(IN)SIGNIFICANT OTHERS: THE IMPACT OF BUYER-SUPPLIER RELATIONSHIPS ON THE SURVIVAL OF MODULAR AND ARCHITECTURAL COMPONENT SUPPLIERS

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ABSTRACT

Relationship duration, supplier autonomy, and customer status affect the performance of suppliers of modular and architectural components differently. Data on U.S. carburetor and clutch manufacturers from 1918 to 1970 shows that suppliers of architectural goods (carburetors) benefit from high status customers, current autonomy, and, to a lesser extent, long-term relationships. Only autonomy affects the survival of modular good suppliers (clutches). Relationships requiring extensive sets of inter-firm routines, as in the case of architectural components, lead to greater relationship benefits and constraints.

Key words: Modularity, architectural components, buyer-supplier relationships, status, autonomy, and relationship duration
The past two decades have seen the rise of two related phenomena in many industries: increasing modularity in product design and a shift to more flexible, disaggregated supply chains (Schilling and Steensma 2001; Zenger and Hesterly 1997). Modular design involves creating end-products that use substitutable components, in contrast with more architectural design in which end products require particular dedicated components (Schilling 2000). Modularity and supply chain flexibility tend to co-occur because increasing product modularity decreases the specialization of the interfaces between the producer of the final product and the suppliers of various components of that product (Sanchez and Mahoney 1996). These trends raise the issue of how different aspects of relationships with buyers influence supplier performance, which has been a long-standing but often understated interest within business strategy research (Martin, Swaminathan, and Mitchell 1998).

Differences in supply relationships can affect the performance of both buyers and suppliers. Supply chain flexibility and component modularity can improve the performance of buyers, that is, the producers of the final product (Vickery, Calantone, and Droge 1999). At the heart of many of the advantages of supply chain flexibility is the buyer’s improved ability to drop, add, or change suppliers in response to changing conditions (Garud and Kumaraswamy 1995). Rather than being locked into pre-existing conditions, a buyer can choose the best supplier at any point in time (Hoetker 2001). Because a producer can consider a larger number of suppliers, the buyer can, in essence, consider the outcomes of multiple experiments in how to design each component, increasing the expected value of the approach ultimately chosen (Baldwin and Clark 2000; Langlois and Robertson 1992).

Although supply chain flexibility offers obvious benefits for producers, we understand much less about how it affects suppliers. If buyers can easily switch between suppliers, what impact does this have on suppliers? A supplier’s bargaining position would seem weaker when it is easier for a customer to walk away. On the other hand, if all buyers are able to switch suppliers easily, a supplier might be able to find a new customer more easily. The end result is ambiguous. Given the importance of buyer-supplier relationships at both the firm and industry evolution (Clark and Fujimoto 1991b) level, it is important to understand how supply relationships for modular components might differ from sales of architectural goods.
This paper contributes to this understanding by comparing and contrasting buyer-supplier relationships for modular and architectural components. We study how three aspects of a supplier's customer relationships affect supplier performance: duration of relationships, autonomy from its customers, and linkages to prominent buyers. We focus on these three aspects of buyer-supplier relationships because theory and empirical results suggest that each should significantly influence firm performance. First, firms involved in enduring dyadic relationships benefit from the knowledge sharing, trust, and interorganizational routines that develop within such relationships (Levinthal and Fichman 1988). Second, the firms that enjoy a higher level of autonomy in their transaction networks occupy advantageous positions in their industries (Burt 1992; Uzzi 1997) while, conversely, firms with little autonomy may become dependent on their partners. Third, firms that affiliate with more prominent partners gain status and experience superior performance (Podolny 1993; Podolny and Page 1998). However, little is known of the relative importance of the three aspects of interfirm relationships in influencing firm performance. Indeed, no study has modeled the joint effects on firm performance of all three aspects of network structure. We argue that how each of the three aspects of buyer-supplier relationships affects supplier performance will differ, depending on whether a relationship involves modular or architectural components.

Our empirical study examines carburetor and clutch suppliers in the U.S. automobile industry from 1918 to 1942, with a supplemental extension to 1970. The data include the populations of the component suppliers and the automobile assemblers to which they sold goods during the study period. This empirical setting suits our intent to compare modular and architectural relationships, because clutches were significantly more modular than carburetors throughout this period.

THEORY AND HYPOTHESES

This section develops our arguments concerning how the duration, autonomy, and customer prominence influence supplier performance. We state the predictions concerning supplier performance in terms of business failure, i.e., business dissolution. Failure is an appropriate performance measure for the empirical context of our study, in which financial performance measures are not available. Moreover, business dissolution is a strong indicator of financial problems, particularly in commercial contexts in which business divestiture offers an alternative means by which more successful firms can chose to exit an industry for strategic reasons. Figure 1 provides an overview of the predictions.

********** Figure 1 about here **********
Duration of Buyer-Supplier Relationships and Supplier Performance

Long-term vertical relationships are common in any context in which small numbers of buyers and suppliers exchange products or services that are complex or involve sensitive delivery systems. Examples include railroad transportation (Macaulay 1963), aerospace (Masten 1984), financial auditing (Levinthal and Fichman 1988), advertising services (Baker, Faulkner, and Fisher 1998), the automotive industry (Cusumano and Takeishi 1991), advanced materials (Ahuja 2000), and apparel manufacturing (Uzzi 1997). Long-term inter-firm supply relationships provide an alternative to simple make-or-buy choices in which firms locate transaction-specific assets internally and govern general assets through short-term contracts (Williamson 1975). Even for components that require transaction-specific investments, long-term relationships with suppliers are often superior to internal sourcing when suppliers can produce higher-quality or lower-cost goods than an internal operation (Nishiguchi 1994). Long-term supply relationships tend to be superior to short-term relationships when products are complex, technology is changing, there are complicated interactions among components, information transfer is difficult and uncertain, or when a trading relationship requires specialized human skills (Helper 1987).

The benefits of long-term supply relationships arise from three related sources: the development of knowledge of each partner, the development of trust, and the development of relationship-specific routines. The first benefit of long-term relationships, as Ring and Van de Ven (1994) argue, is that they generate greater knowledge of each partner's routines because collaborative processes lead to interaction of people from the partner firms. Larson, Bengtsson, Henriksson and Sparks (1998) show that such knowledge can serve as the basis for coordinating joint activities and for reacting to changing circumstances that the partners face in common by developing joint problem-solving arrangements. Dussauge, Garrette and Mitchell (2000) show, in a study of international alliances, that firms' ability to reduce costs, increase quality, and achieve greater timeliness increase as a relationship lengthens by learning from each other and about each other. In turn, these operating advantages may lead to superior performance relative to firms that do not enjoy long-term relationships.

Second, long-term relationships can lead to the development of trust (Uzzi 1996). Zaheer, McEvily, and Perrone (1998) found that high levels of inter-organizational trust correlated with lower costs of negotiation and superior performance for the exchange partners. Trust allows firms to engage in cooperative activities that would be difficult to manage purely by contractual relationships.

Third, the act of interacting over a long period generates relation-specific routines. Each firm
develops internal routines that are especially suited for interacting with the specific partner (Asanuma 1989; Martin 1996). Firms also develop beneficial routines that span the partner organizations (Mitchell and Singh 1996). Examples of such routines include just-in-time delivery systems, systems for exchanging information and personnel, and cooperation in product development, all of which require learning and investment on the part of both buyer and supplier (Clark and Fujimoto 1991a). These routines allow the firms to gain cost, quality, and timeliness advantages that in turn lead to superior performance.

Because of the joint advantages of relationship-specific knowledge, trust, and routines, long-term relationships generate performance advantages for their members. Dyer (1996) found a positive relationship between supplier-automaker specialization and performance in a study of U.S. and Japanese automakers and their suppliers. In Dyer’s study, interfirm human asset cospecialization correlated with superior quality and faster model cycle time, while site specialization correlated with lower inventory costs. In a study of industrial buyers and suppliers, Heide and Miner (1992) found that buyer-supplier cooperation increased both with future anticipated interaction and with higher frequency of contact in the existing relationships. The benefits derived from long-term relationships often generate a sustainable competitive advantage for suppliers, because creating a long-term buyer-supplier relationship, by definition, requires time and, moreover, can often be a difficult process (Eccles 1981; Heide and John 1990). Therefore, we expect supplier firms that have long-term relationships with their buyers will enjoy enhanced survival prospects.

