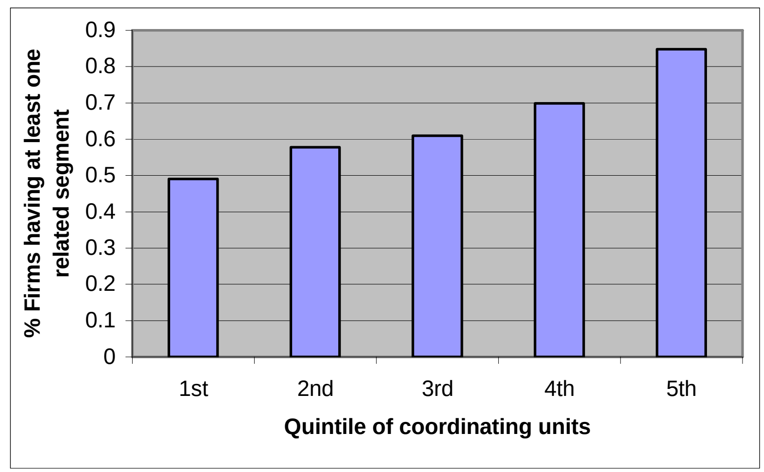
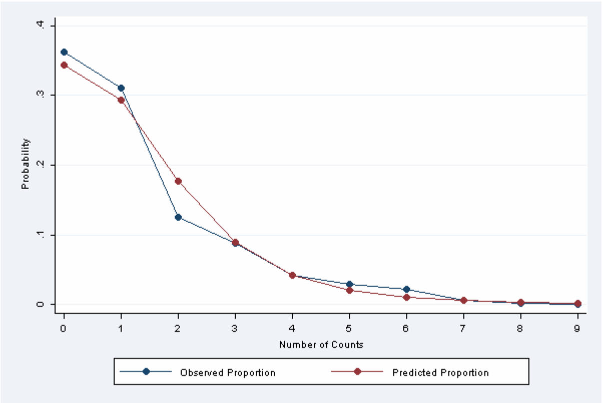
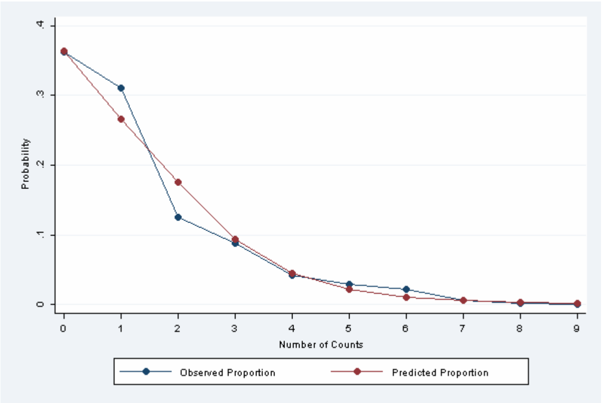