**Hypothesis 1a.** The longer the duration of the relationship between a supplier firm and its assembler buyers, the less likely the supplier will fail.

The effects of relationship duration will be contingent upon the nature of the products that a supplier sells. We distinguish between architectural components and modular components (Henderson and Clark 1990). Architectural components are specialized goods that require substantial customization to fit within a customer's overall product and, indeed, may require refinement of the customer's product to adapt to changes in component technology. By contrast, modular components are more general goods that require little refinement to either component or end-product.

Of course, modular and architectural describe the extremes of a spectrum of inter-relatedness and specificity, rather than indicating two states divided by a distinct line. Nonetheless, when the components under discussion stand far apart in this spectrum, it is convenient to refer to them as simply “modular” and “architectural”, as we do in this paper. We use carburetors as examples.
of architectural goods during our study period, because carburetor design and production required customization to and of automobile ignition systems, fuel systems, power train, and other automobile characteristics. We use clutches as examples of modular components because, by about 1919, the relatively simple single-plate clutch had become the dominant choice of most automobile manufacturers and required little customization for specific customer models.

We expect the benefits of long-term relationships will be greater for suppliers of architectural components than for suppliers of modular components. The supply of architectural components tends to require the relationship-specific knowledge, trust, and routines that flow from long-term relationships. Over time, as a supplier continues to provide architectural components to a buyer, the benefits of operating and technical knowledge, as well as customer commitment and support tend to cumulate and provide resources that improve the supplier’s performance. By contrast, the supply of modular components will require more general investments that are more transparent and derive fewer benefits from relationship-specific knowledge, trust, and routines. Even suppliers that have provided modular components to a given buyer for many years will accumulate fewer benefits that they can draw on to support their business. Instead, the primary benefits that derive from sales of modular components are immediate revenues, which apply whether a supplier has a long term relationship or only recently has begun to sell the goods.

**Hypothesis 1b.** The benefits of long-term relationships will be greater for suppliers of architectural components than for suppliers of modular components.

**Supplier Autonomy and Performance**

We continue by considering supplier autonomy as the second aspect of a supplier’s relationships with its customers. Early work on this aspect of interfirm relationships focused on a firm’s *dependence* on other organizations for resources (Emerson 1962; Pfeffer and Salancik 1978), while much of the more recent work (e.g. Burt 1992) uses the language of *autonomy*, that is, the freedom from dependence.

Suppliers that become dependent on their buyers often face performance problems, resulting either from opportunistic behavior by partners or from lack of access to wider sources of information that arise when suppliers have multiple customers. While there are advantages of specialization economies to a supplier becoming tightly bound to a buyer, dependence is likely to give the buyer significant power over the supplier, because most of the supplier’s efforts are involved in its relationship with the buyer. When a supplier is dependent for the bulk of its sales on a particular buyer, the buyer may use its power to extract rents from the supplier, limit the
ability of the supplier to sell goods to other buyers, or otherwise disadvantage the supplier (Baker 1990; Williamson 1993). Financial problems at the DaimlerChrysler automotive firm during early 2001, for instance, led the company to put extreme pressure on dependent suppliers. Suppliers that had previously benefited from close relationships with Chrysler found themselves facing threats to their survival, as they were forced to cut prices severely and to lay off employees.

In addition to risking problems of opportunistic hold-up, firms in long-term relationships also can face adaptation difficulties if they do not have alternative partners. Firms may come to rely on outmoded inter-firm routines in long-term relationships and thereby miss innovations that take place outside a partnership. Singh and Mitchell (1996) found that firms commonly found it difficult to adapt to environmental change if they became too reliant on partners. Uzzi (1996) found that if a firm became over-embedded in a network, the lack of arms-length relationships isolate it from the market’s imperatives and increase its likelihood of failure. Thus, suppliers will tend to benefit from greater degrees of autonomy from their buyers.

Supplier autonomy is the inverse of dependence, that is, it is the degree to which a supplier can act independently of its buyers. Burt (1992) formalized Emerson’s (1962) observation that the power relationship between two firms depends on a bilateral set of dependency relationships. In the context of buyer-supplier relationships, a supplier’s autonomy in its dealings with a buyer will depend on the difference between how dependent it is on the buyer and how dependent the buyer is on it.

A supplier will be highly dependent on a buyer if that buyer buys a large proportion of its output and it would be difficult for the supplier to find an alternative buyer for that output. However, this dependency can be balanced by a buyer’s dependency on the supplier. Such dependence would exist if the buyer had no alternative sources for the components that the supplier provides or if the firms had formed complex routines that spanned the boundaries of the two firms, making the assembler unable to replace the supplier easily (Baker 1990:594-595; Singh and Mitchell 1996). The key point is that it is the relative level of dependency that determines a supplier’s autonomy. A supplier with a single customer, a customer for which it is the only possible supplier for a component, may be in a better position than a supplier with several customers, each of which could easily switch to alternative suppliers.

The importance of autonomy can be seen through the activities firms undertake to minimize their dependence on outside organizations. A supplier can diversify its customer base either within its current markets or by seeking out entirely new markets. Japanese auto component sup-
pliers, such as Nippon Denso, expanded to the U.S. from the 1960s through the 1980s, in order to reduce their dependence on Japanese auto assemblers (Martin, Swaminathan, and Mitchell 1998).

We extend prior discussions of autonomy by introducing the more fine-grained concepts of current and potential autonomy. The current autonomy of a supplier is the dependence of a supplier on its existing buyers relative to the dependence of those buyers on it. High current autonomy denotes that a supplier with many trading partners is not overly dependent on any one of them, especially if the buyers have few alternative suppliers. In addition, the presence of potential buyers beyond those with which a supplier already trades increases the alternatives of a given supplier, which we refer to as potential autonomy. A supplier’s potential autonomy measures its opportunities to form ties to new buyers—buyers with which it does not currently trade—relative to the opportunities available to its buyers to develop ties to new suppliers. Thus, the current autonomy of a supplier is higher when it has ties to many buyers that on average have ties to few suppliers. The potential autonomy of a supplier, meanwhile, is higher when it has many buyers available outside its current set of buyers and, on average, its buyers have few alternative suppliers.

We predict that higher current and potential autonomy will improve a supplier’s probability of survival. Higher autonomy realizes two benefits. First, higher autonomy provides greater ability to negotiate favorable terms from exchange partners and avoid demands from them (Burt 1992). Second, autonomy is an aggregate measure of a supplier’s dispensability in the eyes of its buyers and the importance of any single buyer to that supplier. Therefore, any given buyer is less likely to terminate purchases from a highly autonomous supplier and such a supplier will be less affected if a buyer does exit the relationship.

**Hypothesis 2a.** The higher the current and potential autonomy of a supplier firm, the less likely the supplier will fail.

We will further distinguish between the influence of current autonomy and potential autonomy based on the product-type contingency of architectural and modular components that we introduced in the prior section. We expect potential autonomy primarily to influence suppliers of modular components. Architectural components tend to face a high need for relation-specific coordination (Monteverde and Teece 1982). In such cases, potential autonomy will tend to have lower influence, because buyers and suppliers cannot easily switch partners, even if there are many other seemingly-potential suppliers and buyers in the industry. By contrast, modular components incur fewer requirements for relation-specific coordination and, as a result, buyers and
suppliers can switch partners more easily. Consequently, greater availability of potential partners offers greater easing of opportunism and coordination problems.

**Hypothesis 2b.** Potential autonomy will have a greater influence on the failure rates of suppliers of modular components than of suppliers of architectural components.

We leave investigation of whether current autonomy has differential impact on architectural and modular component suppliers as an exploratory issue. It is perhaps most likely that current autonomy provides benefits for all suppliers, by providing greater sales opportunities and helping firms resist the demands of a small number of buyers (even suppliers of modular components will incur adjustment costs if they must switch buyers). Alternatively, current autonomy might have a greater influence on architectural suppliers, owing to the high need for relation-specific routines.