**Figure 8. Observed and predicted counts based on various count models**

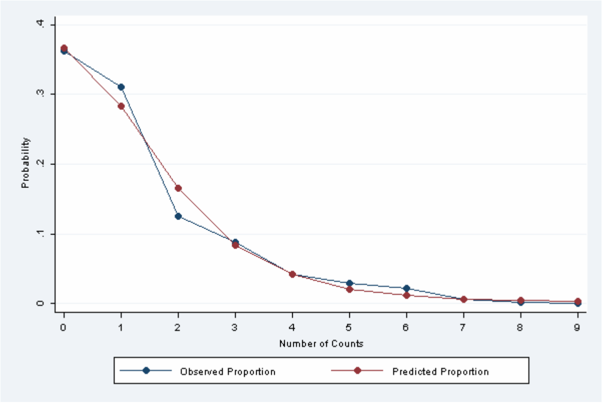
(a) Poisson



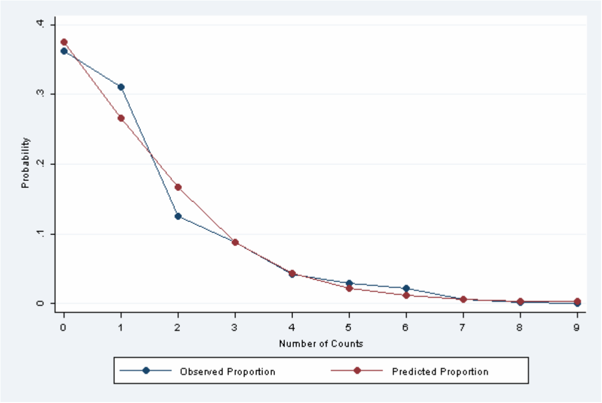

(b) Zero-inflated Poisson




(c) Negative Binomial




(d) Zero-inflated Negative Binomial



## Table 1. Segments operated by U.S. automakers

| Description | SIC codes |
|---|---|
| **Primary industry: motor vehicles and passenger car bodies** | **3711** |
| **Related industries in the transportation equipment sector** | |
| Truck and bus bodies | *3713* |
| Motor vehicle parts and accessories | *3714* |
| Truck trailers | *3715* |
| Motor homes | *3716* |
| **Other sectors:** | |
| Apparel and other textile products | 2399 |
| Rubber and miscellaneous plastics products | 3052 3089 |
| Stone, clay, glass, and concrete products | 3211 |
| Primary metal industries | 3325 |
| Fabricated metal products | 3411 3462 3499 |
| Industrial machinery and equipment | 3519 3531 3537 3541 3544 3545 3568 3585 3599 |
| Electrical and electronic equipment | 3621 3647 3651 3663 3669 3679 3692 3694 |
| Instruments and related products | 3827 |
| Miscellaneous manufacturing industries | 3993 3999 |
| Communications | 4833 4841 4899 |
| Electric, gas, and sanitary services | 4953 4959 |
| Wholesale trade--durable goods | 5012 5013 5015 5051 5065 5082 5084 5088 |
| Wholesale trade--nondurable goods | 5112 |
| Automotive dealers and gasoline service stations | 5511 5531 5599 |
| Miscellaneous retail | 5947 |
| Depository institutions | 6082 |
| Nondepository credit institutions | 6141 6153 6159 6162 |
| Security, commodity brokers, and services | 6211 6282 |
| Insurance carriers | 6311 6331 6399 |
| Insurance agents, brokers, and service | 6411 |
| Real estate | 6531 6552 |
| Holding and other investment offices | 6719 6788 |
| Business services | 7311 7319 7353 7359 7371 7382 7389 |
| Automotive repair, services, and parking | 7513 7514 7515 7539 7549 |
| Engineering and management services | 8711 8731 8734 8741 8742 8748 |

Source: Directory of Corporate Affiliations.

## Table 2. Control variables

| Control Factors | Alternative Measures | Data Source | Primary Industry? | Related Industries? | Firm? |
|---|---|---|---|---|---|
| **Industry growth** | | | | | |
| | Annual growth in shipment value | Census | Yes | Yes | No |
| | Annual growth in value-added | Census | Yes | Yes | No |
| **Industry competition** | | | | | |
| | Share of shipment value by 5/8/20/50 largest companies in the industry | Census | Yes | Yes | No |
| | Herfindahl Index based on shipment value | Census | Yes | Yes | No |
| | Number of firms in the industry | Census/ Compustat/DCA | Yes | Yes | No |
| | Market share of competitors based on sales revenue | Compustat | Yes | Yes | Yes |
| | Market share of competitors based on number of business units | DCA | Yes | Yes | Yes |
| **Industry volatility** | | | | | |
| | Stock price volatility (beta) | CRISP | Yes | Yes | No |
| **Cost structure** | | | | | |
| | CAPEX intensity (Capital expenditure/Sales or Capital expenditure/Shipment value) | Census/Compustat | Yes | Yes | Yes |
| | Labor intensity | Census | Yes | Yes | No |
| | Material intensity | Census | Yes | Yes | No |
| **Knowledge /Intangibles** | | | | | |
| | R&D intensity | Compustat | Yes | Yes | Yes |
| | Advertising intensity | Compustat | Yes | Yes | Yes |
| **Profitability** | | | | | |
| | Profit margin | Census/Compustat | Yes | Yes | Yes |

## Table 3. Summary statistics

| | | mean | sd | min | max |
|---|---|---|---|---|---|
| | **General firm characteristics** | | | | |
| (1) | Firm size: log (sales) | 5.62 | 1.89 | -4.27 | 12.12 |
| (2) | Geographic dispersion: number of countries | 5.39 | 7.90 | 1.00 | 91.00 |
| (3) | Geographic dispersion: number of U.S. states | 4.29 | 4.89 | 1.00 | 45.00 |
| | **Diversification** | | | | |
| (4) | Product diversification: number of segments (N) | 8.00 | 9.67 | 2.00 | 105.00 |
| (5) | Related diversification: number of segments that are related to the primary segment ($D^R$) | 1.56 | 2.06 | 0.00 | 22.00 |
| (6) | Related diversification: the firm operates in at least one related segment (1,0) | 0.66 | 0.48 | 0.00 | 1.00 |
| (7) | Related diversification: the firm operates in at least two related segment (1,0) | 0.34 | 0.47 | 0.00 | 1.00 |
| (8) | Share of sales revenue from the firm's primary segment | 0.86 | 0.20 | 0.22 | 1.00 |
| (9) | Share of sales revenue from the firm's related segments | 0.26 | 0.13 | 0.00 | 0.64 |
| | **Interdependencies** | | | | |
| (10) | Number of interdependent segment pairs (n) | 108.58 | 375.19 | 2.00 | 7946.00 |
| (11) | Share of interdependent segment pairs (K=n/(N*(N-1))) | 0.86 | 0.18 | 0.17 | 1.00 |
| (12) | Number of vertically interdependent segment pairs (n) | 45.71 | 155.55 | 0.00 | 3308.00 |
| (13) | Share of vertically interdependent segment pairs | 0.47 | 0.34 | 0.00 | 1.00 |
| (14) | Number of interdependent segment pairs in manufacturing | 55.33 | 201.43 | 0.00 | 3614.00 |
| (15) | Share of interdependent segment pairs in manufacturing | 0.47 | 0.35 | 0.00 | 1.00 |
| (16) | Number of vertically interdependent segment pairs in manufacturing | 14.36 | 40.85 | 0.00 | 822.00 |
| (17) | Share of vertically interdependent segment pairs in manufacturing | 0.19 | 0.26 | 0.00 | 1.00 |
| | **Organization structure** | | | | |
| (18) | Number of units | 18.13 | 38.50 | 2.00 | 577.00 |
| (19) | Number of units per thousand employees | 10.60 | 19.91 | 0.03 | 500.00 |
| (20) | Number of layers in the corporate hierarchy | 2.43 | 0.72 | 2.00 | 7.00 |
| | **Industry characteristics** | | | | |
| (21) | Number of related industries in the primary sector | 34.39 | 13.50 | 17.00 | 51.00 |
| (22) | Growth rate in shipment value in the primary industry | 0.07 | 0.19 | -0.60 | 1.60 |
| (23) | Avg. growth rate in shipment value in related industries | 0.03 | 0.05 | -0.10 | 0.13 |
| (24) | Capital investment intensity in the primary industry | 0.15 | 0.22 | -0.13 | 1.58 |
| (25) | Labor intensity in the primary industry | 0.49 | 0.18 | 0.04 | 0.49 |
| (26) | Material cost intensity in the primary industry | 0.49 | 0.19 | 0.04 | 0.99 |
| (27) | R&D intensity in the primary industry | 0.19 | 0.24 | 0.00 | 0.96 |
| (28) | Advertising intensity in the primary industry | 0.03 | 0.06 | 0.00 | 0.81 |
| (29) | Herfindahl index in the primary industry | 593.16 | 505.02 | 1.00 | 2717.00 |
| (30) | Average Herfindahl index in related industries | 744.37 | 235.52 | 464.16 | 1345.35 |
| (31) | Firm's market share of sales revenue in the primary industry | 0.09 | 0.85 | 0.90 | 0.00 |
| (32) | Firm's market share of sales revenue in related industries | 0.00 | 1.00 | 0.09 | 0.00 |
| (33) | Firm's market share of units in the primary industry | 0.05 | 0.90 | 0.92 | 0.00 |
| (34) | Firm's market share of units in related industries | 0.00 | 1.00 | 0.09 | 0.00 |