**Supplier Status and Performance**

Potential buyers may have difficulty evaluating the quality of a supplier’s products directly. In such situations, a supplier’s affiliation with prominent partners provides information that helps resolve doubts about its quality. Prominent partners are those that enjoy high status in an industry. Third parties often trust the ability of high-status organizations to judge the quality of their affiliates (Podolny and Page 1998; Stuart 1998). Because of this combination of the prominent organization’s incentives and perceived good judgment, affiliation with a high-status organization provides a strong signal to third parties about the focal firm’s quality.

In the context of buyer-supplier relationships, legitimacy that arises from prominent buyers provides at least two benefits. First, legitimacy improves the supplier firm’s chances of attracting and retaining customers. When buyers have incomplete information about the relative technical sophistication, reliability, and quality of potential suppliers, they will often look for such secondary indicators of supplier characteristics (Podolny 1993:831). The tendency of firms to imitate the behavior of successful competitors (Haveman 1993) further accentuates the effects of status, especially in highly uncertain environments. Buyer firms are especially likely to imitate the supplier selection strategies of prominent buyers. Empirically, Walker, Kogut, and Shan (1997) found that biotechnology firms with higher status were likely to have more relationships with new partners in the subsequent time period (see also Powell, Koput, and Smith-Doerr 1996). Similarly, Baker, Faulkner, and Fisher (1998) found that advertising agencies with higher social status were more likely to maintain links with clients.

Therefore, it is not only the number of partners in a firm’s network, but also the identity of these partners that determines the value of the network to the firm. Because of this, firms may
actively seek out prominent partners. For example, Han (1994) argued that firms seek out the services of prominent auditors because of the impact of the affiliations on their own status. Multiple studies have found benefits to this strategy. Baum and Oliver (1991; 1992) found that day-care centers with links to legitimate organizations such as churches were more likely to survive. Stuart, Hoang, and Hybels (1999) found that ties to high-status alliance partners benefited private biotechnology firms by reducing the time until a start-up goes public and increasing the market value of the firm upon going public. Further, they show that much of this benefit is due to the transfer of status through the affiliation, rather than the flow of financial or technical resources from the partner firm. In a study of investment banks' activities in the non-investment grade market, Podolny and Phillips (1996) find that the higher the status of a bank’s affiliates, the greater the bank’s growth in status itself.

The implicit endorsement of a supplier by a prominent buyer also provides improved access to financial resources by legitimizing the firm in the eyes of potential investors and lenders. This endorsement could be vital in times of fiscal distress (Baum and Oliver 1991). Similarly, Singh, Tucker, and House (1986) found that the legitimacy provided by external linkages played a more important role in improving the survival prospects of new voluntary service organizations than did internal coordination.

The advantages of status require that the signal generated by the affiliation disseminate among potential buyers, investors, and lenders. Industry participants, the business press, and analysts are more likely to notice the actions of prominent buyers. Therefore, the signal generated by affiliation with a high-status buyer is valuable not only because it is a strong endorsement, but because it is likely to be widely disseminated (Stuart, Hoang, and Hybels 1999). Therefore, we hypothesize that selling to a high-status customer will improve a supplier's survival chances.

**Hypothesis 3a.** The higher the status of a supplier’s customers, the less likely the supplier will fail.

The effect of customer prominence on supplier performance is also contingent upon the nature of the component -- architectural or modular -- that the supplier sells to a buyer. The value of status derives from ambiguity about assessing a supplier's routines before entering into a relationship. Such ambiguity will tend to be much stronger for architectural components than for modular components. Because architectural components and the end products that use them require substantial refinement in a specific buyer-supplier relationship, potential buyers will incur difficulties in evaluating how well a potential supplier would fit their needs. Potential buyers need to evaluate not just the component in isolation, but also the ability and willingness of the
supplier to assist in making the required refinements. This ambiguity gives rise to the value of using a high-status customer’s judgment as a signal of supplier quality. By contrast, potential buyers of modular components can assess potential suppliers more easily before entering into relationships and will have less need to rely on the judgment of prominent customers.

Additionally, the cost of choosing a poor supplier is higher for architectural components than for modular component. Buyers can change the supplier of a modular product during a product life-cycle. By contrast, moving to a new supplier for an architectural component requires refining that supplier’s component to suit the end product. Because of the complex interconnectedness between component and end product, it may even require changes in the end product. Because of the extra cost, all information about the supplier’s quality, including the status of its customers, takes on extra value.

**Hypothesis 3b.** Status will have more influence on the failure rate of suppliers of architectural components than on the failure rate of suppliers of modular components.

In summary, the hypotheses address three aspects of a supplier’s relationships with its customers that we expect to influence supplier survival. Figure 1, which we introduced earlier, depicts the predictions. We expect failure rates to decline as the duration of buyer relationships increases, particularly for suppliers of architectural components. We expect failure rates to decline with greater current and potential supplier autonomy, with potential autonomy primarily affecting suppliers of modular components. Finally, we expect failure rates to decline with customer status, particularly for suppliers of architectural components. For suppliers of architectural components, then, survival chances increase with relationship duration, current structural autonomy, and customer status. For suppliers of modular components, meanwhile, survival chances increase with potential autonomy as well as with current autonomy. Together, these predictions describe a set of influences in which potential benefits of long-term relationships may co-exist with possible negative side effects of dependence, unless a supplier can both maintain long-term linkages with existing customers while also creating new linkages that provide concurrent autonomy. While some suppliers may be able to develop this balanced network evolution, others will falter and fail.

**DATA AND METHODS**

**Data**

We studied the survival of U.S. suppliers of carburetors and clutches in the automotive industry. We chose these components for several reasons: they represent important inputs into the automobile production process, there is substantial diversity of firms within these populations of
component manufacturers, the cases provide opportunities to compare architectural and modular components, and data are consistently available for them. Our primary data are drawn from the annual Statistics and Specifications issue of Automotive Industries, which was produced from 1918 to 1972. We focused our core analysis on the 1918 to 1942 period, in order to assess the pre-war evolutionary period of the industry during which entry and exit by both suppliers and assemblers was common. Industry conditions changed markedly during the Second World War when automobile factories converted to war production in 1943, drastically changing the competitive conditions that suppliers faced. Conditions changed again following the war, particularly in the form of consolidation among customers and consolidation among suppliers that meant there were few entries and exits from the component sectors that we study. We conducted supplemental analysis of the full 1918 to 1970 period to check for robustness of the results (the analyses for the 1918-1970 period do not have data for 1943-1945, when there was no consumer automobile production in the U.S.).

Automotive Industries identifies first-tier suppliers, which are the firms that sold components directly to assemblers, listed by automobile model. Since Automotive Industries provided specifications at the level of the division or model without listing the overarching company, we used information from Bailey (1971), Smith (1968), Mandel (1982), Gunnell (1982), and Kimes (1989) to construct life histories of assemblers and to connect divisions and models to the appropriate company. After aggregating the data upwards from the model and division levels to the firm level, we constructed the matrix of ties between supplier firms and buyer firms for carburetors and clutches for each year.

Automotive Industries professes to list every model of automobile produced in the United States. This allows us to overcome two common challenges in studies of buyer-supplier relationships, defining the boundaries of the industry and gathering complete information on the relevant relationships. We can sharply define two populations, including all U.S. commercial assemblers of automobiles and all of their suppliers for these two components. We also gathered a complete inventory of the buyer-supplier relationships for these components.

We gathered information about the performance and life history of individual suppliers from several sources, including annual reports, Poor’s Industrial Manual, Moody’s Manual Of Industrial Securities, the Thomas Register of American Manufacturers, Ward’s Automotive Yearbook, the trade press, corporate web sites and correspondence with suppliers. The Statistics and Specifications issue of Automotive Industries provides information on annual shipments for assemblers of at least medium size. We supplemented this with data from the Automotive News 100-
We use carburetors as examples of architectural goods and clutches as examples of modular goods during our study period. Carburetor design and production required customization to and of automobile ignition systems, fuel systems, power train, and other automobile characteristics. Throughout the study period, carburetors were complex goods (Dyke 1923; Page 1918). As Newcomb & Spurr (1989) noted, "even in the 1960s, the design of the [carburetor] system was still very much a matter of trial and error, and the final design largely a matter of compromise. A layout that could suit one engine might give poor results on another." In turn, this complexity made evaluation of the quality of a given suppliers' carburetors ambiguous for a customer that did not deal with the supplier. In such cases, a potential customer can gain valuable information that will help substitute for its own assessment of product quality by assessing the supplier choices of high status manufacturers. This ambiguity in direct product assessment underlies the value of status.

Clutches, by contrast with carburetors, had become relatively standard by the beginning of the study period. Even before 1920, Page (1918:635) noted, "friction clutches are simple in form, easily understood, and may be kept in adjustment and repair without difficulty." By about 1920, the relatively simple single-plate clutch had become the dominant choice of most automobile manufacturers and required little customization for specific automobile models (Dyke 1923). Newcomb & Spurr (1989:221) stated that "once established [by about 1919] the basic principles of the clutch remained unchanged for many years, though there was considerable improvement in the detail design." As a result, potential customers could evaluate a supplier's clutch quality directly, without needing to rely on the second-hand judgment of other customers, even highly prominent customers.

For an understanding of the early automotive industry, we relied on both historical and contemporary studies including Epstein (1928), Seltzer (1928), Kennedy (1941), Lewis (1947), Rae (1959; 1965; 1984), Smith (1968), Katz (1977) and Carroll, et al. (1996). We gained additional insights on the development of buyer-supplier relationships in the automobile industry from survey and historical research conducted by Womack, Jones, and Roos (1990), Clark and Fujimoto (1991b), Cusumano and Takeishi (1991), Helper (1991), and Hochfeld and Helper (1996). We gathered national economic data from the *Historical Statistics of the United States* (United States Bureau of the Census 1989).

**METHODS AND DEPENDENT VARIABLE**
We define supplier failure as a supplier shutting down its production in the automotive carburetor (clutch) market. We estimate the instantaneous rate of supplier dissolution, denoted by \( r(t) \):

\[
\lim_{\Delta t \to 0} \frac{p_i(t, t + \Delta t)}{\Delta t} = r(t)
\]

where \( p_i \) is the probability that a supplier fails between two discrete time points, while \( t \) measures firm age.

We used a piecewise exponential model. The model is extremely flexible with respect to the form of age dependence, about which we have no theoretical prediction. The model is also appropriate in the presence of left censoring (Barnett and Hansen 1996; Guo 1993), which is a characteristic of our sample. The model assumes a baseline transition rate that is constant within each of multiple time periods, but varies across periods.

The model we estimate can be written as:

\[
r(t) = \exp(\alpha P_t + \beta S_t)
\]

where \( r(t) \) is the baseline hazard rate, \( P_t \) is a matrix of variables measuring environmental conditions (time-varying, but invariant across suppliers), \( S_t \) is a matrix of time-varying variables describing the suppliers and \( \alpha \) and \( \beta \) are parameters to be estimated.

We used four time-periods in our estimation, dividing the data into firm ages of less than 5 years, 6-10 years, 11-15 years and greater than 15 years. Our results are robust to the selection of other cutoff points, as well as to the selection of other parametric forms of age dependence in the mortality rate including the Weibull, log-logistic, and lognormal specifications.

Our data are annual, so we update all time-varying covariates each year. We treated each annual spell as right-censored, except those spells that ended with the dissolution of the supplier. Following Petersen (1991), we treated dissolutions as having occurred midway though the year to reduce potential estimation bias. There were a small number of divestitures during the study period (11 carburetor suppliers and 6 clutch suppliers), which we treated as censoring events, rather than as a competing risk (conceptually, divestitures tend to result from different influences than dissolutions, so that it is not appropriate to pool dissolutions and divestitures into a single class of business exits).

Because we observe multiple annual spells for each supplier, we use a shared frailty model (Clayton 1978; Gutierrez 2002). In a shared frailty model, each supplier \( i \) is assumed to have a hazard rate of

\[
H_i(t | \alpha_i) = \alpha_i h_i(t)
\]

for \( j=1 \) to \( n_i \), where \( \alpha \) is some random positive quantity with mean one and variance \( \theta \). Suppliers for which \( \alpha \) is greater than one have an increased rate of failure (are more frail) for reasons
not explained by the covariates. Similarly, those with $\alpha$ less than one have a decreased rate of failure. This model allows for dependence between all observations of a supplier and may be thought of as the survival analysis equivalent to a random effects model in standard regression. Two distributions are commonly used for $\alpha$, gamma and inverse Gaussian. We report models with a gamma-distributed heterogeneity term,

$$g(\alpha) = \frac{\alpha^{\gamma-1} \exp(-\alpha/\theta)}{\Gamma(1/\theta) \theta^{\gamma}}$$

though we also estimated models with an inverse Gaussian distribution for $\alpha$ to check the robustness of our results.

We estimated separate failure rate models for the two populations of carburetor and clutch suppliers. We conduct these analyses separately for the two organizational populations because there are only two cases of firms manufacturing both carburetors and suppliers. Collapsing the two organizational populations into one would mistakenly constrain the effects of firm and industry-level variables to be equal across the two populations, an assumption that seems unwarranted. For carburetor suppliers, there were 225 firm-year observations involving 35 separate carburetor suppliers between 1918 and 1942 (296 observations and 37 firms between 1918 and 1970). Of these, 24 carburetor suppliers exited through dissolution by 1942 (also 24 by 1970). For clutch suppliers, there were 130 firm-year observations involving 30 separate clutch suppliers between 1918 and 1942 (173 observations and 32 firms between 1918 and 1970). There were 23 clutch supplier dissolutions by 1942 (24 dissolutions by 1970). These counts do not include assemblers that vertically integrated into production of the components. We took these assemblers into account in our calculations of current and potential autonomy, as described below, but did not include them in the sample of suppliers because the forces driving their involvement in component production differed from those of the independent suppliers. Since there were very few exits after 1942, we conduct our primary analysis over the period 1918-1942. We do, however, replicate the best-fitting model over the longer period, 1918-1970 for which data are available.

**Independent Focal Variables**

Table 1 provides descriptive statistics for the variables we used in this study.

********** Table 1 about here **********

To test our predictions, we needed variables for relationship duration, customer status, and supplier autonomy. In addition, as we discussed earlier, we used carburetors as examples of ar-
chitectural components and clutches as examples of components.

**Duration.** We measured the duration of a supplier’s relationship with an assembler as the cumulative years it had supplied the given component for at least one model produced by that assembler. We reset this count to zero if there was a span of greater than five consecutive years during which the supplier did not supply at least one model produced by that buyer. Resetting the count to zero captures the effect of the decay of relation-specific routines. In the case of an acquisition by either a supplier or an assembler, we based our calculations on the acquiring firm, assuming its routines will dominate.

A conceptual question arises with respect to the measurement of relationship duration, concerning whether the benefits of duration arise from a supplier's oldest existing relationship or from its pool of existing relationships. Operationally, the issue is whether maximum duration or average duration is the appropriate measure of relationship duration. We view maximum duration as an appropriate measure of relationship benefits, particularly when one employs dissolution as the measure of performance. In this approach, a supplier derives benefits from working with its longest-standing partner, which provides a resource base with which to protect it from demand fluctuations and to attract new customers. Therefore, we will test the first hypothesis in terms of the maximum duration of a supplier's relationships with its customers. In sensitivity analysis, we investigate the mean duration of a supplier's relationships, in which the benefits of relationships accumulate across partners, although we note that the mean duration measure penalizes suppliers that add new customers over time and thereby reduce the arithmetic mean duration of their relationships. Although further conceptual exploration of these issues would be valuable, data limits constrain us here to the comparison of maximum and mean duration.

**Status.** We measure status in terms of a supplier’s highest status buyer. Our conceptual reason is that the highest status customer will be the focus of other firms' search for information about a supplier's capabilities. The fact that a highly respected customer has chosen a firm to supply components will act as a strong signal of that supplier’s skills and, in turn, will attract more customers, possibly including both high status and lower status customers. In the presence of this signal, we do not believe that a supplier would damage its image if it also sold to lower status customers. However, we test two alternative status measures that incorporate that possibility, mean customer status and minimum customer status, in sensitivity analyses.