## Table 4. Correlation matrix

| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|---|
| **(1)** | Related diversification: number of segments that are related to the primary segment ($D^R$) | 1.00 | | | | | | |
| **(2)** | Related diversification: the firm operates in at least two related segment (1,0) | 0.73 | 1.00 | | | | | |
| **(3)** | Share of sales revenue from the firm's related segments | 0.26 | 0.23 | 1.00 | | | | |
| **(4)** | Share of interdependent segment pairs (K=n/(N*(N-1))) | -0.16 | -0.15 | -0.08 | 1.00 | | | |
| **(5)** | Number of units per thousand employees^ (M) | -0.17 | -0.16 | -0.14 | 0.11 | 1.00 | | |
| **(6)** | Number of related industries in the primary sector | 0.09 | 0.07 | 0.02 | -0.01 | 0.02 | 1.00 | |
| **(7)** | Product diversification: number of segments (N) | 0.68 | 0.44 | 0.18 | -0.33 | -0.26 | -0.07 | 1.00 |
| **(8)** | Growth rate in shipment value in the primary industry | -0.05 | -0.05 | -0.06 | 0.11 | 0.00 | 0.14 | -0.07 |
| **(9)** | Avg. growth rate in shipment value in related industries | 0.01 | 0.02 | -0.02 | 0.03 | 0.05 | 0.03 | -0.02 |
| **(10)** | Advertising intensity in the primary industry^ | 0.01 | -0.01 | 0.01 | -0.02 | -0.16 | -0.13 | 0.10 |
| **(11)** | Herfindahl index in the primary industry^ | 0.03 | 0.03 | 0.04 | -0.09 | -0.18 | -0.50 | 0.12 |
| **(12)** | Firm size: log (sales) | 0.38 | 0.32 | 0.18 | -0.22 | -0.76 | 0.02 | 0.57 |
| **(13)** | Geographic dispersion: number of countries | 0.32 | 0.26 | 0.05 | -0.06 | -0.13 | 0.04 | 0.50 |
| | | **(8)** | **(9)** | **(10)** | **(11)** | **(12)** | **(13)** | |
| **(8)** | Growth rate in shipment value in the primary industry | 1.00 | | | | | | |
| **(9)** | Avg. growth rate in shipment value in related industries | 0.35 | 1.00 | | | | | |
| **(10)** | Advertising intensity in the primary industry^ | 0.06 | 0.00 | 1.00 | | | | |
| **(11)** | Herfindahl index in the primary industry^ | -0.01 | -0.01 | 0.42 | 1.00 | | | |
| **(12)** | Firm size: log (sales) | 0.01 | -0.04 | 0.18 | 0.14 | 1.00 | | |
| **(13)** | Geographic dispersion: number of countries | 0.02 | 0.00 | 0.07 | -0.03 | 0.56 | 1.00 | |

p>0.01 for |r|>0.04; ^ log value.

**Table 5. H1 and H2: Poisson estimation of the impact of interdependencies and coordinating units on the scope of related diversification**

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| **Share of interdependent segment pairs (K)** | | | 8.544*** | 7.705*** | 7.568*** | 6.475*** |
| | | | [0.704] | [0.707] | [1.179] | [1.476] |
| **K^2** | | | -5.559*** | -4.904*** | -5.100*** | -4.476*** |
| | | | [0.451] | [0.455] | [0.781] | [0.978] |
| **Number of units per thousand employees^ (M)** | | | | 0.274*** | 0.190*** | 0.122** |
| | | | | [0.026] | [0.051] | [0.060] |
| Number of industries in the sector | 0.018*** | 0.017*** | 0.017*** | 0.017*** | 0.013*** | 0.020*** |
| | [0.001] | [0.001] | [0.001] | [0.001] | [0.003] | [0.004] |
| Growth in shipment value in the primary industry | -0.415*** | -0.385*** | -0.372*** | -0.305*** | -0.101 | -0.043 |
| | [0.076] | [0.077] | [0.077] | [0.076] | [0.095] | [0.102] |
| Avg. growth in shipment value in related industries | 1.076*** | 1.118*** | 1.089*** | 0.980*** | 0.11 | -0.039 |
| | [0.344] | [0.344] | [0.344] | [0.344] | [0.392] | [0.406] |
| Primary industry HHI^ | -0.090*** | -0.091*** | -0.085*** | -0.079*** | -0.017 | 0.031 |
| | [0.012] | [0.012] | [0.012] | [0.012] | [0.031] | [0.038] |
| Avg. HHI in related industries^ | 0.272*** | 0.232*** | 0.242*** | 0.257*** | -0.231* | -0.536*** |
| | [0.056] | [0.056] | [0.056] | [0.056] | [0.132] | [0.192] |
| Firm size: number of employees (Mil)^ | | 0.121*** | 0.107*** | 0.343*** | 0.281*** | 0.152** |
| | | [0.009] | [0.010] | [0.024] | [0.049] | [0.063] |
| Firm size: sales (MM$)^ | 0.076*** | | | | | |
| | [0.009] | | | | | |
| Product diversification: number of segments | 0.036*** | 0.034*** | 0.032*** | 0.025*** | 0.020*** | 0.015*** |
| | [0.001] | [0.001] | [0.001] | [0.001] | [0.003] | [0.003] |
| Geographic dispersion: number of countries^ | 0.005 | -0.022 | -0.032** | -0.181*** | -0.113*** | -0.096* |
| | [0.015] | [0.014] | [0.015] | [0.020] | [0.044] | [0.058] |
| Constant | -2.293*** | -1.647*** | -4.804*** | -5.094*** | -1.784* | |
| | [0.376] | [0.380] | [0.465] | [0.465] | [0.957] | |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Industry fixed effects | No | No | No | No | No | No |
| Firm random effects | No | No | No | No | Yes | No |
| Firm fixed effects | No | No | No | No | No | Yes |
| Observations | 4610 | 4610 | 4610 | 4610 | 4610 | 3361 |
| Log-likelihood | -7150 | -7105 | -7018 | -6964 | -5584 | -3173 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.

## Table 6. H1 and H2: Alternative specifications

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | ZIP | NB | ZINB | Probit(>1) | Probit(>1) | Probit(>1) | Probit(>1) | Probit(>0) | Probit(>0) |
| **Share of interdependent segment pairs (K)** | 6.576*** | 7.466*** | 5.548*** | 7.667*** | 7.744*** | 11.073*** | 16.077*** | 1.502 | 7.088** |
| | [0.711] | [0.795] | [0.924] | [1.230] | [1.230] | [1.458] | [3.262] | [1.084] | [3.109] |
| **K^2** | -4.061*** | -4.701*** | -3.351*** | -4.699*** | -4.751*** | -6.850*** | -11.075*** | -0.611 | -4.736** |
| | [0.463] | [0.513] | [0.603] | [0.792] | [0.792] | [0.938] | [2.171] | [0.727] | [2.088] |
| **Number of units per thousand employees^ (M)** | 0.239*** | 0.249*** | 0.268*** | 0.197*** | 0.211*** | 0.255*** | 0.448*** | 0.196*** | 0.226 |
| | [0.028] | [0.032] | [0.040] | [0.047] | [0.048] | [0.058] | [0.163] | [0.052] | [0.159] |
| Number of industries in the sector | 0.019*** | 0.016*** | 0.016*** | 0.014*** | 0.014*** | 0.227*** | 0.035*** | 0.029 | 0.024*** |
| | [0.001] | [0.001] | [0.002] | [0.002] | [0.002] | [0.021] | [0.006] | [0.052] | [0.006] |
| Growth in shipment value in the primary industry | -0.178** | -0.291*** | -0.299** | -0.370*** | -0.321** | 0.083 | -0.066 | -0.024 | -0.299 |
| | [0.081] | [0.087] | [0.118] | [0.126] | [0.129] | [0.158] | [0.279] | [0.135] | [0.264] |
| Avg. growth in shipment value in related industries | 0.866** | 0.960** | 1.732* | 0.769* | 2.107*** | 0.078 | -1.418 | 0.215 | -1.908** |
| | [0.358] | [0.422] | [1.044] | [0.438] | [0.632] | [0.526] | [0.899] | [0.483] | [0.918] |
| Primary industry HHI^ | -0.067*** | -0.086*** | -0.086*** | -0.093*** | -0.095*** | 0.044 | -0.171** | 0.086 | -0.07 |
| | [0.014] | [0.015] | [0.018] | [0.024] | [0.024] | [0.098] | [0.084] | [0.097] | [0.080] |
| Avg. HHI in related industries^ | 0.370*** | 0.228*** | 0.417*** | 0.329*** | 0.334*** | 9.297*** | 0.425 | 0.315 | -0.093 |
| | [0.061] | [0.068] | [0.104] | [0.099] | [0.099] | [0.180] | [0.321] | [1.642] | [0.311] |
| Firm employees (M)^ | 0.282*** | 0.313*** | 0.290*** | 0.232*** | 0.245*** | 0.315*** | 0.537*** | 0.301*** | 0.434*** |
| | [0.026] | [0.030] | [0.038] | [0.045] | [0.045] | [0.056] | [0.160] | [0.051] | [0.158] |
| Product diversification: number of segments | 0.025*** | 0.033*** | 0.033*** | 0.076*** | 0.076*** | 0.096*** | 0.145*** | 0.085*** | 0.125*** |
| | [0.001] | [0.002] | [0.002] | [0.005] | [0.005] | [0.006] | [0.013] | [0.007] | [0.016] |
| Geographic dispersion: number of countries^ | -0.145*** | -0.176*** | -0.156*** | -0.113*** | -0.121*** | -0.218*** | -0.222 | -0.251*** | -0.209 |
| | [0.021] | [0.024] | [0.031] | [0.036] | [0.036] | [0.046] | [0.143] | [0.044] | [0.147] |
| Constant | -5.494*** | -4.785*** | -5.412*** | -6.400*** | -6.572*** | -76.617 | -11.679*** | -4.806 | -2.376 |
| | [0.481] | [0.543] | [0.753] | [0.789] | [0.795] | [0.000] | [2.385] | [12.868] | [2.310] |