We measure customer status according to the generally accepted recognition of three status categories within the automobile industry during this period. The contemporary literature clearly indicated that there were three distinct groups of assemblers by 1918: (1) the major assemblers
(Ford, General Motors and, following the acquisition of Dodge, Chrysler); (2) the major independents, which we referred to by that term (e.g., Hudson and Packard); and (3) minor independents (all others, e.g., Dort and Geronimo). We assigned each assembler to one of the three status categories based on the year-by-year commentary of Kennedy (1941), supplemented by Smith (1968) for our supplemental post-War analysis. From early in the industry, the major assemblers stood apart from the remainder of the industry in terms of their impact on the development of the industry and economic success. For example, in 1919, they were the only producers with net incomes over $10 million: Ford had net income of $69 million, General Motors $60 million, and Dodge $24 million (Kennedy 1941:105). The major independents had a lesser, but still significant, presence in the industry. Kennedy (1941:81) made the point clearly, “The history of the automobile industry has been the history of not more than twenty companies.” The minor independents were the other auto producers, many of which “now have more than an antiquarian interest, and their significance was never great” (Kennedy 1941:84). In 1919, the sixty five minor independents combined to produce only twenty-five percent of U.S. automotive production (Kennedy 1941:105).

As a check, we compared these categorizations to the descriptions in the contemporary texts we listed above. The status categorization of assemblers changed slightly over time. Three assemblers spent several years straddling two categories. Our results were robust to moving these three assemblers between the higher and lower of their possible status categories.

We represented status with a set of three indicator variables: low status (minor independents), medium status (major independents), and high status (major assemblers). We set to one the variable corresponding to the highest-status assembler to which a supplier sold; we set the others to zero.

**Autonomy.** For our measures of current and potential autonomy, we draw on the work of Burt (1982; 1983; 1992; 1980). The calculation of our measures differs in two ways from Burt’s (1992) structural autonomy measure in that our sample does not include supplier-supplier or buyer-buyer ties, but only vertical ties between buyers and suppliers.

We measured the current autonomy of a supplier as the ratio of the number of assemblers to which the supplier sold to the mean number of suppliers the focal supplier’s customers had. This variable captures the relative dependence of the supplier on its current ties to buyers. We measured the potential autonomy of a supplier as the ratio of the number of existing assemblers to which a supplier did not sell to the mean number of existing suppliers from which the focal supplier's customers do not buy components. This variable captures the relative ability of a supplier
to create new ties to buyers outside its current network.

We measure autonomy as a ratio because, as we discussed above, autonomy is an explicitly relative concept. Our interest is not whether a supplier has three or six customers; our interest is whether it has twice or only half as many trading partners as its customers do.

We also defined a complementary measure of autonomy, based on customer vertical integration. An assembler can generate greater opportunity to replace a supplier by vertically integrating production of the component in question. Therefore, we include the proportion of the focal supplier’s customers that are vertically integrated as a distinct measure of autonomy. High values indicate greater buyer opportunity and lower supplier autonomy. We use the proportion of customers that are vertically integrated as a separate variable. We expect this variable to contribute to higher dissolution rates of suppliers.

**Independent Control Variables**

We defined control variables for aggregate customer production, supplier size, supplier age, competitor density, national auto production, and national disposable income.

**Customer production.** The customer production variable recorded the aggregate unit production of all of a supplier’s customers in a given year. Ideally, we would like to record supplier-specific sales to customers, but data about how many clutches or carburetors each supplier sold to each assembler in a given year do not exist. However, it is reasonable to assume that suppliers that sold to large assemblers such as GM and Ford would have greater aggregate sales than suppliers that sold components to much smaller firms such as Dort and Geronimo.

**Supplier size.** We take our measure of supplier size from the *Thomas Register of American Manufacturers*, which reports firm capitalization. Suppliers in our sample range from size E (credit rating of $5,000-$9,999) to AAAA (greater than $1,000,000). Our size variable, Large Supplier, takes a value of 1 if the supplier is in the category AAA ($500,000 to $1,000,000 capitalization) or greater, and a value of zero otherwise. Although the precise significance of $500,000 in capitalization may have changed from 1918 to 1942, a rating of AAA or greater continued to indicate a firm with substantial resources, as indicated by the fact that *Thomas Register* did not change the dollar figure associated with its AAA rating. The results are robust to using an ordinal measure of size based on the rank measures in the *Thomas Register*.

The variables for customer production and supplier size help differentiate between the benefits of scale and the benefits of customer status. High status customers also tend to be larger firms, but there is substantial variation in the measures. Similarly, suppliers that sell components to large customers will be more likely to become large themselves. Thus, although the benefits of
assembler scale, supplier scale, and customer status may correlate, we can disentangle the effects empirically by controlling for supplier and customer size. The scale benefits of selling components to a large buyer arise only if the supplier actually achieves larger size itself. The benefits of selling to a high status customer, however, arise whether or not the supplier achieves greater size. We expect hypotheses 3a and 3b, concerning customer status, to hold controlling for supplier size and customer size.

**Firm age.** We also created age variables, which are common measures in studies of business failure. We measured firm age from supplier birth. When that information was not available, generally for smaller suppliers, we generated a random date of birth between the year when the earliest suppliers appear (1903 for clutches and 1907 for carburetors), and 1917, the year prior to the beginning of our observation period. We included a dummy variable indicating the fourteen carburetor suppliers and nine clutch suppliers with randomized founding dates.

The supplier age and size variables help address an alternative argument, which is that a supplier’s capabilities are the primary causes of the supplier’s survival. In the strongest form of this argument, relationship duration, status, and autonomy do not influence performance directly. Instead, more capable firms are able to maintain long-term relationships, attract prominent customers, and attain autonomy, so that the capabilities are the true cause of observed performance. Historical longitudinal studies of business survival, for which fine-grained measures of capabilities typically are not available, commonly use business age and size as measures of capabilities to address this argument (Hannan 1998), on the assumption that firms with stronger capabilities tend to become older and larger than firms with weak capabilities.

**Competition and demand.** Finally, we created one variable for competitive conditions and two variables to assess demand conditions. We measured competition in terms of competitor density, using the count of the number of suppliers of the component in a given year. Drawing on empirical work in organizational ecology, we also included the square of this term in sensitivity analysis. On the demand side, one variable, national auto production, measured total annual time-varying vehicle production in the United States. The second demand condition variable, national disposable income, measured annual time-varying consumer disposable income in the United States. These variables help control the possibility that suppliers are more likely to fail when they face strong competition or adverse demand conditions, which is especially important given the economic disruption of the Great Depression.

**RESULTS**

Table 2 reports the results of the analysis of carburetor and clutch supplier failure. The shared
frailty models in table 2 indicate that unobserved heterogeneity among suppliers does not affect their exit rates. The likelihood ratio test shows that $\theta$, the variance of the unobserved heterogeneity parameter, is not significantly different from zero in all models. This finding rules out the presence of unobserved supplier-specific capabilities as an alternative explanation for the results we report below. We begin by discussing the results for the carburetor analysis. These results apply to the case of producers of architectural components.

********** Table 2 about here **********

The baseline model 1a in Table 2 contains the control variables, including supplier age periods, the left censored indicator, supplier size, aggregate customer production, competitor density, national auto production, and national disposable income. The piecewise analysis with four age periods in model 1a is a statistically significant improvement over an unreported model holding the rate constant. The positive, although insignificant, sign on the coefficient for left-censored firms in model 1a indicates that these firms, which were primarily small firms, exited at a somewhat faster rate. Greater aggregate sales of a supplier’s customers, which correlates with supplier size, lowered the hazard of exit.

Model 1b in Table 2 supports hypothesis 1a, which predicted that failure rates would decline with relationship duration. For each additional year’s duration in the supplier’s longest customer relationship, the rate of exit declines by a factor of 0.24 ($1 - e^{-0.278*1}$). This means that when the duration of the relationship increases from 1 to 4 years, the exit rate falls by about 60%. The relationship duration effect becomes weaker in subsequent models. We note that aggregate customer production loses significance in model 1b, but that model 1b provides a statistically significant improvement over model 1a based on the log-likelihood ratio statistic.