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
|---|---|---|---|---|---|---|---|---|---|
| | **ZIP** | **NB** | **ZINB** | **Probit(>1)** | **Probit(>1)** | **Probit(>1)** | **Probit(>1)** | **Probit(>0)** | **Probit(>0)** |
| Year fixed effects | Yes | Yes | Yes | No | Yes | No | No | No | No |
| Industry fixed effects | No | No | No | No | No | Yes | No | Yes | No |
| Firm random effects | No | No | No | No | No | No | Yes | No | Yes |
| Observations | 4610 | 4610 | 2942 | 4610 | 4610 | 4488 | 4610 | 4265 | 4610 |
| Log-likelihood | -6771 | -6837 | -4190 | -2306 | -2300 | -1809 | -1188 | -2196 | -1334 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.

**Table 7. H1 and H2: Probit estimation of entry into a related industry – primary and target industries' characteristics**

| **SIC=35** | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|---|---|---|---|---|---|---|
| Industry growth in shipment value | | | | | | |
| ----- Primary industry | -0.546*** | -0.507*** | -0.508*** | -0.439*** | | -1.038*** |
| | [0.106] | [0.107] | [0.106] | [0.110] | | [0.123] |
| ----- Target industry | 1.341*** | 1.308*** | 1.315*** | 1.210*** | | 0.854*** |
| | [0.116] | [0.117] | [0.117] | [0.119] | | [0.123] |
| Industry concentration – HHI | | | | | | |
| ----- Primary industry | 0.000* | 0.000* | 0.000* | 0.000** | | -0.000*** |
| | [0.000] | [0.000] | [0.000] | [0.000] | | [0.000] |
| ----- Target industry | -0.000*** | -0.000*** | -0.000*** | -0.000*** | | -0.000*** |
| | [0.000] | [0.000] | [0.000] | [0.000] | | [0.000] |
| Industry capital intensity (CAPEX per $ of shipment value) | | | | | | |
| ----- Primary industry | | 3.025** | | 3.156** | | 11.055*** |
| | | [1.352] | | [1.497] | | [1.460] |
| ----- Target industry | | -2.497** | | -2.563** | | -2.678** |
| | | [1.253] | | [1.281] | | [1.311] |
| Industry R&D intensity (R&D expenditure per $ of shipment value) | | | | | | |
| ----- Primary industry | | | -0.013*** | 0.02 | | |
| | | | [0.005] | [0.015] | | |
| ----- Target industry | | | 0.019*** | -0.035** | | |
| | | | [0.006] | [0.015] | | |
| Industry advertisement intensity (advertisement expenditure per $ of shipment value) | | | | | | |
| ----- Primary industry | | | | -0.206 | | |
| | | | | [0.256] | | |
| ----- Target industry | | | | 0.162 | | |
| | | | | [0.111] | | |

| **SIC=35** | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** |
|---|---|---|---|---|---|---|
| Industry profitability (EBITDA/Sales) | | | | | | |
| ----- Primary industry | | | | 0.012** | | |
| | | | | [0.006] | | |
| ----- Target industry | | | | -0.023*** | | |
| | | | | [0.006] | | |
| Forward horizontal relatedness: primary and target industries' similarity in customer base | | | | | 1.408*** | 1.365*** |
| | | | | | [0.115] | [0.117] |
| Backward horizontal relatedness: primary and target industries' similarity in inputs | | | | | -1.353*** | -1.803*** |
| | | | | | [0.080] | [0.091] |
| Forward vertical relatedness: dollar value of inputs needed from the primary industry to produce $1 of target industry's output | | | | | -4.779*** | -2.15 |
| | | | | | [1.676] | [1.774] |
| Backward vertical relatedness: dollar value of inputs needed from the target industry to produce $1 of primary industry's output | | | | | 8.030*** | 10.662*** |
| | | | | | [1.549] | [1.603] |
| Constant | -1.605*** | -1.619*** | -1.611*** | -1.621*** | -1.187*** | -0.814*** |
| | [0.042] | [0.065] | [0.042] | [0.070] | [0.041] | [0.083] |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 15925 | 15925 | 15925 | 15842 | 15208 | 15208 |
| Log-likelihood | -3167 | -3162 | -3158 | -3131 | -2883 | -2749 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.

**Table 8. H1 and H2: Probit estimation of entry into a related industry – firm characteristics**

| SIC=35 | (1) | (2) | (3) |
|---|---|---|---|
| Firm size: number of employees (Mil)^ | 0.025* | 0.029** | 0.044*** |
| | [0.014] | [0.015] | [0.016] |
| Product diversification: number of segments | 0.030*** | 0.030*** | 0.038*** |
| | [0.002] | [0.002] | [0.003] |
| Geographic dispersion: number of countries^ | 0.007 | 0.01 | -0.03 |
| | [0.020] | [0.021] | [0.023] |
| Forward horizontal relatedness | | | 1.338*** |
| | | | [0.121] |
| Backward horizontal relatedness | | | -2.091*** |
| | | | [0.096] |
| Forward vertical relatedness | | | 0.35 |
| | | | [1.770] |
| Backward vertical relatedness | | | 11.769*** |
| | | | [1.647] |
| Primary industry growth in shipment value | | -0.315*** | -0.894*** |
| | | [0.112] | [0.128] |
| Target industry growth in shipment value | | 1.365*** | 0.859*** |
| | | [0.120] | [0.127] |
| Primary industry concentration – HHI | | -0.000* | -0.000*** |
| | | [0.000] | [0.000] |
| Target industry concentration – HHI | | -0.000*** | -0.000*** |
| | | [0.000] | [0.000] |
| Primary industry capital intensity | | 2.521* | 10.932*** |
| | | [1.426] | [1.545] |
| Target industry capital intensity | | -2.977** | -2.949** |
| | | [1.294] | [1.354] |
| Constant | -1.951*** | -1.816*** | -0.881*** |
| | [0.039] | [0.074] | [0.093] |
| Year fixed effects | Yes | Yes | Yes |
| Observations | 15925 | 15925 | 15208 |
| Log-likelihood | -3096 | -3008 | -2579 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.

## Table 9. H1 and H2: Probit estimation of entry into a related industry – interdependencies and coordinating units

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | **SIC=35** | **SIC=35** | **SIC=34** | **SIC=36** | **SIC=37** | **SIC=38** |
| **Share of interdependent segment pairs (K)** | 1.899*** | 1.726*** | 1.296* | 1.196*** | 1.445 | 1.460** |
| | [0.474] | [0.475] | [0.784] | [0.320] | [0.943] | [0.575] |
| **K^2** | -1.236*** | -1.087*** | -0.847 | -0.783*** | -0.772 | -0.892** |
| | [0.340] | [0.343] | [0.620] | [0.260] | [0.771] | [0.450] |
| **Number of units per thousand employees^ (M)** | | 0.125*** | 0.266** | 0.123*** | 0.075 | 0.1 |
| | | [0.045] | [0.105] | [0.043] | [0.107] | [0.074] |
| Firm size: number of employees (Mil)^ | 0.040** | 0.150*** | 0.311*** | 0.106*** | 0.169 | 0.083 |
| | [0.016] | [0.043] | [0.101] | [0.040] | [0.105] | [0.069] |
| Product diversification: number of segments | 0.036*** | 0.032*** | 0.007 | 0.029*** | 0.029*** | 0.024*** |
| | [0.003] | [0.003] | [0.008] | [0.003] | [0.006] | [0.004] |
| Geographic dispersion: number of countries^ | -0.035 | -0.106*** | -0.048 | -0.05 | -0.310*** | -0.012 |
| | [0.023] | [0.034] | [0.075] | [0.034] | [0.092] | [0.056] |
| Forward horizontal relatedness | 1.334*** | 1.330*** | 0.451*** | 0.069 | 1.376*** | 0.368*** |
| | [0.121] | [0.121] | [0.154] | [0.090] | [0.170] | [0.122] |
| Backward horizontal relatedness | -2.129*** | -2.141*** | -2.493*** | -1.009*** | -3.748*** | -2.690*** |
| | [0.097] | [0.097] | [0.161] | [0.087] | [0.276] | [0.127] |
| Forward vertical relatedness | 0.715 | 0.651 | 11.065*** | 1.977*** | 1.854* | 22.815*** |
| | [1.776] | [1.775] | [3.916] | [0.533] | [1.018] | [4.717] |
| Backward vertical relatedness | 11.848*** | 12.038*** | 9.900* | 2.260*** | 6.835*** | 25.105*** |
| | [1.653] | [1.654] | [5.622] | [0.521] | [1.156] | [4.042] |
| Primary industry growth in shipment value | -0.925*** | -0.865*** | 0.421 | -0.178 | -0.237 | -1.022*** |
| | [0.129] | [0.130] | [0.575] | [0.138] | [0.513] | [0.303] |
| Target industry growth in shipment value | 0.854*** | 0.849*** | -0.219 | 1.529*** | -0.307 | 0.223 |
| | [0.127] | [0.127] | [0.422] | [0.150] | [0.388] | [0.258] |
| Primary industry concentration – HHI | -0.000*** | -0.000*** | -0.000* | 0 | -0.000*** | -0.000*** |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| Target industry concentration – HHI | -0.000*** | -0.000*** | -0.001*** | -0.001*** | -0.000* | -0.000*** |
| | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] | [0.000] |
| Primary industry capital intensity | 11.679*** | 11.818*** | -3.662 | 1.322 | -4.427 | 0.77 |
| | [1.565] | [1.572] | [4.971] | [1.542] | [5.619] | [2.393] |
| Target industry capital intensity | -2.915** | -2.934** | -0.809 | -0.501 | 26.511*** | -2.525 |
| | [1.357] | [1.358] | [3.563] | [1.406] | [4.153] | [2.147] |
| Constant | -1.540*** | -1.667*** | -0.634** | -1.715*** | -0.936** | -0.429* |
| | [0.182] | [0.187] | [0.322] | [0.141] | [0.382] | [0.240] |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes |
| Observations | 15208 | 15208 | 3152 | 11246 | 1465 | 3954 |
| Events of entry | 801 | 801 | 229 | 822 | 234 | 522 |
| Log-likelihood | -2567 | -2564 | -617 | -2516 | -453 | -1151 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.