Model 1c in Table 2 supports hypothesis 2a for current autonomy. The table shows that failure rates for carburetor suppliers, that is, of suppliers of architectural goods, decline with current autonomy. Each increase of one in the current autonomy score reduces the exit rate by a factor of 0.77 ($1 - e^{-1.487}$). This result persists in later models.

At the same time, though, model 1c does not support hypothesis 2a for potential autonomy. Although the coefficient takes the expected negative sign, the results are statistically insignificant. Thus, current autonomy has a stronger effect that potential autonomy on supplier performance, at least in the case of architectural components. This suggests that it is difficult to switch suppliers for architectural components.

Model 1c indicates having a large proportion of customers that are vertically integrated into production of the supplier’s component increases the likelihood of supplier failure. This result
persists in later models. Buyer with experience making a component might internalize production of that component if desired, putting them in advantageous bargaining positions with external suppliers. In parallel with the findings for current autonomy, this result suggests that suppliers suffer when dealing with buyers that have credible options for replacing them.

Model 1d in Table 2 supports hypothesis 3a, which predicted that failure rates would decline with customer status. Having a customer of either medium or high status dramatically lowers the failure rate for carburetor suppliers, relative to having only low status customers. The effect of medium and high status customers is statistically indistinguishable, suggesting that it was not necessary to have GM, Ford or Chrysler as a customer to receive an imprimatur of quality. Even selling to Hudson, Nash, or the other major independents sufficed.

Note that the relationship duration result loses significance in model 1d, with the addition of customer status, after becoming only weakly significant when autonomy was added in model 1c. The change suggests that supplier autonomy and the particular status of a firm's customers are often more important than simply how long a relationship exists.

Model 1d in Table 2 also shows an intriguing change in the supplier age results, as we find that the lower failure rate associated with increasing age in model 1a becomes weaker in model 1d. The change occurs as we add the relationship duration, autonomy, and status variables to the analysis. The results suggest that the negative age dependence obtained in earlier models reflected the effects of the supplier’s customer relationships and provide a conceptual implication about how supplier age influences survival. The correlations between firm age and the autonomy and status measures are weak (see Table 1), so that the changes in the age results do not arise from simple correlation among the variables. Rather, the results suggest that older suppliers with low autonomy and low status gain fewer benefits from age, which instead apply only to suppliers that achieve reasonable levels of autonomy and/or gather high status customers as they age. Moreover, note that the incremental log-likelihood chi-square statistics in models 1b, 1c, and 1d report significant improvement, showing that the relationship measures add independent explanatory power to the models, even controlling for supplier age.

Model 1e in Table 2 replicates the carburetor supplier analysis for the full set of data, including the post-war period, from 1918 to 1970. The results are similar to those in model 1d, with the exception of age dependence. Younger suppliers have an increased likelihood of failure, peaking between six and ten years.

We now turn to the second set of models in Table 2, which report the results of the clutch supplier analyses. These results test the hypotheses concerning suppliers of modular components.
Overall, the models provide significant explanatory power, based on the model log-likelihood chi-square statistic.

Model 2a in Table 2 introduces the control variables. The age results here are slightly more significant than in the carburetor analysis. The other control variables tend to affect the failure rate in the same direction as in the carburetor analysis, but only the left-censoring variable is statistically significant.

The subsequent models in Table 2 provide parallel analyses to those that we discussed for carburetor suppliers. Model 2b shows that the duration of customer relationships does not affect the failure of modular suppliers. This result is consistent with hypothesis 1b, which predicted that the benefits of long-term relationships would be greater for suppliers of architectural components than for suppliers of modular components.

Model 2c of Table 2 also shows that current autonomy influences modular component supplier failure, as it did in the case of architectural components. Each increase of one in the structural autonomy score reduces the exit rate by a factor of 0.85 (1-e^{-1.892}). The implication is that current autonomy is a major influence on the performance of all suppliers by providing immediate alternatives and/or direct negotiation power with existing customers when need arises. This result again is consistent with hypothesis 2a.

Model 2c of Table 2 also shows that potential autonomy does not have a significant influence on the failure of modular suppliers, counter to hypothesis 2b, although the coefficient takes the expected negative sign. The magnitude of the potential autonomy effect is somewhat greater for clutches than in the case of the architectural carburetor analysis, consistent with the prediction, but the coefficient only approaches statistical significance. Thus, the results provide only qualitative support for hypothesis 2b, which predicted that potential autonomy would have more influence on the failure rates of suppliers of modular components, which face few switching costs, than of architectural components.

Model 2c of Table 2 also shows that suppliers of modular components do not incur a higher failure rate by selling to a large number of vertically integrated customers. This contrasts with the findings for architectural components. One explanation is that, while it is complex to successfully begin design and production of architectural components, the self-contained nature of modular components makes it relatively easy for a buyer to begin internal production. Already having production does not make internalization a significantly more credible threat in negotiations with external suppliers. While not conclusive, the data is consistent with this explanation. Of 200 automotive assemblers that were not vertically integrated into carburetors when they en-
tered the data, only five ever subsequently produced their own carburetors and, of the five, only one did so for more than one year. On the other hand, of the 155 assemblers that were not integrated into clutch production when they entered the data, fifteen subsequently produced their own clutches, doing so for an average of over three years.

Model 2d of Table 2 shows that customer status does not affect the failure rates of modular suppliers. Not only are the coefficients for to selling medium and high status customers not statistically significant, the addition of the status variables does not significantly improve the explanatory power of the model based on the log-likelihood ratio statistic. This result is consistent with hypothesis 3b, which predicted that customer status would have more influence on the failure of suppliers of architectural components than for suppliers of modular components. Because buyers are better able to evaluate the supplier quality for the modular clutch themselves, suppliers gain less from the signal of quality provided by selling to high status customers.

One control variable is significant in model 2d. Suppliers for whom founding dates were unavailable fail at a higher rate. We interpret this primarily as a liability of smallness, as these were small, often private, suppliers. Model 2e of Table 2 replicates the clutch supplier analysis for the full study period, from 1918-1970. The one substantive difference is that potential autonomy now becomes moderately significant, consistent with Hypothesis 2b.

We carried out several sensitivity analyses. We investigated alternative measures of relationship duration and customer status, finding no significant impact of non-monotonic relationship duration (duration squared), mean duration, minimum customer status, or mean customer status in either the carburetor or clutch results. In addition, the results did not change when we dropped the density variable, in order to check whether an arithmetic relationship between density and autonomy might affect the results. The square of the density variable was never significant. Lastly, we estimated each model with both the gamma and inverse Gaussian distribution for the shared frailty, receiving substantively similar results for each.

DISCUSSION

Our results show that key aspects of customer relationships have different influences on the failure rates of suppliers of modular and architectural components. For suppliers of modular components, only autonomy has a major influence, with benefits arising primarily from current autonomy and, to a lesser extent, from potential autonomy. By comparison, suppliers of architectural components, which tend to involve substantial switching costs and relation-specific routines, benefit from higher customer status as well as from greater current autonomy, while achieving little or no benefit from greater potential autonomy. We found initially that longer-
term relationships with buyers enhanced the survival chances of suppliers of architectural components, but this effect declined once we introduced the effects of autonomy and status.

This comparison speaks directly to the contingent nature of the influence of interfirm relationships (Burt 1997), with the benefits and constraints deriving in large part from the nature of the inter-firm routines that a firm must create in order to coordinate its relationships. Relationships that require extensive sets of inter-firm routines tend to lead to greater benefits and constraints, while relationships that require less intensive inter-firm routines are less influenced by the structure of a supplier’s relationships. Nonetheless, even producers of seemingly standard products benefit from having many current trading partners relative to their customers.

Our findings suggest that in the world of increasing modularity, suppliers will find the value of their customer relationships changing. Basing one’s success on long-time ties to loyal customers will become less viable. The reputation boost once available to firms by selling to prominent customers will fade as customers are better able to evaluate directly how well the supplier’s more modular products meet their needs.

Suppliers can also benefit from these changes, however. A series of short-term relationships with different customers becomes a viable strategy, giving supplier flexibility in seeking out customers. A start-up firm is more able to succeed by virtue of the quality of its product, even before it gains the legitimacy that comes from sales to a large company. As new firms often lack the capacity or contacts to win orders from industry leaders, this is a significant benefit. The key, as is also true for suppliers of architectural components, is to avoid dependence on a small set of customers.