**Table 10. H3 and H4: OLS estimation of the impact of environmental volatility and task indecomposability on the number of coordinating units**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| **Environmental Volatility** | | | | | | | |
| **----- Industry stock return beta** | | -0.014** | | | | -0.015** | -0.010 |
| | | [0.007] | | | | [0.007] | [0.007] |
| **----- Industry stock return variance** | | | -0.606** | | | | |
| | | | [0.257] | | | | |
| **Task indecomposability** | | | | | | | |
| **----- 1/(Modularity index)**[a] | | | | -0.000*** | | | |
| | | | | [0.000] | | | |
| **----- Portfolio not decomposable at all (1,0)** | | | | | -0.088** | -0.088*** | -0.089** |
| | | | | | [0.020] | [0.020] | [0.237] |
| Less than five segments (1,0) | | | | -0.216*** | -0.219*** | -0.220*** | -0.200*** |
| | | | | [0.026] | [0.026] | [0.028] | [0.028] |
| Share of interdependent segment pairs (K) | 2.777*** | 2.767*** | 2.796*** | 1.802*** | 1.787*** | 2.050*** | 2.028*** |
| | [0.295] | [0.295] | [0.298] | [0.312] | [0.312] | [0.351] | [0.351] |
| K^2 | -2.111*** | -2.105*** | -2.123*** | -1.389*** | -1.380*** | -1.474*** | -1.456*** |
| | [0.199] | [0.199] | [0.201] | [0.212] | [0.212] | [0.238] | [0.238] |
| Firm size: number of employees (Mil)^ | -0.911*** | -0.912*** | -0.911*** | -0.920*** | -0.920*** | -0.920*** | -0.921*** |
| | [0.007] | [0.007] | [0.007] | [0.007] | [0.007] | [0.010] | [0.010] |
| Product diversification: number of segments | 0.032*** | 0.032*** | 0.031*** | 0.030*** | 0.029*** | 0.030*** | 0.030*** |
| | [0.001] | [0.001] | [0.001] | [0.001] | [0.001] | [0.001] | [0.001] |
| Geographic dispersion: number of countries^ | 0.648*** | 0.648*** | 0.648*** | 0.646*** | 0.645*** | 0.706*** | 0.707*** |
| | [0.010] | [0.010] | [0.010] | [0.010] | [0.010] | [0.012] | [0.012] |
| Firm age: years since establishment^ | 0.067*** | 0.067*** | 0.031** | 0.052*** | 0.052*** | 0.018 | 0.018 |
| | [0.016] | [0.016] | [0.015] | [0.016] | [0.015] | [0.048] | [0.048] |
| Constant | 0.156 | 0.179 | 0.258** | 0.652*** | 0.678*** | 0.571*** | 0.576*** |
| | [0.115] | [0.115] | [0.115] | [0.126] | [0.126] | [0.208] | [0.208] |
| Year fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| Firm random effects | Yes | Yes | Yes | Yes | Yes | Yes | No |
| Firm fixed effects | No | No | No | No | No | No | Yes |

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| Observations | 4610 | 4609 | 4609 | 4610 | 4609 | 4609 | 4609 |
| Number of firms | 965 | 965 | 965 | 965 | 965 | 965 | 965 |
| Chi2/F-stats | 19868 | 19882 | 19251 | 20377 | 20395 | 634 | 604 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.
[a] For portfolios that are not decomposable at all, the indecomposability index is set at 1/0.005=200.

## Table 11. H1 and H2: IV Probit and 3SLS

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | **Probit (Table 6, Column 4)** | **IVProbit Stage 1** | **IVProbit Stage 2** | **IVProbit Stage 1** | **IVProbit Stage 2** | **3SLS** | **3SLS** |
| **Dependent variable** | **$D^R$ >1 (1,0)** | **M** | **$D^R$ >1 (1,0)** | **M** | **$D^R$ >1 (1,0)** | **M** | **$D^R$** |
| **Number of related segments ($D^R$)** | | | | | | 0.035 | |
| | | | | | | [0.030] | |
| **Number of units per thousand employees^ (M)** | 0.197*** | | 0.643* | | 1.078*** | | 0.859*** |
| | [0.047] | | [0.363] | | [0.315] | | [0.323] |
| **Share of interdependent segment pairs (K)** | 7.667*** | 2.665*** | 6.221*** | 2.631*** | 4.449** | 2.434*** | 1.735 |
| | [1.230] | [0.294] | [1.788] | [0.295] | [1.833] | [0.316] | [1.272] |
| **K^2** | -4.699*** | -2.106*** | -3.592*** | -2.083*** | -2.283* | -1.957*** | -0.469 |
| | [0.792] | [0.196] | [1.259] | [1.274] | [0.196] | [0.208] | [0.929] |
| Firm age: years since establishment^ | 0.014*** | 0.079*** | | 0.076*** | | 0.073*** | |
| | [0.002] | [0.009] | | [0.009] | | [0.010] | |
| Environmental volatility | -0.370*** | -0.034*** | | -0.026** | | -0.033*** | |
| | [0.126] | [0.012] | | [0.012] | | [0.010] | |
| Change in CEO (1,0) | 0.769* | | | -0.045*** | | -0.039*** | |
| | [0.438] | | | [0.013] | | [0.013] | |
| Number of industries in the sector | -0.093*** | | 0.013*** | | 0.012*** | | 0.020*** |
| | [0.024] | | [0.002] | | [0.002] | | [0.002] |
| Firm size: number of employees (Mil)^ | 0.329*** | -0.075** | -0.307** | -0.079** | -0.228* | -0.883*** | 0.809*** |
| | [0.099] | [0.037] | [0.137] | [0.037] | [0.136] | [0.006] | [0.284] |
| Product diversification: number of segments | 0.232*** | 0.785*** | 0.337 | 0.805*** | -0.119 | 0.026*** | 0.103*** |
| | [0.045] | [0.137] | [0.564] | [0.137] | [0.543] | [0.004] | [0.011] |
| Geographic dispersion: number of countries^ | 0.076*** | -0.020*** | -0.081*** | -0.020*** | -0.063** | 0.555*** | -0.526*** |
| | [0.005] | [0.008] | [0.027] | [0.028] | [0.008] | [0.008] | [0.181] |
| Growth in shipment value in the primary industry | -0.113*** | 0.041 | 0.302*** | 0.038 | 0.263*** | -0.066* | -0.232** |
| | [0.036] | [0.030] | [0.102] | [0.030] | [0.101] | [0.037] | [0.118] |
| Avg. growth in shipment value in related | -6.400*** | -0.878*** | 0.620** | -0.879*** | 0.995*** | 0.769*** | 0.228 |

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) |
|---|---|---|---|---|---|---|---|
| | **Probit (Table 6, Column 4)** | **IVProbit Stage 1** | **IVProbit Stage 2** | **IVProbit Stage 1** | **IVProbit Stage 2** | **3SLS** | **3SLS** |
| **Dependent variable** | **$D^R$ >1 (1,0)** | **M** | **$D^R$ >1 (1,0)** | **M** | **$D^R$ >1 (1,0)** | **M** | **$D^R$** |
| industries | | | | | | | |
| | [0.789] | [0.005] | [0.316] | [0.005] | [0.271] | [0.140] | [0.508] |
| Primary industry HHI^ | 7.667*** | 0.029*** | 0.061*** | 0.029*** | 0.042*** | -0.017*** | -0.110*** |
| | [1.230] | [0.001] | [0.015] | [0.001] | [0.016] | [0.008] | [0.025] |
| Avg. HHI in related industries^ | -4.699*** | 0.553*** | -0.361* | 0.553*** | -0.601*** | 0.033 | 0.264*** |
| | [0.792] | [0.008] | [0.203] | [0.008] | [0.176] | [0.027] | [0.093] |
| Constant | 0.197*** | 0.158 | -6.404*** | 0.21 | -6.156*** | 0.307* | -3.416*** |
| | [0.047] | [0.784] | [0.784] | [0.225] | [0.805] | [0.195] | [0.685] |
| Observations | 4610 | 4609 | | 4609 | | 4560 | 4560 |
| Log-likelihood | -2306 | -5117 | | -5111 | | | -10505 |
| R2 | | | | | | 0.87 | 0.41 |

Standard errors in brackets. * significant at 10%; ** significant at 5%; *** significant at 1%. ^ log value.

**Table 12. H5: Performance implication**

| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|---|
| Number of related segments ($D^R$) | 0.003 | 0.003 | -0.003 | -0.002 | -0.001 | -0.001 | -0.003 | -0.002 |
| | [0.002] | [0.002] | [0.003] | [0.003] | [0.002] | [0.002] | [0.003] | [0.003] |
| Number of units per thousand employees^ (M) | -0.034*** | -0.041*** | -0.042*** | -0.030*** | -0.019*** | -0.026*** | -0.042*** | -0.030*** |
| | [0.007] | [0.007] | [0.009] | [0.010] | [0.005] | [0.005] | [0.009] | [0.010] |
| **Mismatch** | -0.021*** | -0.020*** | -0.032*** | -0.036*** | -0.008 | -0.006 | -0.032*** | -0.036*** |
| | [0.008] | [0.008] | [0.008] | [0.008] | [0.006] | [0.006] | [0.008] | [0.008] |
| Firm size: number of employees (Mil)^ | -0.001 | -0.005 | 0.024*** | 0.053*** | 0.007 | 0.002 | 0.024*** | 0.053*** |
| | [0.007] | [0.007] | [0.009] | [0.011] | [0.005] | [0.005] | [0.009] | [0.011] |
| Product diversification: number of segments | -0.002*** | -0.002*** | 0.000 | 0.001 | -0.001*** | -0.001** | 0.000 | 0.001 |
| | [0.001] | [0.001] | [0.001] | [0.001] | [0.000] | [0.000] | [0.001] | [0.001] |
| Geographic dispersion: number of countries^ | 0.035*** | 0.037*** | 0.023*** | 0.005 | 0.019*** | 0.021*** | 0.023*** | 0.005 |
| | [0.006] | [0.006] | [0.009] | [0.010] | [0.004] | [0.004] | [0.009] | [0.010] |
| Capital intensity (CAPEX/Sales)^ | 0.025*** | 0.019*** | -0.006 | -0.009** | 0.013*** | 0.009*** | -0.006 | -0.009** |
| | [0.004] | [0.004] | [0.004] | [0.004] | [0.003] | [0.003] | [0.004] | [0.004] |
| R&D intensity (R&D/Sales)^ | -0.060*** | -0.056*** | -0.126*** | -0.155*** | -0.048*** | -0.045*** | -0.126*** | -0.155*** |
| | [0.003] | [0.003] | [0.005] | [0.006] | [0.002] | [0.002] | [0.005] | [0.006] |
| Constant | 0.016 | 0.021 | -0.294*** | -0.401*** | -0.122*** | -0.116*** | -0.294*** | -0.401*** |
| | [0.017] | [0.019] | [0.024] | [0.026] | [0.012] | [0.014] | [0.024] | [0.026] |
| “Chop-shop” approach | No | No | No | No | Yes | Yes | Yes | Yes |
| Year fixed effects | No | Yes | Yes | Yes | No | Yes | Yes | Yes |
| Firm random effects | No | No | Yes | No | No | No | Yes | No |
| Firm fixed effects | No | No | No | Yes | No | No | No | Yes |
| Observations | 4059 | 4059 | 4059 | 4059 | 4053 | 4053 | 4053 | 4053 |
| R-squared | 0.15 | 0.16 | | 0.24 | 0.16 | 0.18 | | 0.24 |
| Chi2/F-stat | | | 1110.18 | 56.98 | | | 1108.31 | 56.88 |