This work contributes to growing literature on modularity by refining our understanding of modularity’s impact on interfirm relationships. The fact that duration does not contribute to performance suggests that the interfirm trust and coordination routines built up over time are not particularly useful for modular products. Despite this, current customers contribute to survival prospects while other potential customers do not, suggesting value in existing relationships. This is consistent with the argument that integrating modular products requires less interfirm coordination (Hoetker 2001; Sanchez and Mahoney 1996; Schilling 2000), but suggests a limit to the argument. Sufficient coordination is required that having some trust and interfirm routines is valuable, although there is no payoff to the trust and routines being particularly deep. Although we study suppliers, these findings support and potentially extend prior research on modularity’s effect on buyers, the focus of much of the modularity literature.

The results for customer status point to a less prominent feature of modularity. For a modu-
lar component, potential buyers do not value the signal generated by a supplier selling to a prominent customer. This suggests that modularity reduces ambiguity about how well a component will perform once integrated into the end-product. The buyer is able to evaluate the component in isolation, without having to consider a web of interactions with other components.

Although we do not model the evolution of the supplier relationships at the industry level in this paper, our work can inform the growing literature that does so (Achrol 1997; Schilling and Steensma 2001; Vickery, Calantone, and Droge 1999). Our findings suggest that, as modularity increases, relationships will become more transitory because they bring less value. The propensity of firms to trade only with those of similar status (Podolny 1994) should lessen as customer status becomes a less important signal of supplier quality. Knowledgeable buyers and suppliers will continue to avoid dependence on a small number of trading partners; firms with few partners are likely to seek to increase the number of their partners.

Clearly, research that refines and extends this study would be useful. Limitations of this study include the fact that we lack fine-grained capability measures and profitability information for the firms (almost all the suppliers were private companies that did not report public financials, while few firms filed carburetor or clutch patents during the study period). Possible extensions include assessing whether autonomy and status have differential effects during periods of healthy and adverse industry conditions. It is possible that these aspects of network structure have their greatest impact during tough times in an industry, when adaptation opportunities will be particularly valuable and constraints will be particularly binding. In addition, it would be useful to determine whether network structure affects a supplier’s survival chances following the failure of a buyer. For instance, it is possible that suppliers with high autonomy will be better able to ride out the loss of a customer. We believe that such avenues will provide fruitful venues for continuing work.
Table 1. Descriptive statistics and product-moment correlations (1918-1942 period)

<table>
<thead>
<tr>
<th></th>
<th>Carburator suppliers (225 cases)</th>
<th>Clutch suppliers (130 cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean s.d. min. max</td>
<td>mean s.d. min. max</td>
</tr>
<tr>
<td>Supplier age: 0-5 years</td>
<td>0.22 0.41 0.00 1.00 1.00</td>
<td>0.29 0.46 0.00 1.00 1.00</td>
</tr>
<tr>
<td>Supplier age: 6-10 years</td>
<td>0.19 0.39 0.00 1.00 -0.25 1.00</td>
<td>0.20 0.40 0.00 1.00 -0.30 1.00</td>
</tr>
<tr>
<td>Supplier age: 11-15 years</td>
<td>0.24 0.43 0.00 1.00 -0.29 1.00</td>
<td>0.24 0.43 0.00 1.00 -0.35 1.00</td>
</tr>
<tr>
<td>Supplier age: 16+ years</td>
<td>0.35 0.48 0.00 1.00 -0.37 -0.37 -0.43 1.00</td>
<td>0.27 0.45 0.00 1.00 -0.37 -0.31 0.37 1.00</td>
</tr>
<tr>
<td>Competitor density</td>
<td>11.02 4.22 3.00 19.00 0.11 0.15 0.20 -0.39 1.00</td>
<td>11.15 4.73 3.00 18.00 -0.13 -0.10 0.26 -0.04 1.00</td>
</tr>
<tr>
<td>Unknown founding date</td>
<td>0.34 0.48 0.00 1.00 -0.17 0.10 0.09 -0.02 0.32 1.00</td>
<td>11.15 4.73 3.00 18.00 -0.13 -0.10 0.26 -0.04 1.00</td>
</tr>
<tr>
<td>Large supplier</td>
<td>0.47 0.50 0.00 1.00 -0.09 -0.10 -0.18 0.33 -0.58 -0.33 1.00</td>
<td>0.47 0.50 0.00 1.00 -0.09 -0.10 -0.18 0.33 -0.58 -0.33 1.00</td>
</tr>
<tr>
<td>Aggregate cust. pdn. (mln units)</td>
<td>0.63 0.87 0.00 3.79 -0.12 -0.01 -0.18 0.27 -0.40 -0.30 0.46 1.00</td>
<td>0.63 0.87 0.00 3.79 -0.12 -0.01 -0.18 0.27 -0.40 -0.30 0.46 1.00</td>
</tr>
<tr>
<td>National auto production (mln units)</td>
<td>2.60 1.06 0.22 4.46 -0.04 -0.18 -0.05 0.23 -0.28 -0.17 0.25 0.37 1.00</td>
<td>2.60 1.06 0.22 4.46 -0.04 -0.18 -0.05 0.23 -0.28 -0.17 0.25 0.37 1.00</td>
</tr>
<tr>
<td>National disposable income ($ mln)</td>
<td>68.0 10.8 45.5 116.9 -0.06 -0.15 -0.03 0.21 -0.18 -0.09 0.09 0.16 0.48 1.00</td>
<td>67.3 8.3 45.5 83.3 -0.05 -0.11 -0.09 0.23 -0.09 -0.13 0.09 0.05 0.74 1.00</td>
</tr>
<tr>
<td>Max. duration of cust. relationship</td>
<td>7.28 6.07 0.00 24.00 -0.51 -0.19 0.16 0.44 -0.06 -0.05 0.22 0.13 0.07 0.08 1.00</td>
<td>7.28 6.07 0.00 24.00 -0.51 -0.19 0.16 0.44 -0.06 -0.05 0.22 0.13 0.07 0.08 1.00</td>
</tr>
<tr>
<td>Current autonomy</td>
<td>3.92 6.60 0.25 15.18 -0.18 -0.04 0.12 0.07 0.18 -0.02 0.01 0.07 -0.12 -0.06 -0.29 1.00</td>
<td>3.92 6.60 0.25 15.18 -0.18 -0.04 0.12 0.07 0.18 -0.02 0.01 0.07 -0.12 -0.06 -0.29 1.00</td>
</tr>
<tr>
<td>Potential autonomy</td>
<td>5.03 2.22 0.58 9.83 0.15 0.18 0.15 -0.41 0.58 0.24 -0.57 -0.46 -0.32 -0.16 -0.17 -0.08 1.00</td>
<td>5.03 2.22 0.58 9.83 0.15 0.18 0.15 -0.41 0.58 0.24 -0.57 -0.46 -0.32 -0.16 -0.17 -0.08 1.00</td>
</tr>
<tr>
<td>Prop. of vertically integrated cust.</td>
<td>0.09 0.19 0.00 1.00 0.13 -0.01 0.03 -0.13 0.06 -0.18 -0.04 0.02 0.08 0.01 -0.02 -0.13 0.18 1.00</td>
<td>0.09 0.19 0.00 1.00 0.13 -0.01 0.03 -0.13 0.06 -0.18 -0.04 0.02 0.08 0.01 -0.02 -0.13 0.18 1.00</td>
</tr>
<tr>
<td>Customer status (max.)</td>
<td>2.26 0.78 1.00 3.00 -0.18 0.10 -0.10 0.15 -0.34 -0.12 0.41 0.62 0.08 -0.08 0.18 0.07 -0.26 0.39 1.00</td>
<td>2.26 0.78 1.00 3.00 -0.18 0.10 -0.10 0.15 -0.34 -0.12 0.41 0.62 0.08 -0.08 0.18 0.07 -0.26 0.39 1.00</td>
</tr>
</tbody>
</table>
Table 2: Piecewise exponential model of supplier failure rates
(negative coefficient = lower failure rate)

<table>
<thead>
<tr>
<th>Supplier age</th>
<th>Carburetors</th>
<th>Clutches</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-5 years</td>
<td>1918-1942</td>
<td>1918-1970</td>
</tr>
<tr>
<td>Supplier age</td>
<td>1a 1b 1c 1d 1e</td>
<td>2a 2b 2c 2d 2e</td>
</tr>
<tr>
<td>5-10 years</td>
<td>-2.476 -1.919 -0.169 0.256 1.828</td>
<td>-3.170 -3.454 0.797 0.402 2.560</td>
</tr>
<tr>
<td>1918-1942</td>
<td>(2.718) (2.655) (2.569) (2.064)</td>
<td>(2.825) (2.889) (3.684) (3.900) (2.062)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>1.325 2.934</td>
<td>-5.676* -5.823* -0.908 -1.073 1.453</td>
</tr>
<tr>
<td>Supplier age</td>
<td>(2.730) (2.714) (2.591) (2.074)</td>
<td>(2.942) (3.016) (3.928) (4.228) (2.334)</td>
</tr>
<tr>
<td>11-15 years</td>
<td>-4.195 -1.653 -0.340 0.688 2.342</td>
<td>-5.867* -5.937* -1.164 -1.571 0.620</td>
</tr>
<tr>
<td>1918-1942</td>
<td>(2.863) (2.845) (2.719) (2.183)</td>
<td>(2.835) (2.908) (3.863) (4.119) (2.372)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>-4.155 -4.266 -0.146 -0.484 1.593</td>
<td></td>
</tr>
<tr>
<td>Supplier age</td>
<td>(2.847) (2.744) (2.648) (2.059)</td>
<td>(2.925) (3.001) (3.783) (4.046) (2.132)</td>
</tr>
<tr>
<td>16+ years</td>
<td>-0.018 0.017 0.058 -0.007 0.002</td>
<td>0.043 0.028 0.025 0.016 0.003</td>
</tr>
<tr>
<td>Density (no. of suppliers in industry)</td>
<td>(0.086) (0.072) (0.069) (0.080) (0.082)</td>
<td>(0.060) (0.061) (0.062) (0.063) (0.058)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>0.054 0.820 0.867 1.124</td>
<td>1.057</td>
</tr>
<tr>
<td>1918-1970</td>
<td>(0.769) (0.564) (0.634) (0.653) (0.683)</td>
<td>(0.649) (0.650) (0.726) (0.726) (0.749)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>-0.487 -0.296 -0.410 -0.464 -0.489</td>
<td>-0.304 -0.423 -0.097 0.079 -0.075</td>
</tr>
<tr>
<td>1918-1970</td>
<td>(0.627) (0.596) (0.588) (0.625) (0.637)</td>
<td>(0.509) (0.528) (0.528) (0.557) (0.538)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>-1.172† -0.915 -1.467† -0.407 -0.468</td>
<td>-0.803 -0.676 0.425 -0.669 -2.248</td>
</tr>
<tr>
<td>1918-1970</td>
<td>(0.616) (0.571) (0.800) (0.864) (0.897)</td>
<td>(0.993) (0.950) (1.841) (2.575) (2.282)</td>
</tr>
<tr>
<td>Auto production (units)</td>
<td>0.442 0.286 -0.009 -0.000 0.145</td>
<td>0.160 0.199 0.026 0.125 0.452</td>
</tr>
<tr>
<td>1918-1942</td>
<td>(0.355) (0.361) (0.354) (0.316) (0.362)</td>
<td>(0.363) (0.360) (0.342) (0.404) (0.333)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>0.009 -0.009 0.009 0.013 -0.018</td>
<td>0.020 0.028 0.015 0.022 -0.015</td>
</tr>
<tr>
<td>National disposable income</td>
<td>(0.039) (0.042) (0.037) (0.030) (0.017)</td>
<td>(0.049) (0.050) (0.047) (0.052) (0.010)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>-0.278** -0.121† -0.075 -0.097</td>
<td>-0.257 -0.030 -0.090 -0.113</td>
</tr>
<tr>
<td>1918-1970</td>
<td>(0.095) (0.088) (0.095) (0.093)</td>
<td>(0.226) (0.204) (0.214) (0.216)</td>
</tr>
<tr>
<td>Max. duration of cust. Relationship</td>
<td>-1.487** -1.685** -1.580** -1.892** -1.976** -2.013**</td>
<td></td>
</tr>
<tr>
<td>1918-1942</td>
<td>(0.507) (0.574) (0.553)</td>
<td>(0.736) (0.764) (0.782)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>-0.15 -0.069 -0.067</td>
<td>-0.176 -0.197 -0.250</td>
</tr>
<tr>
<td>Current autonomy</td>
<td>-0.15 (0.151) (0.164) (0.163)</td>
<td>(0.160) (0.166) (0.155)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>1.701† 1.754† 1.808†</td>
<td>-0.169 -0.428 -0.234</td>
</tr>
<tr>
<td>1918-1970</td>
<td>(1.217) (1.252) (1.286)</td>
<td>(0.688) (0.757) (0.702)</td>
</tr>
<tr>
<td>Potential autonomy</td>
<td>-2.177** -2.056** -0.015</td>
<td>(0.908) (0.883) (0.734)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>(0.688) (0.757) (0.702)</td>
<td>(0.908) (0.883) (0.734)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>1.795* -1.792*</td>
<td>0.999 1.519</td>
</tr>
<tr>
<td>Maximum customer status=medium</td>
<td>-1.795* -1.792* (0.985) (0.996)</td>
<td>(1.348) (1.290)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>(0.985) (0.996)</td>
<td>(1.348) (1.290)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>1.701† 1.754† 1.808†</td>
<td>-0.169 -0.428 -0.234</td>
</tr>
<tr>
<td>Maximum customer status=high</td>
<td>-2.177** -2.056** -0.015</td>
<td>(0.908) (0.883) (0.734)</td>
</tr>
<tr>
<td>1918-1942</td>
<td>(0.688) (0.757) (0.702)</td>
<td>(0.908) (0.883) (0.734)</td>
</tr>
<tr>
<td>1918-1970</td>
<td>1.795* -1.792*</td>
<td>0.999 1.519</td>
</tr>
<tr>
<td>Observations</td>
<td>225 225 225 225 225</td>
<td>225 225 225 225 225</td>
</tr>
<tr>
<td>Log-likelihood</td>
<td>-28.27 -22.52 -12.07 -7.14 -7.80</td>
<td>-11.50 -10.77 -1.94 -1.36 -4.07</td>
</tr>
<tr>
<td>Log-likelihood ratio (df)</td>
<td>11.9 (1)** 20.9 (3)** 9.9 (2)** 1.5 (1) 17.7 (3)** 1.2 (2)</td>
<td></td>
</tr>
<tr>
<td>Log-likelihood ratio test of 8=0, Χ²(1)</td>
<td>0.36 (8.02E-08 1.04E-07 7.39E-08 1.56E-08 3.29E-08 9.60E-08 9.41E-08 6.68E+08 7.99E-08 0.29 4.10E-07 0.00E+00 1.00E-05 6.10E-07 4.90E-08 0.00E+00 5.11E-05 0.00E+00</td>
<td></td>
</tr>
</tbody>
</table>

Standard errors in parentheses
† significant at 10%; * significant at 5%; ** significant at 1% (one-tailed tests for hypotheses; two-tailed tests for control variables)
assuming gamma distribution of shared frailty term with variance θ
FIGURE 1

Impact of Buyer-Supplier Relationships on Supplier Survival

- Longer relationship duration (H1a)
- Contingency: Architectural > Modular (H1b)

- Greater autonomy (H2a)
- Contingency
  - Potential autonomy: Modular > Architectural (H2b)

- Greater customer status (H3a)
- Contingency: Architectural > Modular (H3b)
Reference List


Bailey, L.S. 1971. The American car since 1775; the most complete survey of the American automobile ever published. 1st ed. [New York?].


Dyke, A.L. 1923. *Dyke's automobile and gasoline engine encyclopedia; the elementary principles, construction, operation and repair of automobiles, gasoline engines and automobile electric systems; including trucks, tractors, and motorcycles, simple, thorough and practical*. Chicago: The Goodheart-Willcox Company Inc.


